ANNALS OF FACULTY ENGINEERING HUNEDOARA
– International Journal of Engineering
Tome XI (Year 2013) – FASCICULE 3 (ISSN 1584 – 2673)

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INVESTIGATION INTO FOUNDRY PROPERTIES OF OSHOGBO AND SAKI SILICA SAND DEPOSITES

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ABSTRACT: The quality of moulding sand used in foundry usually exerts significant influence on cast properties. It is therefore imperative that the moulding characteristics of a green sand deposit are established prior to its application. This work compares the foundry properties of moulding sand from River Osun and Saki with a view to determining their suitability for casting household utensils. In addition, it also investigated the effect of termite hill activities on moulding sand. Samples of the sands were obtained from different locations within the deposits in Oshogbo and Saki respectively. AFS sieve analysis was performed on the sand to obtain 600 μm grain sizes. These compositions were later mixed in different proportions and then subjected to green and dry compression strengths, shatter index, permeability and moisture content tests. The results obtained indicated that Oshogbo sand deposit has superior green and dry compression strengths values of 16.35 kN/m^2 and 14.49 kN/m^2 over that of Saki which exhibited 9.3 kN/m^2 and 8.3 kN/m^2 respectively. The highest permeability of 193 ml/min was demonstrated by Saki compared with 79 ml/min by Oshogbo deposits while the difference in their moisture contents is insignificant. The shatter index of 64 % and 72 % was obtained for Oshogbo and Saki sands respectively. These results demonstrated the possible utility of both sands for making of sand casting moulds. However, Oshogbo deposit is recommended for its higher fraction of the 600μm grain being the preferred size with demonstrable foundry sand desired properties.
KEYWORDS: Tempering water, green and dry compression strength, moulding sand

INTRODUCTION

Foundry sand for metal casting is usually sourced from either natural deposit or synthetic mix of refractory sand grain, binder and moisture [1]. Each of the mix constituent is important in determining the characteristics of sand [2]. The binding agent is responsible for bindability thereby determining the size of voids by sand grain while moisture level determines the plasticity of the moulding sand [3].

In recent years, large deposits of suitable foundry sand and other related raw materials have been discovered in various parts of Nigeria. Amongst these foundry raw materials are dolomite [4] found in Osara, Edo State, clay in Ibule [5] and Ijapo [6] both in Ondo State and naturally bonded Foundry sand in River Osun, Osun State [7]. Other States in the federation which have been found to have abundant deposits of bentonite include Abia, Taraba, Kogi and Enugu. The largest deposit of 70-80 million metric tonnes of bentonite was also discovered in Afuze, Edo State [8]. The Nigerian Mining Corporation has also confirmed the existence of bentonite clay reserve of 700 million metric tonnes in Nigeria [4]. These avalanches of sand deposits and their associated raw materials are capable of boosting foundry activities in the southern part of Nigeria coupled with prospect for export.

It has demonstrated that the quality of casting is influenced significantly by sand properties such as; green compressive strength, dry strength, permeability, mould hardness, compactibility and shatter index. All these properties invariably depend on such parameters as the quality of binder used, amount of water and sand grain size [10]. Development of Igbokoda clay in the South Western part of Nigeria as a binder for synthetic moulding sand has been done [11]. Their work established that Igbokoda clay is good as a binder for synthetic moulding sand.

The shatter index also showed a significant decrease in collapsibility as the water content decreases at constant clay content. The effect of the variation of moisture content on the properties of Nigerian gum arabic bonded foundry sand mould was carried out [12]. The result indicates that sand bonded with powdered gum Arabic exhibited stronger bonds than with pre-solutionized gum Arabic. This implies that the amount of moisture in gum Arabic moulds could have significant effects on bonding performance of a moulding sand. The aim of this work is to investigate the physical moulding properties of Oshogbo and Saki sand deposits with a view to determine their suitability for foundry use.

EXPERIMENTAL PROCEDURE

The lump sample used in this work was obtained from River Osun in Oshogbo while pure silica and termite hill were sourced from Saki all in Nigeria. Figures 1 and 2 show respectively the locations of Oshogbo and Saki. The naturally bonded moulding sand from River Osun was collected from different points both at the surface and interior within 5 km apart. The procedures used in preparing moulding sand in Saki include mixing pure silica with termite hill and tempering water. AFS sieve analysis testing using serial sieves of gauges 150, 300, 600, 833 and 11167 μm was carried out on the pure silica and naturally bonded moulding sand. Equal amount of sands were placed on top of the sieves and the shaken for 15 minutes. Prior to mixing, pure silica, clay and naturally bonded moulding sand specimens were washed in boiling distilled water with some quantity of ammonia. The moulding specimens were later dried in an oven at temperature of 120^oC for 15 minutes, in order to ensure that specimens are free of water and contaminants such as organic matter.

For this work, the retained sand grain size below 600μm which is approximately 32 % of the total sand sieved was used for the preparation of moulding sand specimens. This selected grain size was considered adequate for use as moulding sand. The chemical composition of this sand was then obtained using ray fluorescence analysis. Separate portions of both washed sands were adequately mixed with clay and water using laboratory Muller for selected grains below 600μm. In addition, part of the naturally bonded moulding sand was tested without addition of termite hill. For washed naturally bonded moulding sand, the added water percentage was set to lie in the range 4 and 12%, while the clay was kept constant at 14 %. For Saki composition, the added water ranged between 4 and 12 % while the termite hill was varied from 6 to 14 %. 12 cm height by 5 cm diameter test specimen of average weight of 130 g were rammed in three dropping with weight from a height of 12 cm. The mixing compositions are shown in Tables 2-5.

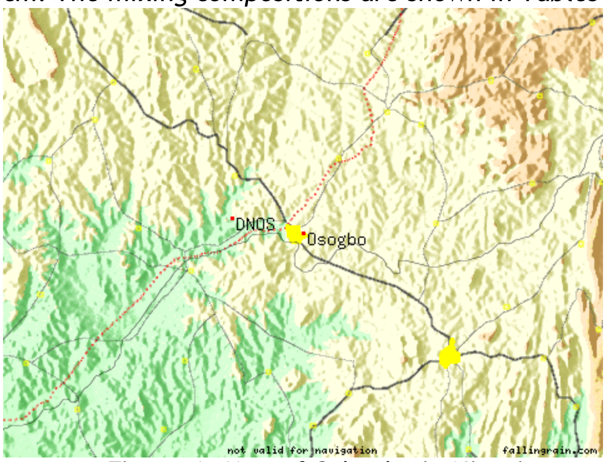

Figure 1. Map of Oshogbo in Nigeria

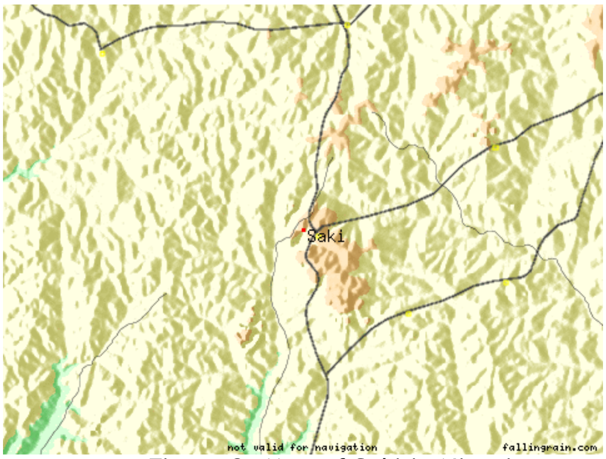

Figure 2. Map of Saki in Nigeria

Relevant test carried out on the specimens are green/dry compression strength; permeability; shatter index and moisture content. The green/dry compression strengths were measured using a universal sand-strength testing machine. A steadily increasing compressive force was applied on the specimen until failure occurred and compression strength in kN/m^2 read instantaneously. The specimen shatter index was determined [13]. A steady moisture teller was used to measure the moisture content and instantaneous readings of percentage of moisture were measured [14]. Permeability was measured using a permeability meter, by passing standard air pressure of 9.8x10^2 N/m^2 through a specimen tube containing prepared sand specimens. The time recorded for 2000 cm^3 of air to pass through each sand specimen, in accordance with the procedure stipulated by Sarkar (1967) aided the specimen permeability measurement [15].

Moisture tests were carried out to determine the dampness of sand mould samples, green compressive strength tests were conducted to measure the ability of the sand mould samples to withstand the pressure of molten metal during casting, shatter index tests were undertaken to measure collapsibility of the sand after casting for easy shake out and cleaning, while permeability tests were done to measure ease of escape of evolved gases to forestall defects like pin holes and gas inclusions in castings.

RESULTS AND DISCUSSION

Table 1 gives the chemical composition of the major components of the control sample. From the values given in Table 1, it is evident that Silica is the predominant component in the Oshogbo sand. This is of good advantage since high percentages of silica in sand [16], usually enhance its refractory and thermal stability. While it is noted that the presence of iron oxide, potassium oxide and lime can cause objectionable lowering of the fusion point in sands, none of these properties were determined in the present work, as this was not part of the objectives of the study.

Table 1. Chemical Composition of Oshogbo Sand Deposit

Constituents	Al_2O_3	SiO_2	Fe_2O_3	CaO	MgO	K_2O
% Wt	2.19	96.08	0.84	0.25	0.36	0.28

The results of the relevant mould sand properties tests are presented in Tables 2, 3, 4 and 5. Table 2 shows the influence of varying tempering water addition 4-12 percent on the naturally bonded moulding sand in the range of 88-96 percent. Water is often added to the naturally bonded moulding sand to develop its adhesive characteristics thereby enhancing the sand plasticity. As established [17], the amount of clay required for a moulding sand ranges from 4 to 20 percent.

Table 2: Mould Sand Properties of As-received Oshogbo Sand at Varying Water Addition (AOS)

Sand (%)	Added H_2O (%)	Green Strength (kN/m^2)	Dry Strength kN/m^2)	Shatter Index (%)	Moisture Content (%)	Permeability (ml/min)
96	4	14.08	12.04	50.30	2.10	78.3
94	6	15.01	13.00	55.04	5.70	79.1
92	8	14.94	14.94	59.80	5.85	80.5
90	10	16.35	14.49	63.40	8.05	79.4
88	12	15.78	13.36	64.10	9.35	78.2

The moulding sand physical properties developed on addition of 14 % termite hill on the as-received Oshogbo sand are presented in Table 3.

Table 3: Mould Sand Properties of Oshogbo Sand on addition of 14 % termite hill ($ARSC_{14\%}$)

Sand (%)	Added H_2O (%)	Green Strength (kN/m^2)	Dry Strength kN/m^2)	Shatter Index (%)	Moisture Content (%)	Permeability (ml/min)
82	4	10.8	8.77	49.3	1.52	90.5
80	6	11.1	9.08	43.28	4.80	87.5
78	8	11.93	9.82	41.36	4.84	85.4
76	10	12.52	10.5	40.30	9.29	83.6
74	12	14.26	11.03	20.40	11.20	81.4

Table 4 contains the values of mould sand properties developed by the Saki sand on addition of 14 percent termite hill.

Table 4: Mould Sand Properties of Saki Sand on Addition of 14 % termite hill ($SSC_{14\%}$)

Sand (%)	Added H_2O (%)	Green Strength (kN/m^2)	Dry Strength kN/m^2)	Shatter Index (%)	Moisture Content (%)	Permeability (ml/min)
82	4	2.7	2.2	71.52	1.75	180.3
80	6	6.1	5.1	63.98	3.91	193.3
78	8	6.98	6.0	43.9	4.73	170.3
76	10	6.3	5.3	25.8	8.11	150.0
74	12	9.3	8.3	5.7	9.74	123.3

Variation of the termite hill contents from 6 to 14 percent impact significantly on the moulding sand properties developed by the Saki sand. The values there proportion are given in Table 5.

Table 5: Mould Sand Properties of Saki Sand at varying termite hill addition ($SSC_{6-14\%}$)

Sand (%)	Clay content (%)	Added H_2O (%)	Green Strength (kN/m^2)	Dry Strength kN/m^2)	Shatter Index (%)	Moisture Content (%)	Permeability (ml/min)
82	14	4	2.7	2.2	71.52	1.75	123.3
82	12	6	9.5	8.3	60.90	3.11	142.3
82	10	8	9.7	8.6	50.00	4.15	153.3
82	8	10	8.6	7.6	21.00	8.31	140.7
82	6	12	9.5	8.4	11.80	10.22	120.0

In order to present a scientific analysis of the properties developed by both sands, the values attained as contained in Tables 2 – 5 are illustrated in Figures 1, 2, 3, 4 and 5.

Figure 3 shows the variation of the green compression strength with moisture content for the four cases of specimens considered. Gradual rising in the green compression strength was observed across the four types of specimens. The AOS is characterised with optimum green compression strength which ranged from 14 to 16.2 $KN/m^2$with moisture content of 2.1 to 9.35 % respectively. The peak value of 16.35 KN/m^2 was attained at 90 % as-received sand, 10 % tempering water addition and 8.05 % moisture content. $SSC_{6-14\%}$ which is the practice used in Saki exhibited the list green compression strengths ranging between 2.7 and 9.5 KN/m^2. Its peak green compression strength of 9.5 KN/m^2 occurred at 82 sand %, 6 % termite hill and 12 % added water which corresponded to 10.22 % moisture.

As demonstrated in Figure 3, the sand green compression strengths increase with increasing moisture content up to the temper point. This however varies for the different sand specimens. Temper points for the AOS, $ARSC_{14\%}$, ($SSC_{14\%}$) and ($SSC_{6-14\%}$) specimens tested here is recorded in the figure as being coincident with moisture contents of 8.05%, 12%, 9.74% and 10.22%, respectively, at *which points respective optimum green compression strengths of 16.35kN/m^2, 14.26kN/m^2, 9.3kN/m^2 and 9.5kN/m^2 were recorded. Increasing the water content in sand increases the green compressive strength to a point, referred to as temper point [18]. The percentage of added water required to reach the temper point for the AOS, ARSC$_{14\%}$, (SSC$_{14\%}$) and (SSC$_{6-14\%}$) specimens was found to be 10% for the as-received specimen (Table 1) and 12% for other sand specimens (Tables 2-4).*

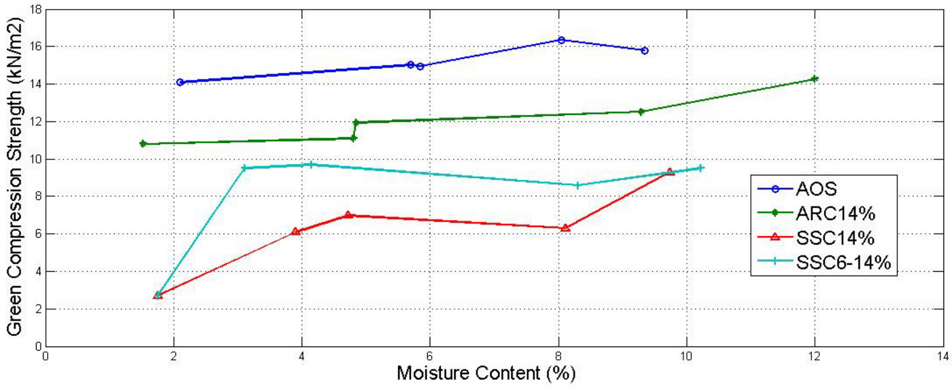

Figure 3. The variation of the green compression strength with moisture content for the four cases of specimens

The influence of moisture content on the dry compression strengths of the four sand mixures is presented in Figure 4. The specimens demonstrated increse in strength as moisture content increased. The as-received moulding sand (AOS) from Osogbo shows highest dry compression strength (12-13.4 kN/m^2) at all levels of comparison with other three moulding sands specimens. However, the dry compression strengths of SSC$_{6-14\%}$and SSC$_{14\%}$ sand specimens increase progressively from 2.2 – 8.4 kN/m^2 with moisture content in the range 1-10 percent.

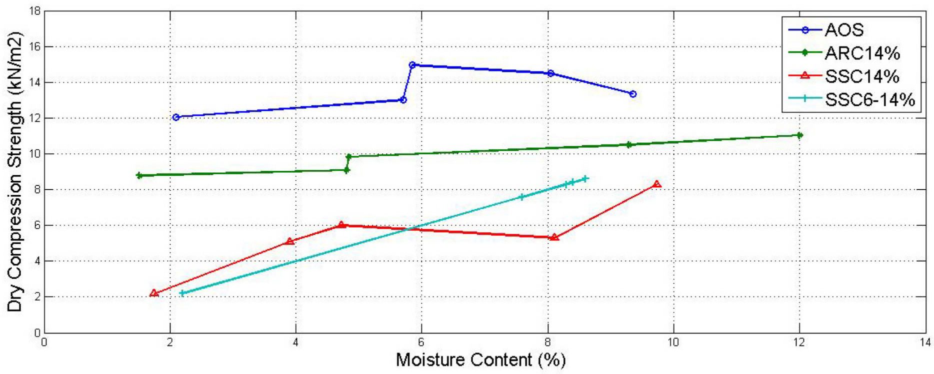

Figure 4. The influence of moisture content on the dry compression strengths of the four sand mixures

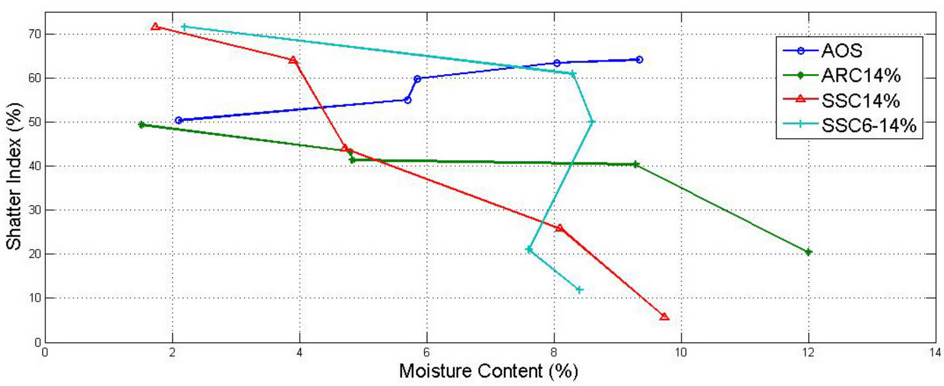

Figure 5. Shatter Index against Moisture Content

The AOS curve in Figure 5 exhibit linear relationship between the Shatter Index and the Moisture Content. While ARSC$_{14\%}$, SSC$_{14\%}$ and SSC$_{6-14\%}$ sand specimens are characterised by decrease in shatter index as moisture content increases however, AOS specimens exhibited improved toughness due to improved shatter index response with increase in moisture content. This trend is consistent with the observations made early [12] that as moisture increased with increased added water the bonded particles of the sand moulds become loose resulting to easier escape of gases. The weakening of bond strength eventually gave rise to higher collapsibility. Similar behaviour was not observed for other specimens on the addition of termite hill. Shatter index increased from 50.3% at 2.1% moisture *to 64.1% at 9.35% moisture for AOS sand but decrease from 49.3% at 1.52% moisture to 20.4% at 11.2% moisture, 71.52% at 1.75% moisture to 5.7% at 9.74% and 71.52% at 1.75% moisture to 11.80% at 10.22% respectively for the $ARSC_{14\%}$, $SSC_{14\%}$ and $SSC_{6-14\%}$ specimens. The shatter index was found to be highest for the unwashed sand, and generally higher for the as-received sand than for the washed sand.*

Figure 6 illustrates the relationship between the permeability and the moisture content for AOS, $ARSC_{14\%}$, ($SSC_{14\%}$) and ($SSC_{6-14\%}$) specimens. Permeability measures the "openness" of the sand mixture. It indicates the ease with which mould and core gases flow within and out ofthe mould. The permeability of the AOS, $SSC_{14\%}$ and $SSC_{6-14\%}$ sand specimens was observed to increase with increase moisture content in the range of 2-6%, 1-4% and 1-4%, respectively before falling gradually. The $ARSC_{14\%}$ specimen however exhibited a decreasing trend throughout the entire range of moisture content considered.

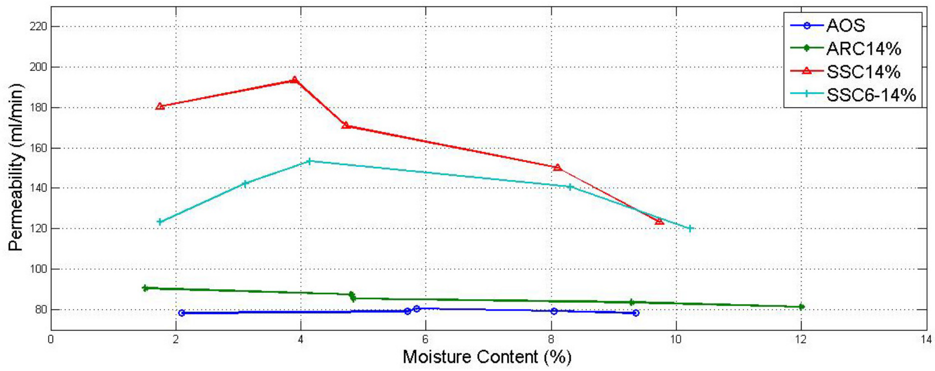

Figure 6. Permeability against moisture content

The curves of $SSC_{14\%}$ and $SSC_{6-14\%}$ in the figure exhibited higher values of permeability of 123-193 ml/min and 120-153 ml/min respectively. It seems that activities of termites are responsible for changing binding properties impacted on the sand. This however, enhanced the permeability of the $ARSC_{14\%}$, $SSC_{14\%}$ and $SSC_{6-14\%}$.

In contrast, the curves of AOS and $ARSC_{14\%}$ are characterized with relatively lower permeability when compared with standard values established for sands used in casting light and heavy steels, these values that fall in the ranges 78-81 ml/min and 81-91 ml/min respectively [10]. On the other hand, the sands used in casting aluminium, medium grey iron and malleable iron fall in the range 10-80ml/min. The comparative lower values of permeability for the sands investigated were due to the fine nature of the sand grains used (below 600 µm) compared to 354 µm grain size that is prevalent in moulding sand. This is desirable because fine grain aggregates enhance particle packing arrangement within the mould [16].

The influence of water addition on the resulting mould moisture content is presented in Figure 7. Similar trends are observed in all the curves. Moisture increased from 2.1 to 9.35, 1.52 to 11.2, 1.75 to 9.74 and 1.75 to 10.22 for AOS, $ARSC_{14\%}$, $SSC_{14\%}$ and $SSC_{6-14\%}$ respectively at the range of 4-12 % added water. This behaviour appears to be in tandem with contribution that the initial water added to a sand mix is absorbed by the binder till saturation [12]. After water saturation of the sand mix is attained, any further addition is held up as free water thereby accounting for the continuous increase in moisture content observed in Figure 6.

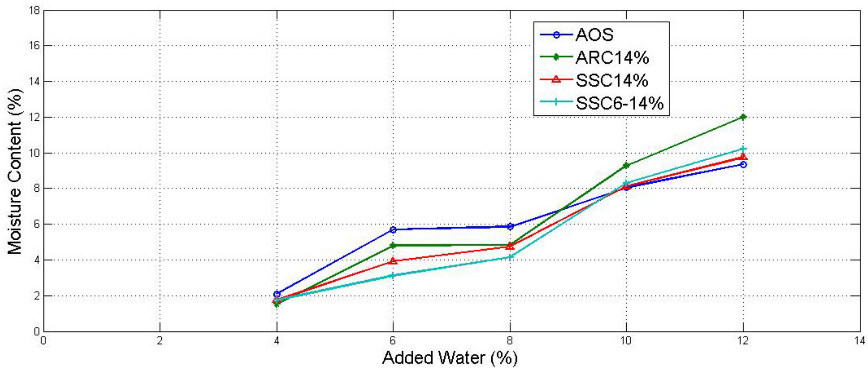

Figure 7. Moisture content against water addition

Further, the amount of water required by moulding sands is determined by sand purity bonding clay and supplementary additives which appears to have influenced the sand behaviour.

CONCLUSIONS

This study has shown that

- *The as-received sand specimen obtained from Oshogbo deposit exhibited better green/dry compression strengths over that of Saki sand.*

- *Increase in moisture content of the AOS specimen resulted in increased shatter index and therefore increase in toughness. However, the reverse is the results obtained for the other three sand mixes.*
- *Permeability response was observed to be lower for AOS and ARSC$_{14\%}$ sand mixes compared to SSC$_{14\%}$ and SSC$_{6-14\%}$ specimens. However, the values obtained for ARS and ARSC$_{14\%}$ are quite suitable for casting aluminium, malleable iron, heavy grey iron and medium grey iron.*
- *The Oshogbo silica sand is recommended for use in the foundry as replacement for imported synthetic silica. Sand which is rather exorbitant.*
- *Further research aimed at detail investigation on the influence of termite activities on the binding properties of moulding sands is suggested.*

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