LAUTECH JOURNAL OF ENGINEERING AND TECHNOLOGY 3(1) 2005: 48 – 54

DEVELOPING GOOD QUALITY CASTING-SANDS FROM NIGERIAN SOILS

A.Olaniyan and K.A. Yusuff

Mechanical Engineering Department, The Polytechnic, Ibadan

ABSTRACT

The suitability and the range of application of Termite soil in sand moulds have been investigated both experimentally and practically through castings (Ferrous and non-ferrous) of engineering components. The experimental tests were conducted in accordance with the American foundry society specifications to determine the moulding properties. The experimental results of the termite soil based sands and bentonite based sands were compared and various sand conditions based on the comparison were selected for castings of bronze, aluminum and cast iron. The investigation show that 37.5%, 40% and 45% termite soil at 5% to 7.5% moisture contents, and 8% to 10% bentonite at 2% to 4% moisture contents are comparable in terms of their moulding properties, and these are in good correlation with the standard properties. The practical castings revealed that the sand conditions between 30% and 40% termite soil at 6% to 8% moisture content are most recommended for castings of engineering components.

INTRODUCTION

There are some twenty-four identified species of termites in Nigeria, the list covering all the ecological zones from the mangrove forest to the Sudan Savannah. Most of the termite soils erect light brown chimney-shaped soils, which tower above the ground, sometimes up to 3m high in the Mangrove forests, Rain forests and forested areas of the Savannah. In the southern Guinea Savannah, around Mokwa and Bida in Niger State of Nigeria, they tower as high as 10m, forming cathedral spines with prominent ribs on the outside (Omo-Malaka, 1977).

From the analysis of the termite soil, it was shown that the mounds are generally enriched in clay and the metallic minerals, particularly potassium, calcium and magnesium, relative to the surrounding soils (Omo-Malaka, 1973). This probably explains why termite soils show a high degree of bond and have been used for "hard-surfacing" of tennis lawns in village schools.

In accordance with the experimental findings, Nwajagu and Okafor, (1980) on a study of the moulding properties of sand bonded by Ukpor clay shows that up to 14% Ukpor clay as binder and 4% water ensured good combination of all properties studied. This has rightly indicated a promising excellent bonding properties on Nigerian soils.

The present study is to establish to what extent the applicable range of the moulding characteristics already existing in natural composite soils especially the termite soil.

EXPERIMENTAL PROCEDURE

Sand testing detects any variation from the standard quality and adjustment of the sand mixtures of specific requirement can be made to reduce the number of bad castings. Sand testing also improves surface finish by making the choice of sand mixtures to give a desired surface finish, this sand testing is one of the dominating factors in the foundry.

The termite soil was crushed, ground dry and sieved into powdered form using (710-530) ∝m sieve size. The sand sample was mixed in varying proportions and tested under different conditions of moisture content against the bulk properties. The mining and milling operations of the silica sand, termite soil and water were carried out on Fisdale Laboratory Mill. These were done to secure even distribution of constituents and a smooth lump free constituency.

The Specimen Preparation

Standard specimens (Davies, 1960) were used to determine all the bulk properties at room temperature, the 50.8mm diameter x 50.8mm high (2in x 2in) cylindrical specimens were prepared by ramming the sand using the ramming machine.

Physical Properties Determination

Determination of Moisture content in the Moulding Sand:

The moisture content was determined by using the Risdale-Dieter moisture teller. The percentage moisture content was calculated from:

$$\text{Percentage moisture content} = \frac{L - M}{L} \times 100$$

Where, L is the initial weight of the sample and M is the final weight after drying

Grain shape Determination:

With the aid of a magnifying glass or an optical microscope, the grain shape of the foundry sand was determined by inspecting few taken samples.

Relative Density:

The value of relative density was determined using the relation:

Relative density (RD) = $\frac{\text{Mass of substance}}{\text{Mass of equal volume of water}}$

Estimation of clay contents:

To estimate clay content requires the removal of clay from sand grains by vigorous agitation in water and the addition of a deflocculating agent to the water to maintain the clay in suspension during test.

Ignition Loss Determination:

The percentage loss on ignition = $\frac{P - Q}{P} \times 100$ (%)

Where, P is the initial mass of sample and Q is the final mass of sample.

Sieve Analysis and Fineness of the Sands:

Using sieve number 1.7mm to 0.053mm. The grain fineness number was calculated from:

A.F.S. Grain Fineness Number (GFN) = $\frac{\sum (ai \times fi)}{\sum ai}$

Where, ai = % weight retained and fi = multiplier of each sieve

Bulk Properties Determination

Determination of green and dry compressive strengths:

To determine the green strength, the specimen was tested immediately after ramming before the water dries out. The test was carried out using the Rinsdale Dieter. pendulum machine, an AFS standard 2in x 2in (50.8mm x 50.8mm) test specimen was inserted between the compression heads. At the point where the specimen breaks, the reading was taken for the green compressive strengths.

For dry compressive strength, three standard test pieces were made for each, baked in the oven for about two hours at 120^{0}C and allowed to cool to the ambient temperature before standard dry compression strength test was carried out on them.

Determination of Green and Dry Shear Strengths:

Like in the determination of compression strength test, specimens for the green and dry shear strength were prepared in the same manner. Readings were taken appropriately.

Permeability number

The permeability number of moulding sand is an indication of the porosity of moulding sand.

Permeability (Pn) = $\frac{V \times h}{P \times a \times t}$

Where, V = volume of air in milliliter (ml) passing through the specimen,

h = height of the test specimen, P = pressure of air in cm of water

a = area of cross-section of specimen in cm^2,

t = time in minute, for exhaustion of 200ml of air through the sand specimen.

Since, v = 200ml, h = 50.8mm and a = 20.262cm^2

P = 10 atmospheric pressure

Therefore, **Pn = $\frac{3007.2}{t \text{ (sec)}}$**

Shatter Index:

This is a measure of that property of moulding sand, which aids satisfactory lift during pattern withdrawal. The tests were carried out on Risdale Shatter Index tester.

Shatter Index = $\frac{\text{Weight retained on the sieve}}{\text{Total weight of sand sample}}$

Flowability

The flowability of a moulding sand is a measure of its ability to flow around and over a pattern during ramming. The flowability was determined inside the same apparatus that the 50.8mm x 50.8mm specimen was made. Instead of taking the specimen out of the cylinder after the third drop of the weight (i.e. the normal ramming), the weight was dropped for the fourth time and the indicator was set into position. The fifth ramming was done and the reading on the indicator was recorded as percentage flowability.

Bulk Density:

This is a measure of the total mass of the moulding sand that gives AFS specimen. The bulk is estimated from the expression.

Bulk density = $\frac{\text{Mass}}{\text{Volume}} = \frac{4M}{d^2h}$

Where, h = d = 50.8 x 10^{-3}m

Therefore, Bulk density = 9711 x M (kg/m^3)

Where M is the mass of sand to give AFS specimen.

RESULTS AND DISCUSSIONS

Some of the physical properties of termite soil are shown in the Table 1. The corresponding values for the percentage loss on ignition are 14 and 1.20 respectively. This shows a clear difference in the percentage loss on ignition, which implies a high content of organic materials which can burn off on the introduction of molten metal to form the basis for the collapsibility of the mould as investigated by Omo-Malaka (1977). The distribution of sand grains for the two sand samples are given in the Tables 2a and 2b and plotted as shown in Fig. 1.

Mechanical grading:

Tables 2a and 2b show the sieve analysis of Termite soil and silica sand respectively. The GNF of the Termite soil is higher than that of silica sand. This difference in values resulted from the variation in grain size, grain shape and distribution of the sands.

Fig. 1 shows, the cumulative grading curves of Termite soil and silica sand. The curves show similar characteristics. But the silica sand curve, shows more increase in the cumulative percentage retain with increasing sieve opening than that of Termite soil. The graph of the Termite soil is almost linear at one stage of sieve openings, that is, between 0.150 and 0.425 millimeters. In line with Balogun et al. (1980), the former result may indicate that the silica sand has less bond than Termite soil.

Clay Content:

From the result obtained in Table 1, the clay content of termite soil (49.12%) has suggested that it can be used as binder in moulding sand, since the amount and type of clay also have a great influence on the strength and other properties of moulding sand. [Nwajagu and Okafor, 1980]

Chemical Analysis:

The silica sand has higher percentage of silica (96.97%). This according to Burns (1989), favours their better performance when used in synthetic sand practice.

Green and Dry Strengths:

Figures 3a, 5a and 3b , 5b show the influence of silica sand and moisture content on green compression and shear strengths of termite soil and bentonite powder respectively.

Judging from the bonding characteristics of the two binders. The bentonite curves appeared to be more perfect than the termite soil curves. The bonding ability of the bentonite is more effective at lower moisture around 1.5 to 3 percents, while that of termite soil required high moisture before the bonding properties became more active; around 3 – 5 percents.

In Figs. 3b and 5b, the variation in strength due to the increase in moisture content accounts for the difference in their bonding capabilities. The other properties of sand that a ffects the strength are grain shape, the grain size and distribution. These sizes and shapes of the particles of binding material are important factors in the ability of the clay to absorb water and spread in a thin film around the sand grain. The thinner and more adhesive the film, the b etter t he b onds and the l ess excessive the clay wasted in filling up the spaces above the grains of sand.. The bonding power of a clay is the degree of cohesiveness it exhibits in holding the grains of moulding sand together. Clay with the smallest particle size and higher moisture absorption properties gives the highest bond strength and cohesiveness to the sand mixures [Mathew and Aku, 1984]. Also, Omo-Malaka (1977), discussed that when water is added to the sand mixture, the strength increases and with further addition of the water content, the s trength d ecreases at a critical v alue o f water [Omo-Malaka, 1977].

Figures 10a and 10b show the variation in green and dry compression strengths with percentage binder content at a fixed moisture content. In figure 10b, the dry strength decreases and at a critical value of 37.5% for 3% water content and the value of 40% for 5% water content, the strength of the mixture increases. The dry strength of the bentonite is greater at 2% moisture content. At 5% moisture content, it posses low value of dry strength. This shows that the termite soil exhibit the same properties with the bentonite for green and dry strengths. These similar strength properties reveals that termite soil with a range of 25% to 45%, can be developed t o perform b etter when used as synthetic foundry sand binder, since it exhibits similar properties and are comparable with a range of 6% to 20 %bentonite-bounded sands.

Permeability:

Close examination of Figures 2a and 2b show that permeability number of termite soil bonded sands and bentonite bonded sands have similar trends. The permeability increases with increase in moisture content, and at a critical percentage of moisture content the permeability starts decreasing. The two binders show similar properties at lower and higher percentage additions, that is, 35, 37.5, 40 and 45 percents termite soil show similar trends with 16 and 20 percents bentonite mixes.

Figures 12a and 12b show the effect of increasing binding content on permeability number of constant moisture content. The figures show that termite soil has similar permeability properties with 6 to 10 percents bentonite mixes. This calls for the development of termite soil to be used as moulding sand binder with range 25 to 45 percents addition.

Shatter Index:

The variation of shatter index with moisture content is shown in Fig. 7a. Fig. 7b shows the shatter index increases with increase in moisture content for 6, 12, 16 and 20 percents bentonite. While at 10 and 8 percents bentonite, the mixes show similar properties with 35, 37.5, 40 and 45 percents termite soil mixes.

Figures 11a and 11b show the effects of binder content on shatter index of the mixes. The result from t hese f igures sh ow t he t rends t o predict that termite soil will be suitably used as binder for making sand moulds at 5 and 8 percents moisture contents, since it can be compared with the bentonite as binder at 2 and 5 percents moisture contents.

Flowability:

Figure 8a shows the effect of silica sand and moisture content on flowability of termite soil. As compared with bentonite bonded sand in Figure 8b, 35, 40 and 45 percents termite soil mixes executed similar characteristics curves with 8, 10 and 16 percents bentonite mixes. The flowability increases with increase in moisture content and at a critical percentage of moisture addition, 7 percent for Termite soil mixes and within 2 and 4 percent for bentonite mixes, the flowability decreases with further increase in moiture content.

Bulk Density:

Figure 9 shows that the bulk density of the termite soil-bonded sand increases with increase in moisture content and the graph obtained from the resulted values are almost linear.

Practical Castings

Cast iron, bronze and aluminum castings have been produced in the mould made from the selected sand conditions in Tables, 4, 5 and 6 and the resulting castings have been investigated and compared with each other to know the most suitable sand condition for each metal castings.

The three sand conditions used in Table 4 for cast iron gave good account of their properties. Sample 40/7.5 in Fig. 13 gave the best surface finished casting followed by samples 30/7.5 and 50/10 also have good cast products except that the surface of the castings were fairly rough with few sand pick-ups.

Using the conditions given in Table 5 with references to Fig. 14, Samples 50/10 and 40/10 gave poor surface finishes with pin holes, shrinkage porosities and gas cavities. Sample 40/7.5 gave a surface appearance with very little metal penetration and sticky sand. While sample 30/7.5 gave the best surface finish of all the sand conditions used for bronze castings.

In Fig. 15 with the conditions given in Table 6, aluminum sample 30/10 gave a poor surface finish with gas cavity. When the water content was reduced from 10% to 7.5%, sample 30/7.5 gave a better surface appearance, but possesses some sand holes which resulted from weak ramming or inadequate blowing off of the mould cavity or due to falling sand when the drag was covered with the cope. Sample 40/7.5 also gave a fairly good surface finish, but when the core was removed, it formed gas cavity around the core. The surface finish of sample 50/10 is bad due to excessive water content, which resulted in very low permeability. Therefore, from prevailing discussions on aluminum castings, it would be concluded that samples 30/7.5 and 40/7.5 gave the fair results. These samples also gave the best cast iron and bronze castings.

APPENDIX

Table 1: Some Physical Properties of Termite Soil and Silica Sand

Sand	Grain Fineness Number (GFN)	Grain Shape	Colour	Clay Content (%)	Ignition Loss (%)	Relative Density (Kg/m)	Moisture Content (%)
Termite soil	126.04	Sub-angular	Brown	49.12	14.00	2.20	0.6
Silica Sand	47.83	Sub-angular	Light Brown	1.30	1.20	2.35	0.2

Table 2a: Sieve Analysis of Termite-Hill Soil

Calculation of A.F.S. grain fineness number of Termite Soil						Mechanical Grading	
U.S. Sieve equivalent number	Sieve opening (mm)	Amount retained on sieve		Multiplier	Product	Percentage retained	Cumulative percentage retained
		(gm)	(%)				
16	1.000	0.00	0.00	8	0.00	0.00	0.00
25	0.600	1.00	2.00	16	32.00	2.00	2.00
36	0.425	7.00	14.00	25	350.00	14.00	16.00
52	0.300	4.30	8.60	36	309.00	8.60	24.60
70	0.212	5.00	10.00	52	520.00	10.00	34.60
100	0.150	5.80	11.60	70	812.00	11.60	46.20
200	0.075	12.80	25.60	100	2,560.00	25.60	71.80
270	0.053	2.20	4.40	200	880.00	4.40	76.20
Pan		11.90	23.80	300	7,140.00	23.80	100.00
Total		50.00	100.00		2,603.60	100.00	
A.F.S. Grain Fineness Number		**= 12,603.60/100 = 126.04**					

Table 2b Sieve Analysis of Silica Sand

Calculation of A.F.S. grain fineness number of Silica Sand						Mechanical Grading	
U.S. Sieve equivalent number	Sieve opening (mm)	Amount retained on sieve (gm	(%)	Multiplier	Product	Percentage retained	Cumulative percentage retained
16	1.000	0.00	0.00	8	0.00	0.00	0.00
25	0.600	0.60	1.20	16	19.20	1.20	1.20
36	0.425	7.30	14.60	25	365.00	14.60	15.80
52	0.300	16.60	33.20	16	1,195.20	33.20	49.00
70	0.212	18.30	36.60	25	1,903.20	36.60	85.60
100	0.150	6.80	12.00	36	840.00	12.00	97.60
200	0.075	0.30	0.60	52	60.00	0.60	98.20
270	0.053	0.07	1.40	70	280.00	1.40	99.60
Pan		0.20	0.40	100	120.00	0.40	100.00
Total		50.00	100.00		4,782.60	100.00	

A.F.S. Grain Fineness Number = 4,782.60/100
= 47.83

Table 3 Chemical Composition of Silica Sand

Chemical Constituents	Percentage
SO2	96.97
AL203	1,90
Fe203	1.06
K20	0.07
Ti02	Nil
Ca0	Nil
Mg0	Nil
Na20	Nil

Table 4: Sand conditions used for cast Iron castings

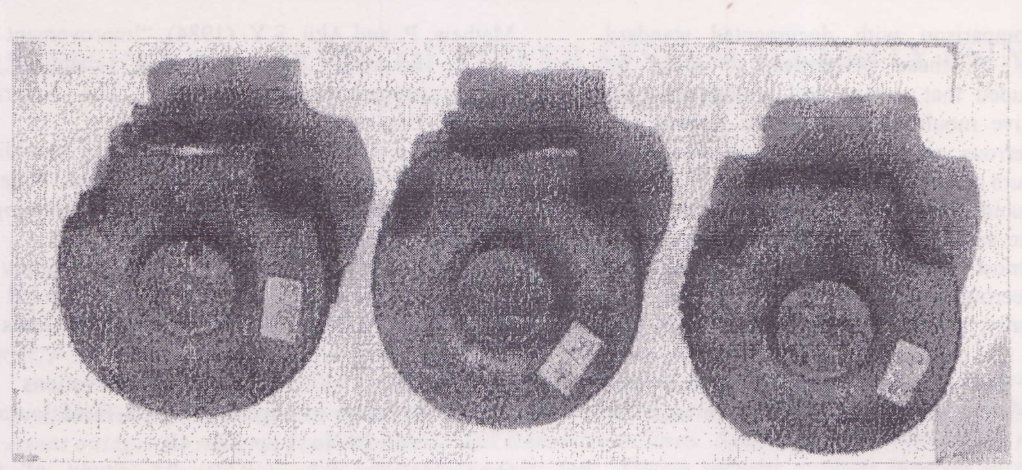
S/No	Sand specimen (Silica sand) +	Moisture Content (%)	Green Strength (KN/m^2)	Permeability Number	Shatter Index	Flowability (%)
1.	30% termite soil	7.5	39.97	81.19	36.67	25
2.	40% termite soil	7.5	69.25	59.30	58.86	42
3.	50% termite soil	10	74.77	29.48	88.80	34

Table 5: Sand conditions used for Bronze castings

S/No	Sand specimen (Silica sand) +	Moisture Content (%)	Green Strength (KN/m^2)	Permeability Number	Shatter Index	Flowability (%)
1.	30% termite soil	7.5	39.97	81.19	36.67	25
2.	40% termite soil	7.5	69.25	59.30	58.86	42
3.	40% termite soil	10	59.16	36.61	62.20	29
4.	50% termite soil	10	74.77	29.48	88.80	34

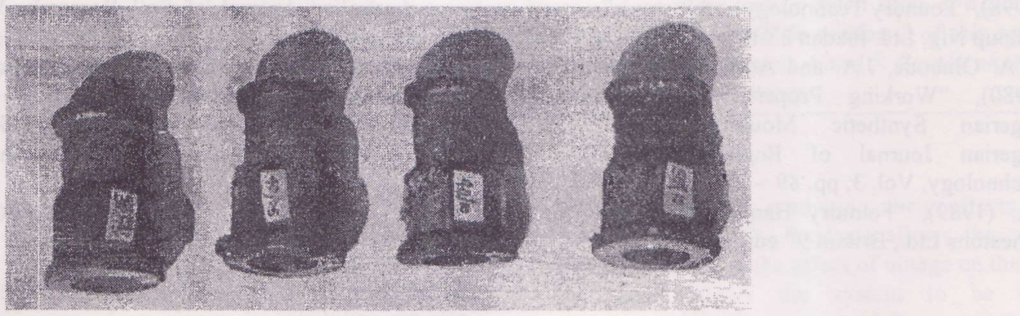
Table 6: Sand conditions used for Aluminum castings

S/No	Sand specimen (Silica sand)	Moisture Content (%)	Green Strength (KN/m^2)	Permeability Number	Shatter Index	Flowability (%)
1.	30% termite soil	7.5	39.97	81.19	36.67	25
2.	30% termite soil	10	32.40	57.00	37.42	24
3.	40% termite soil	7.5	69.25	59.30	58.86	42
4.	50% termite soil	10	74.77	29.48	88.80	34



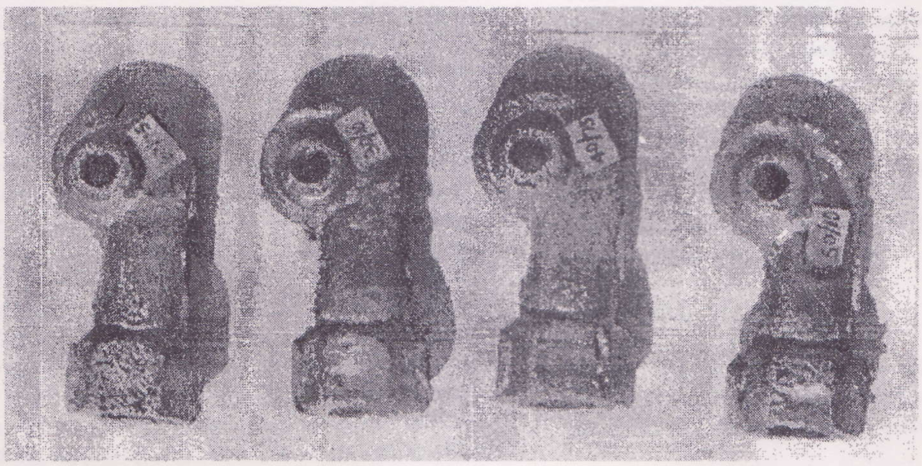
(Sand condition 1) (Sand condition 2) (Sand condition 3)

Fig. 13: Cast Iron (Pipe bending tool) Castings



(Sand condition 1) (Sand condition 2) (Sand condition 3) (Sand condition 4)

Fig. 14: Bronze (Reducing channel) cast products



(Sand condition 1) (Sand condition 2) (Sand condition 3) (Sand condition 4)

Fig. 14: Aluminium (spray Nozzles) cast products

CONCLUSIONS

Standard tests for moulding materials have been carried out on the termite soil to investigate its suitability in formulating local casting sands. Comparing the results obtained for the termite soil to that of bentonite, the following conclusions are evident:

(i) Despite a relatively high clay content, termite soil has good collapsibility, permeability, shatter index and a tolerable limit of green compression strength.

(ii) In comparison with documented standard values of these properties, it could be concluded that termite soil would make an effective moulding material for ferrous and non-ferrous castings, but at somewhat high moisture content of about 7.5%.

(iii) The sand condition between 30% and 40% termite soil and 6% to 8% moisture content are most recommended for castings of engineering components.

Finally, sand conditions between 30% and 40% termite soil can further be investigated in order to improve and eliminate the little defects that resulted when these sand conditions were used for castings.

REFERENCES

Ayangbesan, T. Adedoyin, S. and Olaniyan, A. (1998), "Foundry Technology and Practice". Ginpup Nig. Ltd. Ibadan 3rd Edition.

Balogun, S.A. Olubode, J.A. and Aderibigbe, D.A. (1980), "Working Properties of some Nigerian Synthetic Moulding Sand". Nigerian Journal of Engineering and Technology, Vol. 3, pp. 89 – 97.

Burns, T.A. (1989), "Foundry Handbook" BPCC Wheatons Ltd., Britain 9th edition.

Mathew, P. and Aku, S.Y. (1984), "Improvement on Foundry Sands through changes in preparation techniques". The Nigerian Engineer, Vol.19 pp.63–68.

Mathew, p. (1982), "Local Synthetic Moulding Mixture for Foundry Application", Nigeria Journal of Engineering and technology, Vol.5 pp.57–65.

Nwajagu, C.O. and Okafor, I.C.I. (198) "A Study of the moulding properties of sand bonded by Ukpor Clay: Elservier Science Publishers B. C. Amsterdam.

Omo Malaka, S.L. (1973), "Observations on Termites in Nigeria" Nigeria Field Journal. Vol. 38 No. 1 pp. 22 – 40.

Omo Malaka, S.L. (1977), "A Study of the Chemistry and Hydraulic conductivity of mould materials and soils from different habitants of some Nigerian termites" Australian Journal of Soil Research, Vol. 15, pp. 87 – 91.

Risdale – Dieter. "Foundry Sand Testing Equipment and Operation Instruction". England.

Zrimsek,A. H. and Vingas, G. T.(1963), "Steel Foundry Green Facing Sand". Trans AFS, Vol.71 pp36.