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Review IJSMFE

Experimental Study on Effects of Moisture and Clay Content on the Properties of Moulding Sand

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Abstract

Sand casting, a time- honoured technique for casting both ferrous and nonferrous metals, remains widely utilized due to its cost-effectiveness, material abundance, and reusability, particularly with sand as a primary resource. This study delves into the intricate dynamics of sand casting, examining its crucial parameters through meticulous analysis of existing research. The investigation focuses on the influence of factors such as sand composition, moisture levels, clay content, and binder type on mould strength. Findings from experiments in the present study reveal a significant correlation between clay percentage and compression strength, with an optimal value of 700 g/cm^2 observed at 14% clay content. Similarly, shear strength demonstrates a peak value of 220 g/cm^2 with 5% moisture content and 87% sand composition, declining thereafter with increasing clay content. Moreover, variations in water content exhibit a notable impact on compression and shear strength, with an optimum compression strength of 340 g/cm^2 at 4% moisture content. The refinement of sand mixtures to improve mouldability and reduce defects in metal casting processes is the result of numerous researchers' collective efforts. Defects related to mould preparation are a common cause of casting product rejection. To mitigate this issue, it is necessary to explore adjustments in the sand mixing process, including the proportions of natural and chemical binders added to the mixture. This article aims to identify the optimal balance of these parameters to develop superior moulding sand mixtures, thereby reducing rejection rates. These insights underscore the intricate interplay of material composition and process parameters in sand casting, offering valuable guidance for optimizing casting performance.

Keywords: Moulding Sand, Moisture Content, Bentonite, Mechanical Property, Fineness number

INTRODUCTION

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Sand mould casting stands as a widely embraced and favoured method among foundry workers. Its popularity stems from the use of inexpensive raw materials such as silica sand, river sand, clay binder, organic matter, and chopped straw—all readily available and reusable. The resulting moulds exhibit excellent permeability, crucial for allowing gases and air to escape the mould cavity, as well as the necessary strength to endure the pressure exerted by molten metal during pouring. These properties, including strength, hardness, and permeability, make moulding sand ideal for casting purposes. Permeability is influenced by factors such as sand grain size and shape, clay and water content, while mould strength hinges on the compactibility of the moulding sand, determined by the proportion of raw materials mixed. To meet the rising demands for casting quality, chemical binding agents are increasingly incorporated during moulding sand preparation. The study begins with a meticulous sieve analysis of untreated sand to determine grain fineness. Sand mixtures are then prepared with varying clay and moisture content. For green compression strength testing, standard specimens are crafted and subjected to compression using a specialized machine. Similarly, green shear strength is tested using controlled shear forces. These tests evaluate the mechanical properties of the sand mixtures, crucial for ensuring precise castings in moulding processes. The study explores how changing clay and moisture levels affect the compression and shear strength of natural sand in sand casting. Higher clay content boosts compression and shear strength up to certain thresholds, after which strength declines. Optimal compression strength is achieved at 14% clay and 5% moisture, while shear strength peaks at 5% moisture and 87% sand composition. Higher moisture levels decrease both compression and shear strength, with optimal values observed at 4% moisture content and 6% clay composition [1].

Moulding and casting Process

Sand moulding is a fundamental process in foundry work, utilized for crafting intricate metallic parts from both ferrous and nonferrous metals. The process unfolds through several key stages. Firstly, patterns are meticulously crafted to replicate the final part's shape, considering factors like shrinkage and draft angles. Next, sand cores are prepared separately to form internal hollow areas within the cast. High-quality sand is then mixed with binders like clay and water to provide cohesion and strength to the mould. This sand mixture is packed into a two-part mould box, enclosing the pattern and forming the mould cavity. Molten metal is then poured into this cavity, where it solidifies to take the shape of the pattern. Finally, after cooling, the mould is opened, and the finished cast part is carefully extracted. This sequential process ensures the precise creation of complex metallic components and is illustrated in Figure 1.

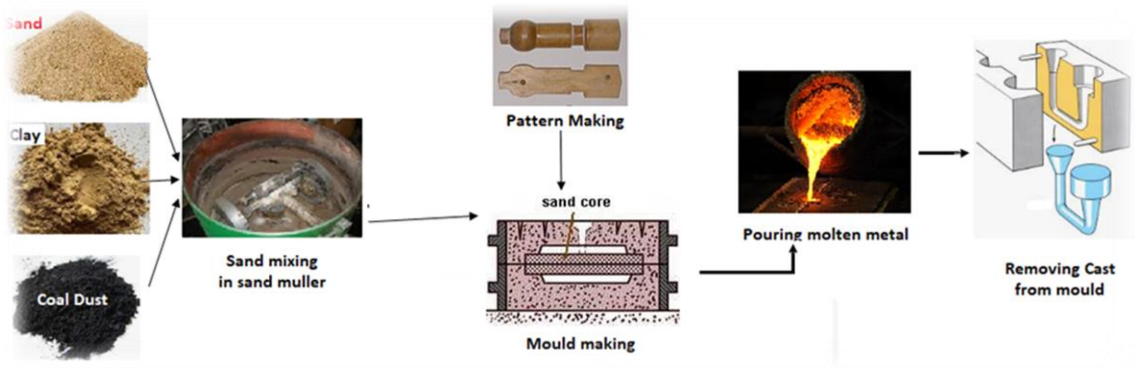

Figure 1. Diagram of moulding and casting process [1]

Literature Review

Research over several decades has delved into optimizing the properties of synthetic moulding sand for efficient metal casting processes. Investigations on factors like sodium carbonate, clay, moisture content, and binders have been pivotal in enhancing sand mould performance. Notable studies include *Loto* and Adebayo's [2] exploration of Igbokoda pure silica sand, which revealed improvements in moulding sand properties with added Na_2CO_3, albeit with slight collapsibility issues. *Abdullah* et al. [3] analysed tailing sand samples from Perak State, Malaysia, noting the critical role of moisture content in permeability and green sand strength. *Azhar* et al. [4] studied the impact of sand grain size and moisture content on green compression strength, emphasizing the significance of grain size in mould strength. *Sun* et al. [5] explored the influence of chemical binders on foundry sand performance, underscoring the importance of sand origin and grain shape. *Joshua* et al. [6] compared different binders' effects on River Niger silica sand, highlighting bentonite's superior binding capability. *Munusamy* et al. [7] investigated the use of industrial powders and fly ash as binders, demonstrating improved green sand strength with incremental fly ash addition. *Sadarang* et al. [8] examined the effect of binder material and moisture content on sand mould properties, finding optimal compactibility at specific moisture and binder ratios. *Apeh* et al. [9] analysed moisture content variation's impact on moulding sand properties, concluding the Fori river bank sand's suitability for casting metallic materials. *Ihom* et al. [10] explored Yola natural sand's characteristics at varying moisture levels, identifying optimal moisture content for green and dry strength. *Saikaew* and *Wiengwise*t [11] optimized sand composition for iron casting quality, using recycled moulding sand with specific water and bentonite proportions. *Pradana* and *Ariono* [12] studied sand grain size's influence on permeability and compressive strength, highlighting the importance of grain size selection for mould quality improvement. Overall, these studies collectively contribute to refining sand mixtures for enhanced mouldability and defect reduction in metal casting processes. The rejection of casting products often stems from defects linked to mould preparation. To mitigate this issue, adjustments in the sand mixing process and the proportions of natural and chemical binders added to the sand mixture want to be explored. The ideal balance of these parameters to create superior moulding sand mixtures, thereby minimizing rejection rates, is aimed to be determined by this article.

Experimental Setup

Sieve Shaker

The experimental setup of a sieve shaker includes a stack of sieves arranged by aperture size, onto which the sample material is loaded. The sieve shaker applies controlled vertical and horizontal movements to the stack, facilitating particle separation based on size. After shaking, the retained material on each sieve is collected and analysed to determine particle size distribution. (Figure 2)

Sand Muller

The sand muller experimental setup comprises a chamber with rotating blades for mixing sand, water, and binders. It features a control panel for setting parameters, loading and discharge ports, and safety mechanisms. This equipment efficiently blends ingredients to prepare moulding mixtures. (Figure 3)

Digital Weighing Machine

The weighing machine consists of a platform, load cell, and display unit to measure and show the weight of objects accurately. It includes a calibration mechanism, power source, and tare function for adjusting and resetting the scale as needed. With out weighing machine the whole experiment cannot carried out. (Figure 4)

Sand Rammer

In a sand testing procedure, to use a mechanical sand rammer, first mix the sand sample thoroughly and fill the specimen tube in even layers. Position the tube under the rammer, then set the compaction force and number of blows according to the test standard. Activate the rammer to compact each layer uniformly. Repeat this process until the tube is completely filled. Carefully remove the compacted sand specimen and proceed with the intended test. This method ensures the preparation of uniform and consistent specimens, leading to reliable and repeatable test results. (Figure 5,6)

(a) Sieve Shaker

(b) Sieve Baskets

Figure 2. Sieve Shaker Setup

Figure 3. Sand Muller

Figure 4. Digital Weighing Machine

Figure 5. Universal Sand Testing Machine

(a) Manual Sand Rammer **(b) Stripper** **(c) Specimen Tube**
Figure 6. Sand Rammer Setup

Methodology

Sieve Analysis

Initially, 100g of the untreated sand was meticulously weighed and then desiccated until reaching a stable weight using an electric oven. Following this, the sand was accurately weighed and poured into the uppermost sieve within a series of sieves organized in ascending order of aperture size. The arrangement of sieves was placed onto a sieve shaker and vibrated for a duration of 15 minutes. The sieves varied in aperture size, ranging from the largest, with an opening of 1700 microns, to the smallest, with an opening of 53 microns. The obtained data was meticulously recorded and subsequently utilized to determine the grain fineness number of the untreated sand.

Moulding Mixture Preparation and Standard Test Specimen

The sand mixture was moulded using a laboratory-sized muller, specifically manufactured by Versatile Equipment Pvt. Ltd., bearing serial No. VCS4/030801. Mixing was carried out for 5 minutes before discharge. Each batch consisted of 1kg of natural sand blended with water and clay. Two main types of mixtures were produced. In the first type, moisture content was maintained at a constant 5%, while clay content was varied from 4% to 14%, and sand percentage from 91% to 81%, resulting in five samples. In the second type, clay percentage remained constant at 6%, while moisture content was varied from 4% to 12%, and sand percentage from 90% to 82%, again yielding five samples. The sand mixture thus prepared was utilized for crafting standard test specimens measuring 50mm x 50mm, employing a digital weighing balance and a sand rammer Figure 7.

Figure 7. Test Specimen

Green Compression Strength (GCS)

The standard test specimens, prepared as described above, were promptly transferred to the universal strength testing machine manufactured by Versatile Equipment Pvt. Ltd. with serial No. VUM/060901. Utilizing the compression head accessory, the specimens were subjected to green compression testing. During this process, the machine's green compression scale recorded the results. This testing procedure involves the preparation of cylindrical specimens of sand mixture, followed by the measurement of their dimensions. Subsequently, a compression testing machine is set up, and the specimens are placed between the platens. A constant-rate compressive load is applied, and the force exerted is recorded at regular intervals until failure. The green compression strength is then calculated using the maximum load applied and the cross-sectional area of the specimen. Finally, the obtained results are analysed to evaluate the mechanical properties of the sand mixture, and a comprehensive test report is prepared.

Green Shear Strength

The specimens underwent shear strength testing using a universal strength testing machine. Controlled shear forces were applied, measuring the sample’s resistance until failure. Shear strength, which is vital for moulding sand as it determines its ability to maintain shape and withstand forces during the moulding process, ensuring precise castings without deformities or defects, was calculated from the maximum force endured before failure. The results are scrutinized to assess the mechanical attributes of the sand mixture.

Results & Discussion

TABLE 1: Sieve Analysis

SL NO.	ISO Aperture (microns)	Weight Retained (g)	Weight Retained (%)	Cumulative Weight (%)	Sieve No	Product
1	1700	44.5	4.45	4.45	5	22.25
2	850	269.5	26.95	31.4	10	269.5
3	600	163	16.3	47.7	20	326
4	425	235	23.5	71.2	30	705
5	300	204	20.4	91.5	40	815
6	212	69.5	6.95	98.55	50	347.5
7	150	8.5	0.85	99.4	70	59.5
8	106	3.5	0.35	99.75	100	35
9	75	1	0.1	99.85	140	14
10	53	1	0.1	99.95	200	20
11	SIEVE PAN RETURN FAIL	0.5	0.05	100	300	15
						2626.75

Grain Fineness Number (GFN) = 2626.75/100.00=26.27 AFS;

The process of sieve analysis, also referred to as a gradation test, holds significant importance in understanding the distribution of particle sizes within granular materials. Particle size plays a pivotal role in determining a range of material properties, from flow behaviour and conveyance in bulk materials to reactivity, solubility, and compressibility. Table1 gives the grain fineness number of the natural sand as 26.27 AFS.

TABLE 2: Strength vs % of clay

Sl. No	% of sand	% of clay	Compressive Strength (g/cm^2)	Shear Strength (g/cm^2)	% of water
1	91	4	300	140	5
2	89	6	320	180	5
3	87	8	340	220	5
4	85	10	450	110	5
5	81	14	700	180	5

Table 2 gives the result of percentage of clay variation on natural sand with the Compressive strength of the sand. The effect of the compressive strength is clearly shown in figure 7. The figure shows that as the percentage of clay content increase in the natural sand the compression strength of the sand is also increased. It is also worth noting that the percentage of water in the sand is kept constant which is 5%. The Compressive strength got increases and got the optimum value of 700 g/cm^2 at 14 % of clay.

Shear Strength vs % of clay

Table 2 shows the results of shear strength of natural sand as the percentage of clay increased. The effect of the variation of the clay content on the shear strength is shown in figure 8. As the clay content increases the shear strength also increased to a high value of 220 g/cm^2 corresponding to 5% moisture and 87% sand in the mixture, after which it started decreasing with increase in clay content.

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TABLE 3: Strength vs % of water

Sl. No	% of Sand	% of Water	Compressive Strength (g/cm^2)	Shear Strength (g/cm^2)	% of clay
1	90	4	340	180	6
2	89	5	180	10	6
3	88	6	320	140	6
4	86	8	300	120	6
5	82	12	160	10	6

Table 3 shows the results of compressive strength of natural sand as the percentage of water increased. The effect of the variation of the water content on the compressive strength is shown in figure 9,10. As the water content increases the compressive strength start decreasing at 5% water content. The optimum compressive strength is 340 g/cm^2 at 4% moisture content and the percentage of clay is kept 6% through out.

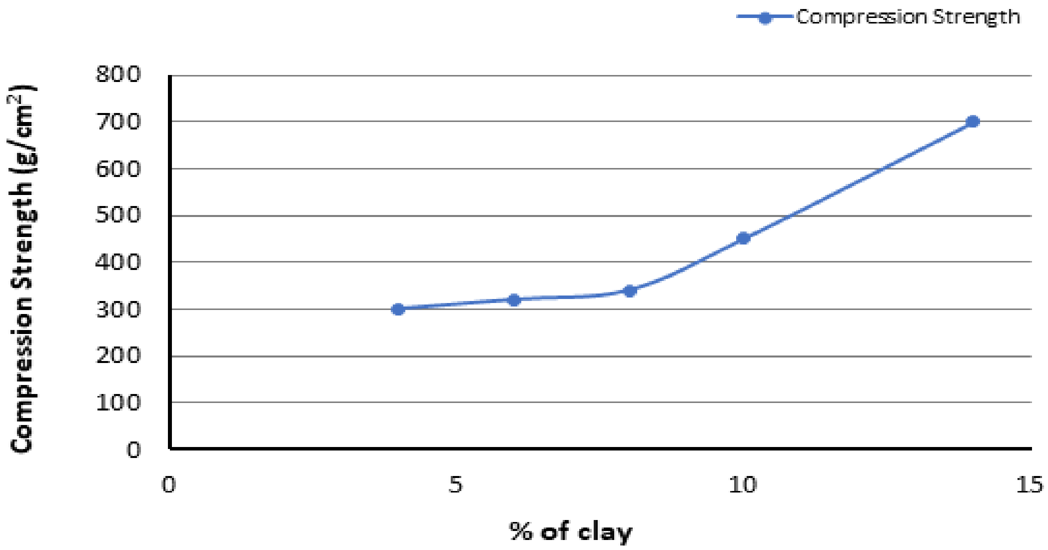

Figure 8. Compression Strength vs % of clay

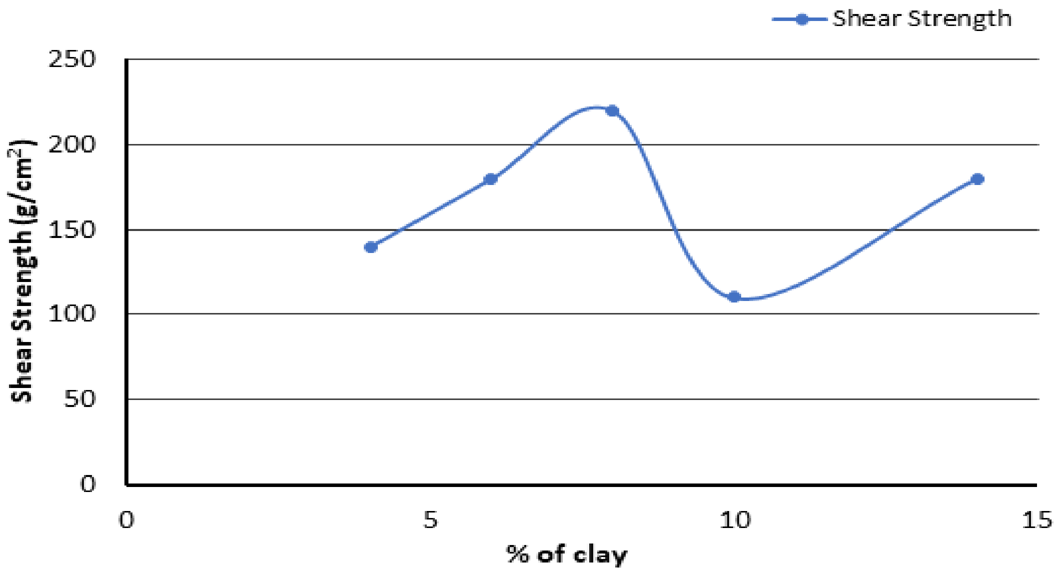

Figure 9. Shear Strength vs % of clay

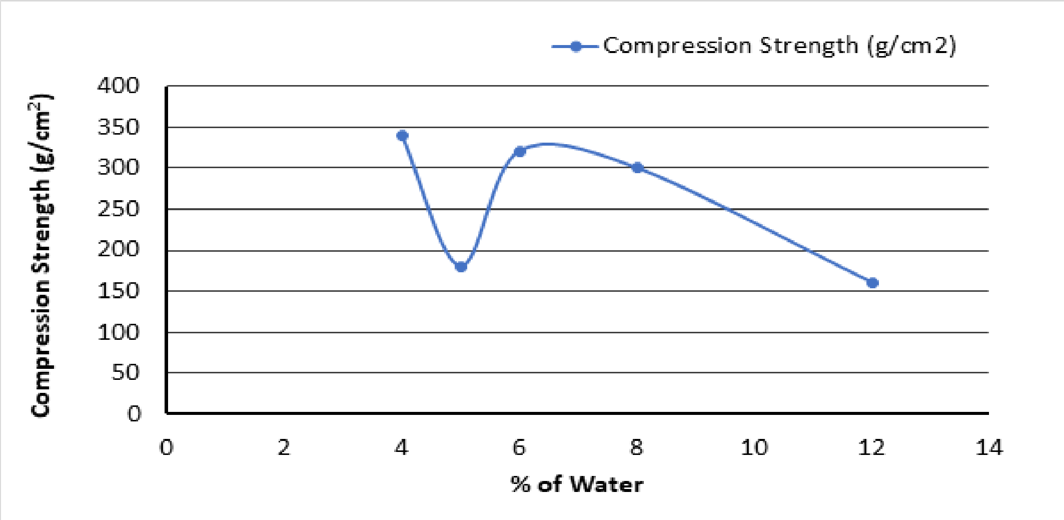

Figure 10. Compression Strength vs % of water

Shear Strength vs % of water

Table 3 shows the results of shear strength of natural sand as the percentage of water increased. The effect of the variation of the water content on the shear strength is shown in figure 11. As the water content increases the shear strength start decreasing from 5% water content. The optimum shear strength is 180 g/cm^2 at 4% moisture content and the percentage of clay is kept 6% through out.

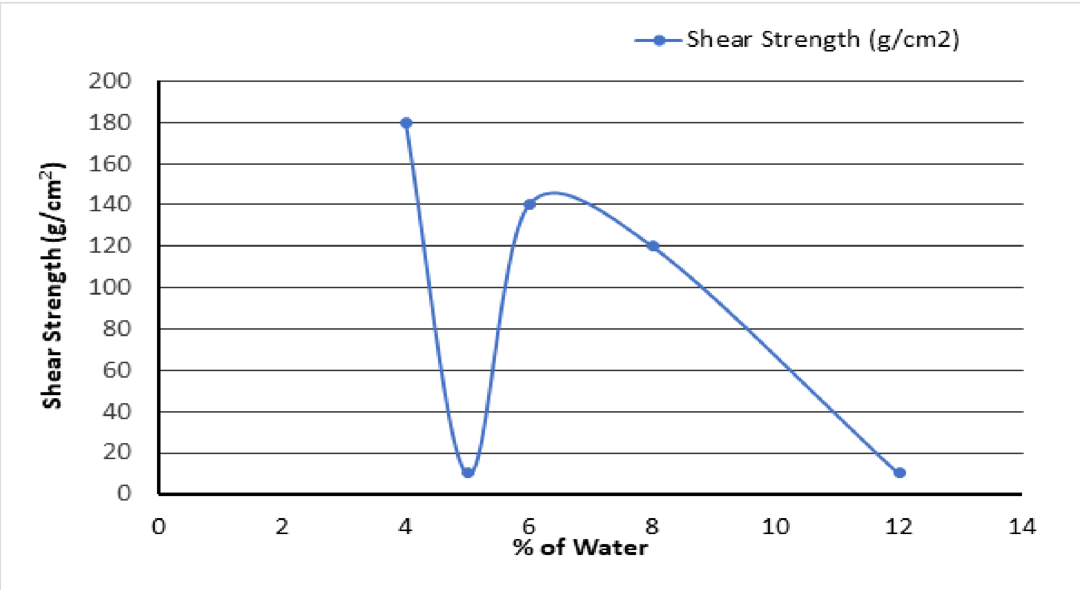

Figure 11. Shear Strength vs % of water

CONCLUSION

- The investigation demonstrates a clear relationship between clay content and compression strength of natural sand.
- Increasing clay content leads to higher compression strength, reaching an optimal value of 700 g/cm^2 at 14% clay.
- Similarly, shear strength increases with clay content up to a peak value of 220 g/cm^2 at 5% moisture and 87% sand.
- Beyond this point, further increases in clay content result in a decline in shear strength.

- Moisture content also influences compression strength, with higher levels leading to decreased strength, particularly beyond 5% water content.
- Optimal compression strength of 340 g/cm^2 is achieved at 4% moisture content and 6% clay composition.
- These findings underscore the importance of material composition and process parameters in determining the mechanical properties of sand for casting applications.

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