



## Suitability of Different Nigerian Sourced Natural Molding Sands for Green Sand Casting using Scheffe's Model

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### ABSTRACT

*The Nigerian foundry industry faces challenges in achieving optimal casting quality, largely due to the lack of standardized approaches to designing moulding sand mixtures. This study investigates the suitability of locally sourced sands—Zungeru, Bida, Minna, Jos, and Kaduna—for green sand casting, using Scheffe's mixture design model as the design of experiment (DOE) technique. Synthetic sand mixtures (SSMs) were developed by combining natural sands with additives such as bentonite, coconut shell fibre, and rice husk fibre. A total of 35 experimental blends were analyzed for permeability, compressive strength, plastic index, and other key parameters following ASTM Standards D2434, D2216, D4318, and D2487 for permeability, moisture content, plastic index, and fineness modulus respectively. The findings reveal that Zungeru sand, in particular, met the requirements for Al-6063 green sand casting applications. This study shows the potential of optimizing natural sands for foundry applications, contributing to the development of sustainable and cost-effective casting processes in Nigeria.*

**Keywords:** Nigerian foundries; green sand casting; Scheffe's model; synthetic sand mixtures.

### 1.0 INTRODUCTION

Casting is a fundamental manufacturing process employed in a variety of industries, such as automotive, aerospace, construction, and heavy machinery. This technique facilitates the mass production of complex metal components in diverse shapes, eliminating the need for joining methods like welding, while ensuring precision and efficiency [1]. The Nigerian casting industry is essential to the nation's industrial development, producing components for the automotive, agricultural, and construction sectors. Despite this, foundry practices in Nigeria often rely on trial-and-error methods, especially in the design of moulding sands, which limits the quality of cast products. Moulding sands, primarily composed of silica sand and various additives, significantly impact casting properties such as surface finish, dimensional accuracy, and mechanical performance [2]. The use of natural sands in foundry operations is both cost-effective and environmentally sustainable [3], but the lack of standardized optimization methods has hindered their widespread adoption in Nigeria.

The strength of the foundry is however dependent on the sand behavior as Sand is the primary moulding material used in foundry operations for all types of castings, whether ferrous or non-ferrous [2]. Its widespread use is due to its essential properties that are crucial for foundry applications. One of its key

attributes is its refractory nature, allowing it to withstand the high temperatures of molten metal without melting or fusing [4]. Green sand casting is one of the most widely used methods for producing metal parts due to its low cost, simplicity, and adaptability. The process involves forming a mould from a mixture of sand, water, and clay, which serves as a binder. The quality of the cast product depends heavily on the properties of the moulding sand, including permeability, green compressive strength, moisture content, and plasticity. Various studies have shown that natural sands, when properly conditioned, can meet the stringent requirements of foundry applications [2,5-6]. However, these studies often fail sufficiently to provide a systematic method for optimizing sand mixtures, which is critical for ensuring consistent casting quality.

Several studies have investigated the properties of Nigerian sands for casting purposes. For instance Zungeru, Bida, and Minna sands have shown promise due to their high silica content and favorable grain size distribution [7-9] while Jos and Kaduna sands have been used in traditional foundry settings [5-6]. However, a comprehensive evaluation of these sands using an experimental design model like Scheffe's to the best of our knowledge has not been previously reported. In addition, Scheffe's model is a mathematical approach used in mixture design experiments, particularly in optimizing the proportions of different components in a blend. In foundry applications, the model helps in determining the optimal mix of sand and additives to achieve desired casting properties. Previous research has successfully applied Scheffe's model to improve the performance of construction materials, food formulations, and pharmaceutical blends, but its application in foundry sand optimization is relatively under explored, especially in Nigeria. This study aims to evaluate the suitability of locally sourced sands—Zungeru, Gbanchitako Bida, Chanchaga in Minna, Vom in Jos, all in North central Nigeria and Rigasa, Kaduna in north western Nigeria—for Al-6063 green sand casting, using Scheffe's mixture design model to optimize sand mixtures. By employing a science based approach, this research seeks to improve the competitive advantage of Nigerian foundries, contributing to both the local economy and the global casting industry.

## 2.0 MATERIALS AND METHODS

### 2.1 Materials

The materials used for the development of the green moulding sand includes Aluminium Al- 6063 shown in Figure 1, sourced from china using the aliexpress, an online market with its chemical composition reported in Table 1.0. Sand was collected from five locations in Nigeria- Zungeru, Bida, Minna, Jos, and Kaduna, Nigeria with a Global Positioning System (GPS) coordinates presented in Table 1. Each sample was characterized for grain size, specific gravity, and clay content. To enhance the binding properties and strength of the moulding sand, additives comprising of bentonite obtained from Nigerian institute of mining and geosciences, Jos, Plateau State as the binding agent, coconut shell fiber purchased from a kasuwan Gwari, a popular market in Minna, Niger state, rice husk purchased from YBG rice mill in Minna, Niger State shown in Figure 3, and distilled water were used. The materials and their sources are presented in Table 2.0

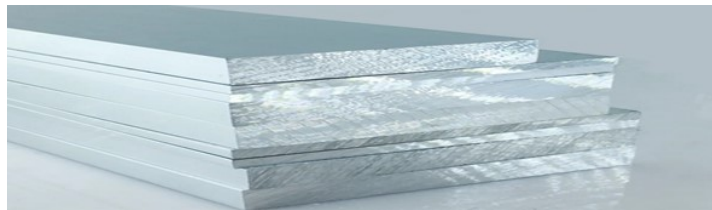


Figure 1: Aluminium Al-6063 alloy

**Table 1.** Chemical composition of Al-6063 [10]

Element	Mn	Fe	Mg	Si	Zn	Ti	Cr	Cu
%wt	0.10	0.35	0.90	0.60	0.10	0.10	0.10	0.10

**Table 2.** Materials used for the green moulding sand

S. n	Material	Source	Coordinates	Function
1	Silica Sand	Zungeru	9° 49' 36.62N 6° 09' 15.73E	Contributes to the overall strength and stability of the mould as the base material
		Kaduna	10° 31' 46.53N 7° 23' 34.39E	
		Chanchaga	9° 31' 56.76N 6° 35' 13.74E	
		Bida	9° 04' 55.49N 6° 00' 32.09E	
		Jos	9° 43' 53.24N 8° 47' 36.35E	
2	Bentonite	Jos		Binding agent to improve the sand green compressive strength and cohesion to the sand
3	Coconut shell fiber	Minna		Additive to increase thermal stability and permeability
4	Rice husk fiber	Minna		Additive to enhance sand permeability and tendency for casting defects
5	Water	Chanchaga		Added to adjust the moisture content of the green sand mixture to the desired levels



**Figure 2.** Sand sourced from (a) Zungeru, (b) Kaduna, (c) Chanchaga, (d) Bida, (e) Jos



**Figure 3.** Additives (a) Coconut shell fiber, (b) Rice husk, (c) Bentonite

## 2.2 Methods

Natural sand collected from the five different locations in the form of lumps and particles. The collected sand was then broken to reduce the sizes of the lumps using a hand rammer at the department of civil engineering, Federal University of Technology Minna. The broken lumps and particles were then washed in distilled water to remove clay contents and other unwanted particles from it. This was then subsequently dried in the sun for 24 hours and then sieved for onward analysis. The samples were then screened

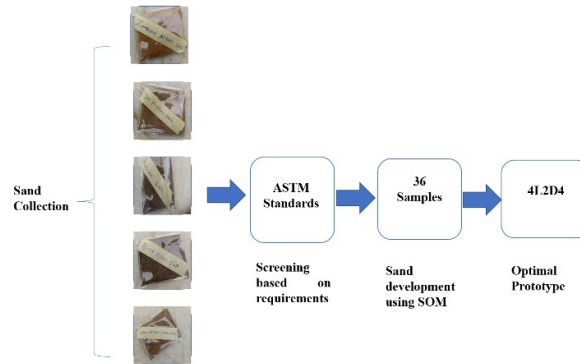


Figure 4. Graphical description of the research method

### 2.2.1 Particle size analysis

The dried known quantity 50 g of the sand grains free of clay was used to determine the fineness number, using a set of standard testing sieves based on ASTM D 2487 specification. The BSS No. of 6, 12, 20, 30, 40, 50, 70, 100, 140, 200 and 270 was used. The sand was placed on the coarsest sieve at the top and after 15 minutes of vibration, which is the recommended shaking time to achieve complete classification of the sand, the weight of the sand retained on each sieve obtained was converted to a percentage equivalent. each percentage was multiplied by a factor and the fineness number was obtained by adding all the resulting products, dividing the total by the percentage of sand retained and grain fineness number (BSS) were computed according to Equation 1.

$$\text{Gain fineness, } f_g = \frac{n}{r} \quad (1)$$

Where:  $n$  = total weight of moulding sand pass in gramme,  $r$  = percentage of total weight of moulding sand retained.

### 2.2.2 Specific gravity analysis

The specific gravity of the material was determined by weighing 5 g using weighing balance according to ASTM D854. The mass of empty cylinder was determined using weighing balance.

The cylinder was half filled with water and its new mass is determined using weighing balance. The 5 g of the material was gently poured into measuring cylinder containing water and new mass of the content was noted. The total mass of (d) was then determined. The specific gravity (SG) of the moulding sand was determined according to ASTM D854 using Equation 2 [11]

$$\text{SG} = \frac{m_2 - m_1}{(m_3 - m_1) (m_3 - m_4)} \quad (2)$$

Where:  $m_1$  = empty cylinder mass,  $m_2$  = total mass of material and cylinder,  $m_3$  = total mass of material, cylinder, and water,  $m_4$  = mass of cylinder and water.

### 2.2.3 Permeability test

the permeability test was conducted to assess the ability of the collected sand samples, to allow gases to pass through the sand mould during the green sand casting of Al-6063 [12]. The test followed the ASTM D2434 standard, which measures the rate at which air or gases pass through a compacted mould. According to [13], the samples were cylindrical samples of approximately 50 mm in diameter and 50 mm in height by compacting synthetic moulding sand mixture.

### 2.2.4 Green compressive test

the green compressive strength test was performed to determine the strength of the locally sourced moulding sands, when in a moist, unbaked condition. This test followed the ASTM D695 standard, which measures the resistance of the sand to deformation or breakage under compressive load. Green compressive strength is an important property for ensuring that the sand mould can maintain its shape and withstand the pressures during the metal pouring process in the green sand casting of Al-6063.

### 2.2.5 Moisture content test

the moisture content test was conducted to measure the amount of water present in the locally sourced moulding sands. [14] Moisture content is an important parameter in green sand casting, as it influences the sand's cohesiveness, permeability, and overall mould quality. Excess moisture can cause steam generation during casting, leading to defects like gas porosity, while insufficient moisture can result in weak moulds. samples were prepared by taking 100 grams of the synthetic moulding sand mixture. The sand was spread evenly on a pre-weighed container to ensure accurate measurement. The sample was then dried in an oven at a controlled temperature of 105°C to 110°C for 24 hours, until a constant weight was achieved. After drying, the sample was removed, allowed to cool, and weighed again to determine the moisture content. The moisture content was calculated as the difference in weight before and after drying, expressed as a percentage of the initial weight based on Equation 1.

$$\text{Moisture Content (\%)} = \frac{W_i - W_f}{W_i} \quad (3)$$

Where:  $W_i$  = initial weight of the sample (before drying) in grams,  $W_f$  = final weight of the sample (after drying) in grams

### 2.2.6 Plastic Index investigation

the plasticity index (PI) of the sourced moulding sands was investigated to assess the sand's workability and its ability to deform under stress without cracking. The test followed the ASTM D4318 standard, which determines the plastic and liquid limits of soil-like materials. The plasticity index which is the difference between the liquid limit and the plastic limit, representing the range of moisture content where the sand remains workable [15]. A higher PI indicates better mould flexibility, which is essential in green sand casting to ensure the mould can handle deformation without breaking [16]. The dimensions of the sample were 50 mm in diameter and 100 mm in height for this test. The PI was calculated based on Equation 2

$$\text{Plasticity Index (PI)} = (LL) - (PL) \quad (4)$$

Where, LL is the Liquid Limit indicating the water content at which the sand changes from a plastic to a liquid state and PL is the Plastic Limit indicating the water content at which the sand changes from a semi-solid to a plastic state.

### 2.2.7 Experimental Design

Four components were used to develop the synthetic moulding sand and number of require experimental design with different vertices points (mix-ratio) as the boundary condition was determined using Equation 5, [17]

$$P_{(n,m)} = \frac{(n+m-1)!}{m!(n-1)!} \quad (5)$$

Where:  $n$  = Require components,  $m$  = face-mix ratio,  $P$  = Number of experimental designs.

The experimental results were analyzed using Scheffe's model to determine the optimal sand mixtures for the Al-6063 casting using the. Scheffe's model was employed to develop synthetic sand mixtures (SSMs) by blending natural sands with the additives. Three levels of mixture design were used

The required numbers of experimental design for moulding sand for the pure, binary and ternary blends are,

Lattice Design (4,1): Four experiments for pure blending as shown in Equation 6

$$P(4,1)_{design} = \frac{(4+1-1)!}{1!(4-1)!} = \frac{4!}{1!(3)!} = 4 \quad (6)$$

Lattice Design (4,2): Ten experiments for binary blending shown in Equation 3

$$P(4,2)_{design} = \frac{(4+2-1)!}{2!(4-1)!} = \frac{5!}{2!(3)!} = 10 \quad (7)$$

Lattice Design (4,3): Twenty experiments for ternary blending shown in Equation 4

$$P(4,3)_{design} = \frac{(4+3-1)!}{3!(4-1)!} = \frac{6!}{3!(3)!} = 20 \quad (8)$$

A control sample of pure blend was also obtained making a total of 35 SSMs.

## 3.0. RESULTS AND DISCUSSION

### 3.1 Suitability of Sand Samples

The developed synthetic sand based on scheffes model for the pure, binary and ternary blends and their suitability based on ASTM standards are presented in this section.

#### 3.1.1 Suitability of the pure blend

For the pure blend, the following was obtained for its suitability for Al-6063 casting using Equation 6

**Table 3:** Result of Pure blend of the SSM

Sample	MC	PI =LL-PL (%)	Specific gravity
	ASTM D2216 (3-5%)	ASTM D4318 (8- 20)	ASTM D854 Requirement <b>(2.5 – 2.8)</b>
4L1D1	MR	18.84 (MR)	MR
4L1D2	MR	12.83 (MR)	DnMR
4L1D3	MR	7.69 (MR)	DnMR
4L1D4	DnMR	4.75 (DnMR)	DnMR

Where; MR: meet requirement and DnMR: do not meet requirement.

The suitability of pure blending of SSM in Table 3 include moisture content, plastic index and specific gravity requirement. However, only 4L1D1 met all the requirement for the Al-6063 green cast. The sample 4L1D1 of SSM was selected for parameter tests such as green compressive strength and permeability

### 3.1.2 Suitability of the binary blend

For the binary blend, the following as presented in Table 4 was obtained for its suitability for Al-6063 green sand casting using Equation 7

**Table 4.** Result of the binary blending

Sample	MC	PI =LL-PL (%)	Specific gravity
	ASTM D2216 (3-5%)	ASTM D4318 (8- 20)	ASTM D854 Requirement
4L2D1	MR	MR	DnMR
4L2D2	MR	MR	DnMR
4L2D3	MR	MR	DnMR
4L2D4	MR	MR	MR
4L2D5	MR	MR	MR
4L2D6	MR	MR	DnMR
4L3D7	DnMR	MR	DnMR
4L3D8	MR	MR	DnMR
4L3D9	MR	MR	DnMR
4L3D10	MR	DnMR	DnMR

From Table 6, only 4L2D4 met all three requirements and 4L2D5 met two requirements. Two samples (4L2D4 and 4L2D5) were selected for parameter tests green compressive strength, permeability and SEM-EDS analyses.

### 3.1.3 Suitability of the ternary blend

For the ternary blend, a total of 20 samples was developed and presented in Table 5 using the Equation 8

**Table 5.** Suitability of the ternary blend.

Sample	MC	PI =LL-PL (%)	Specific gravity
	ASTM D2216 (3-5%)	ASTM D4318 (8- 20)	ASTM D854 Requirement
4L3D1	MR	MR	DnMR
4L3D2	DnMR	MR	MR
4L3D3	DnMR	MR	MR
4L3D4	MR	MR	MR
4L3D5	MR	MR	DnMR
4L3D6	MR	MR	DnMR
4L3D7	MR	MR	DnMR
4L3D8	MR	MR	DnMR
4L3D9	MR	MR	DnMR
4L3D10	DnMR	MR	DnMR
4L3D11	MR	MR	DnMR
4L3D12	MR	MR	DnMR
4L3D13	MR	MR	DnMR
4L3D14	MR	MR	DnMR
4L3D15	MR	MR	DnMR
4L3D16	MR	MR	MR
4L3D17	MR	MR	DnMR
4L3D18	MR	MR	DnMR
4L3D19	MR	MR	DnMR
4L3D20	MR	MR	DnMR

For the ternary blend, samples 4L3D2, 4L3D3, 4L3D4 and 4L3D16 met the requirements based on parameter tests such as green compressive strength, permeability and SEM-EDS analyses.

A total of 34 samples was developed using Scheffe’s model with the addition of zungeru sand as control sample for the control sample design. However, from the 35 blends, only 7 samples met the ASTM requirements and they are 4L1D1, 4L2D4, 4L2D5, 4L3D2, 4L3D3, 4L3D4 and 4L3D16

### 3.2 Sample Analysis

#### 3.2.1 Particle size analysis

**Table 6.** Result of particle size analysis

Sample	Cumulative (%) weight passed using various size (mm)				
	5.00	2.00	0.425	0.075	Fineness modulus 0.075 mm (45% passed)
Zungeru	99.73	99.40	95.37	46.07	MR
Bida	100.00	99.50	92.37	45.30	MR
Minna	99.83	99.53	95.63	47.47	MR
Jos	100.00	99.90	96.13	78.40	MR
Kaduna	100.00	99.23	77.40	24.27	DnMR

The result of the particle size analysis indicated that majority of the sand samples across the selected locations passed through the 5.0mm to 2.00mm sieves indicating a higher cumulative percentage across all the samples as suggested by[18]. However, the sieves that are finer with size 0.0075 mm showed more variation with 45-47% (Table 1) of the sand passing for zungeru, minna and bida which met the required fineness modulus while that of Jos had the highest percentage at 78.4% indicating sand that is finer while that of kaduna had the lowest at 24.27% making it not suitable as it does not meet the requirement for moulding operations [19].

### 3.2.2 Specific gravity analysis

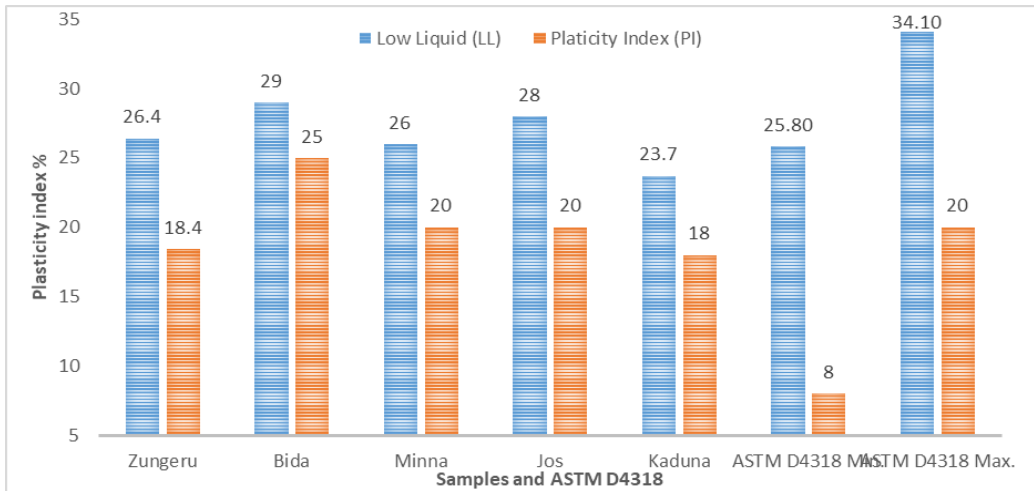


Figure 5: Specific gravity of the samples

In Figure 5, the graph shows the liquid limit (LL) and plasticity index (PI) of the different sand samples (Zungeru, Bida, Minna, Jos, Kaduna) as it relates to ASTM D4318 standards. The result shows that the minimum LL of 25.8% and maximum LL of 34.1%, and PI values between 8% and 20%), all samples except for Kaduna exhibit plasticity within suitable ranges for effective sand molding applications according to [20]

### 3.2.3 Permeability analysis

The result for permeability analysis is presented in Table 7

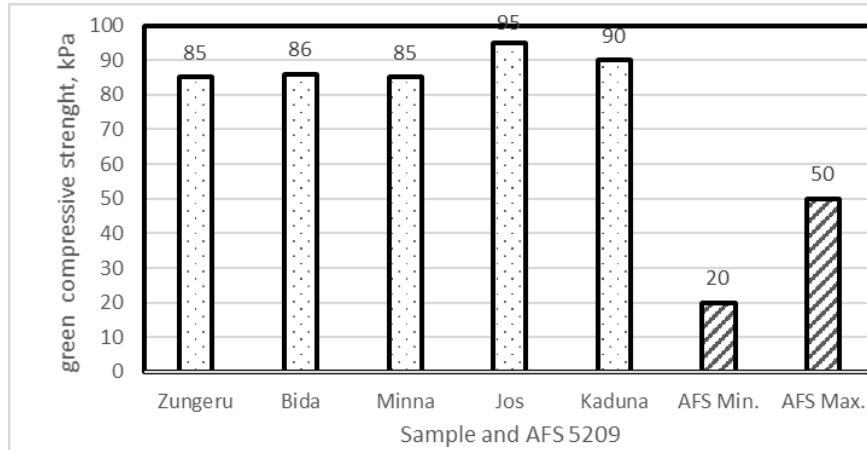
Table 7: Permeability results

Sample	Permeability, k (%)	ASTM D2434 ( $1 \times 10^{-7}$ cm/s - $1 \times 10^{-3}$ cm/s)
Zungeru	$1.4 \times 10^{-6}$	MR
Bida	$2.7 \times 10^{-6}$	MR
Minna	$3.7 \times 10^{-6}$	MR
Jos	$4.0 \times 10^{-6}$	MR
Kaduna	$10.0 \times 10^{-6}$	MR

The permeability test results for the samples from Zungeru, Bida, Minna, Jos, and Kaduna demonstrate that all of them meet the requirements set by ASTM D2434, which specifies a range of  $1 \times 10^{-7}$  cm/s to  $1 \times 10^{-3}$  cm/s for permeability. The permeability values for all the samples fall within this acceptable range, indicating that they allow fluid flow without being overly restrictive or too porous for application.

Among the samples, Kaduna has the highest permeability value at  $10.0 \times 10^{-6}$  cm/s, followed by Jos at  $4.0 \times 10^{-6}$  cm/s, Minna at  $3.7 \times 10^{-6}$  cm/s, Bida at  $2.7 \times 10^{-6}$  cm/s, and Zungeru at  $1.4 \times 10^{-6}$  cm/s. These values reflect varying degrees of permeability across the samples, with Kaduna's sand being the most permeable. This variation in permeability could influence the selection of sand depending during the casting process. Generally, the higher permeability values suggest better venting of gases during metal casting, which reduces the likelihood of casting defects as reported by[21].

**3.2.4 Green compressive test**



**Figure 7:** Green compressive strength (GCS) of the moulding sand

The green compressive strength of the listed moulding sands in Figure 4.3 is good based on research works by[22] that confirmed minimal benchmark of 10.34 kPa. The optimum moisture content (OMC) of the moulding sand is presented in Table 7

**3.3 Performance of The Samples**

The results obtained and presented in Table 8 indicated that Zungeru sand met all the key requirements for foundry sand, including permeability ( $1 \times 10^{-7}$  cm/s to  $1 \times 10^{-3}$  cm/s) according to ASTM D2434, moisture content (8–12%) based on ASTM D2216, and compressive strength (above 10.34 kPa). In comparison, Bida, Minna, Jos, and Kaduna sands showed varying degrees of suitability for Al 6063 sand casting, with some requiring additional conditioning to meet ASTM standards.

**Table 8:** Performance of the samples

Sample	Permeability, k (%)	OMC	GCS	PI =LL-PL (%)	Specific gravity	Particle size
	ASTM D2434 ( $1 \times 10^{-7}$ cm/s - $1 \times 10^{-3}$ cm/s)	ASTM D69 (8-12 %)	10.34 kPa minimal benchmark	ASTM D4318 (8- 20)	ASTM D854 Requirement <b>(2.5 2.8)</b>	0.075mm (45% passed)
Zungeru	MR	MR	MR	MR	MR	MR
Bida	MR	MR	MR	DnMR	DnMR	MR
Minna	MR	MR	MR	MR	DnMR	MR
Jos	MR	DnMR	MR	MR	DnMR	MR
Kaduna	MR	MR	MR	MR	DnMR	DnMR

Where, MR: meet requirement and DnMR: do not meet requirement.

The suitability as presented in Table 8 showed only Zungeru moulding sand certified ASTM requirement on permeability, optimum moisture content, green compressive strength, plastic index, specific gravity and particle size. This means only Zungeru moulding sand is the most suitable among the moulding sand, it met five requirements in Table 4.4. Therefore, Zungeru moulding sand was suitable due to its and selected for the casting process in this study due to requirement while Minna moulding sand serves as alternative moulding sand.

### 3.4 Parameter Analysis of the Samples

Parameter analysis was conducted on the seven (7) suitable SSM according to different ASTM standards. The result is presented in Table 9.

**Table 9:** Green compressive strength of suitable SSM

Designation	Compressive Strength (kPa)	10.34 kPa Benchmark (Brown, 2000)
4L1D1	119.5	MR
4L2D4	131.2	MR
4L2D5	98.0	MR
4L3D2	87.4	MR
4L3D3	120.0	MR
4L3D4	96.0	MR
4L3D16	116.4	MR
Control Design	85.0	MR

All suitable SSM are compliant of benchmark of green compressive strength of 10.34 kPa and above [22]. SSM with sample number 4L2D4 had highest value of strength as 131.2 kPa. Lower strength value was 87.4 kPa observed from SSM with sample number 87.4 kPa and control design which is Zungeru moulding sand had lowest value of 85 kPa. Mass constituent of suitable SSM is presented in Table 10.

**Table 10:** Mass constituent of suitable SSM

Experiment	$m_1$ (g)	$m_2$ (g)	$m_3$ (g)	$m_4$ (g)	GCS (kPa)
4L1D1	221.85	9.65	7.10	7.40	119.50
4L2D4	208.80	9.65	7.10	14.80	131.20
4L2D5	195.75	28.75	7.10	7.40	98.10
4L3D2	204.36	16.02	11.77	7.40	87.10
4L3D3	204.36	16.02	7.10	12.28	120.00
4L3D4	204.36	9.65	11.77	12.28	96.00
4L3D16	195.75	16.02	11.70	12.28	116.40
Control design	261	-	-	-	85.00

Where,  $m_1$ : mass of Zungeru moulding sand in g,  $m_2$ : mass of Bentonite,  $m_3$ : mass of rice husk fibre,  $m_4$ : mass of coconut fibre, GCS: green compressive strength

Table 10 The mass constituents of the suitable synthetic sand mixtures (SSM) and their corresponding green compressive strength (GCS) are detailed in Table 10. The data illustrates the effects of varying mass proportions of the constituents on the GCS values, which are critical for determining the performance of the sand in casting applications.

The experiments indicate that the sample 4L2D4, with constituent masses of 208.80 g ( $m_1$ ), 9.65 g ( $m_2$ ), 7.10 g ( $m_3$ ), and 14.80 g ( $m_4$ ), achieved the highest GCS of 131.20 kPa, suggesting a well-balanced composition that optimizes strength. In contrast, sample 4L2D5, which had a higher mass of 28.75 g for  $m_2$ , resulted in a lower GCS of 98.10 kPa.

**Table 11:** Permeability of suitable SSM

Designation	Permeability, k (%)	ASTM D2434 ( $1 \times 10^{-7}$ cm/s - $1 \times 10^{-3}$ cm/s)
4L1D1	$4.2 \times 10^{-6}$	MR
4L2D4	$3.2 \times 10^{-6}$	MR
4L2D5	$1.1 \times 10^{-6}$	MR
4L3D2	$5.8 \times 10^{-6}$	MR
4L3D3	$1.4 \times 10^{-6}$	MR
4L3D4	$4.4 \times 10^{-6}$	MR
4L3D16	$1.4 \times 10^{-7}$	MR
Control Design	$1.4 \times 10^{-6}$	MR

All suitable SSM are compliant of permeability requirement ASTM2434, therefore they can be used foundry sand due to good aeration in the sand mould.

#### 4.0. CONCLUSION

This study demonstrated the suitability of various Nigerian natural sands for Al-6063 green sand casting, with Zungeru sand as the most optimal. In concise, suitability in Table 8 showed only Zungeru moulding sand certified ASTM requirement on permeability, optimum moisture content, green compressive strength, plastic index, specific gravity and particle size. This means only Zungeru moulding sand is the most suitable among the moulding sand, it met five requirements. Therefore, Zungeru moulding sand was suitable and selected for the casting process in this study due to requirement while Minna moulding sand serves as alternative moulding sand. The use of Scheffe’s model enabled the development of high-performance synthetic sand mixtures that meet ASTM standards for foundry applications. The findings thus highlight the potential for improving the quality and competitiveness of Nigerian foundry products through the optimization of moulding sands. **Device Performance:** The fabricated device offers an accepted level of accuracy and It is lightweight, portable, and user-friendly, making it ideal for educational purposes.

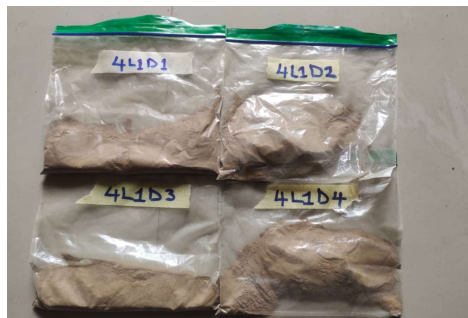
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## APPENDIX

### Appendix A



Pure blending with 4 different samples

### Appendix B



Binary blending with 20 different samples