

DEVELOPMENT OF STANDARD SAND RAMMER

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Abstract. In designing the Standard Sand Rammer, systematic design analysis of the fundamental theories required to make it functional was considered and also the standard specification of the American Foundry Society (AFS) 50mm x Height 50mm as per Metric (Dia. 2" x Height 2" as per AFS.) was taken into consideration. The standard sand specimen is used in various tests including permeability, compressive strength, shear strength, and friability. The sand rammer was designed to avail foundry industries in Nigeria, and small-scale foundries acquire primary foundry equipment to test and control raw materials to improve castings quality. The standard sand rammer was fabricated from locally sourced materials, tested, and found to produce a cylindrical specimen of 50mm by 50mm after three rams. These show similar results compared with an imported rammer.

Keywords: *rammer, specimen, compressive strength, sand rammer, foundry*

Introduction

A sand rammer is a piece of equipment used in foundry sand testing to make test specimen of molding sand by compacting bulk material by free fixed height drop of fixed weight for 3 times. It is also used to determine compatibility of sands by using special specimen tubes and a linear scale. Sand rammer consists of calibrated sliding weight actuated by cam, a shallow cup to accommodate specimen tube below ram head, a specimen stripper to strip compacted specimen out of specimen tube, a specimen tube to prepare the standard specimen of 50 mm diameter by 50 mm height or 2 inch diameter by 2 inch height for an AFS standard specimen (BIS, 1966). Sand is the general name applied to comparatively finely divided, unconsolidated grains of rock, minerals, or slag. This report is concerned primarily with foundry sand; it is perhaps well to consider briefly other important uses of sand. Concrete, plaster and similar sands used in construction represent by far the largest consumption of sand. Foundry sands rank next to construction sand in volume of output. For steel work high silica content is essential for proper refractory qualities. Some molding sands for the non-ferrous metals contain no more than sixty or seventy percent of silica. Sands used for other purposes such as: the manufacture of glass, engine sand to prevent slipping of locomotive wheels, abrasive in grinding operations, filter sand at municipal water filtration plants, fire or furnace sand for lining the bottom of furnaces, as well as sand for other special uses (Brown, 1936).

The properties of molding materials are very vital to the production of sound dimensionally accurate castings. There is an ever-present trend to increase the tonnage of prepared sand from sand preparation units. This has caused the time for mixing to be shortened to such an extent that the quality of the sands has suffered materially. The bond is not being uniformly blended into the sand, nor is mixing being sufficient to make use of the bond. This certainly does not reflect favorably on the foundry industry where better castings are so important. Also, the accelerated development of the foundry Industry imposes new problems on the sand preparation equipment now available. The progress of the foundry industry has been rapid and marked by enormous

casting quality (Troy, 2004). The most common casting process used in the foundry industry is the sand cast system. The principal constituents of moulding sands are: silica sand grains, clay (bond), moisture, and organic additives. Virtually all sand cast moulds for ferrous castings are of the green sand type (Chowdhary, 2008). In Nigeria, founding and metallurgical practices have been known and practised long before the advent of European civilization. The industry has not developed tremendously. Beyond artifacts, Nigeria has a total of 160 foundries (Ezekwe, 1995) of which only five are commercial in contrast with India, which has 9000, registered foundries. Also, a recent study by National Agency for Science and Engineering Infrastructure, (NASeni) shows that the foundries located around the country have an average capacity utilization of 33%.

Conventional ramming machine

The cam is actuated by a user by rotating the handle, causing a cam to lift the weight and let it fall freely on the frame attached to the ram head. This produces a standard compacting action to a pre-measured amount of sand. Variety of standard specimen for Green Sand and Silicate based (CO₂) sand are prepared using a sand rammer along with accessories. The sand rammer machine can be used to measure compatibility of prepared sand by filling the specimen tube with prepared sand so that it is level with the top of the tube. The tube is then placed under the ram head in the shallow cup and rammed three times. Compatibility in percentage is then calculated from the resultant height of the sand inside the specimen tube (*Figure 1* and *Figure 2*) (Anegundi et al., 2014).

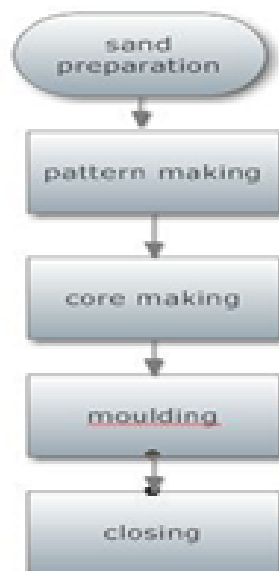


Figure 1. The sand making.

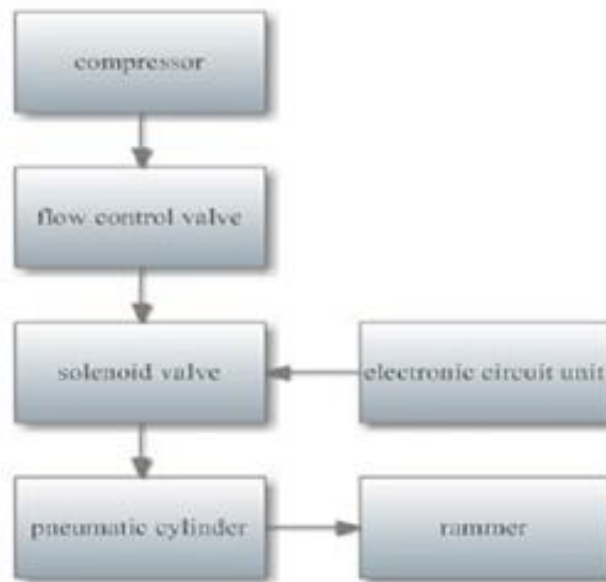


Figure 2. The sand inside the specimen tube.

Materials and Methods

The various parts that made up the Standard Sand Rammer Machine: (1) rammer frame; (2) cams; (3) collar; (4) ramming weight; (5) hand know; (6) rammer rod; (7) piston/plunger; and (8) base plate. Material selected for design of this machine is mild steel. Some of the conditions or factors considered in selecting materials are: Pressure and load involved Operating temperature, Availability, Cost, and Functionality with those above, material requirements and their properties in view.

Design consideration

The design consideration of the standard sand rammer is based on the standard parameters of AFS for obtaining the standard specimen. These include: (1) Diameter of specimen=50.0±0.02 mm; (2) Height of specimen=50.0±0.02 mm; (3) Ramming mass=6.35 kg; and (4) Height of drop of ramming mass=50.0 mm.

Design analysis for specimen tube

This holds the moulding sand and subsequently the specimen. The volume of moulding sand required to produce standard specimen is given by Eq. (1):

$$V_s = \frac{M_{st}}{\rho_s} = \frac{\pi d_t^2 h_t}{4} \quad \text{Eq. (1)}$$

Where, M_{st} = mass of sand required for specimen production (kg); ρ_s = density of moulding sand (kg/m³); d_t = diameter of specimen tube (m); and h_t = height of specimen tube (m). Therefore;

$$h_t = \frac{4M_{st}}{\pi\rho_s d_t^2} \quad \text{Eq. (2)}$$

Design analysis for ramming weight

The ramming weight has a mass of 6.35 kg and is cylindrical in shape with a hole drilled into the central axis to allow for ramming rod passage. Assuming a ram height diameter ratio of 1.5, we obtain (Eq. (3)):

$$H_w = 1.5D_w \quad \text{Eq. (3)}$$

Where, H_w =height of ramming weight (m); and D_w =diameter of ramming weight (m). Similarly, if the diameter of hole for rammer rod is d_h , then the volume of ramming weight is given by (Eq. (4)):

$$V_w = \frac{\pi(D_w^2 - d_h^2)H_w}{4} \quad \text{Eq. (4)}$$

Substituting Eq. (3) in Eq. (4) gives:

$$V_w = \frac{1.5\pi D_w(D_w^2 - d_h^2)}{4} \quad \text{Eq. (5)}$$

$$V_w = \frac{M_w}{\rho_w} \quad \text{Eq. (6)}$$

Where, M_w =mass of ramming weight (kg); ρ_w =density of weight material (kg/m³). Substituting the Eq. (6) into Eq. (5) gives;

$$D_w^3 - D_w d_h^2 - \frac{4M_w}{1.5\pi\rho_w} = 0 \quad \text{Eq. (7)}$$

Where, Eq. (7) is a third-degree polynomial with second terms absent. The solution (Avallone et al., 2007) follows:

$$D_w = \sqrt[3]{\frac{4M_w}{3\pi\rho_w} + \sqrt{\frac{16M_w^2}{9\pi^2\rho_w^2} - \frac{d_h^6}{27}}} + \sqrt[3]{\frac{4M_w}{3\pi\rho_w} - \sqrt{\frac{16M_w^2}{9\pi^2\rho_w^2} - \frac{d_h^6}{27}}} \quad \text{Eq. (8)}$$

Design analysis for dynamic force under impact

The velocity of fall of weight under gravity is given by:

$$V = \sqrt{2gh} \quad \text{Eq. (9)}$$

Where, h =height of drop of ramming weight (m); and g =acceleration due to gravity (m/s²). To determine the force responsible for the impact action, the law of conservation of energy is employed. Therefore, equating kinetic energy of falling body to potential strain energy of the bar, work done by falling weight is:

$$W_w = M_{w,q}(h + \Delta l_d) \quad \text{Eq. (10)}$$

Where, Δl_d =dynamic deformation (shortening of the bar). Potential energy of strain in compression is:

$$P_s = \frac{\Delta l_d^2 EA}{2l} \quad \text{Eq. (11)}$$

Where, E=modulus of elasticity (N/m²); A=cross sectional area of ramming rod (m²); and l=length of rod under compression (m). Therefore,

$$M_{wg}(h + \Delta l_d) = \frac{\Delta l_d^2 EA}{2l} \quad \text{Eq. (12)}$$

Expanding and dividing through by EA gives:

$$\Delta l_d^2 - \frac{M_{wg}l2\Delta l_d}{EA} - \frac{2M_{wg}hl}{EA} = 0 \quad \text{Eq. (13)}$$

For statically applied load, static deformation is given by:

$$\Delta l_s = \frac{4M_{wg}l}{\pi E d_r^2} \quad \text{Eq. (14)}$$

Where, d_r =diameter of rod (m). Therefore,

$$\Delta l_d^2 - 2\Delta l_s \Delta l_d - 2\Delta l_s h = 0 \quad \text{Eq. (15)}$$

$$\Delta l_d = \Delta l_s \mp \sqrt{\Delta l_s^2 + 2h\Delta l_s} \quad \text{Eq. (16)}$$

And since a solution with the minus sign before the radical is contrary to the physical meaning of the problem, we obtain:

$$\Delta l_d = \Delta l_s \left(1 + \sqrt{1 + \frac{2h}{\Delta l_s}} \right) \quad \text{Eq. (17)}$$

$$= \Delta l_s K_d \quad \text{Eq. (18)}$$

Where, K_d =dynamic load factor= $\frac{\Delta l_d}{\Delta l_s}$. This implies that the dynamic effect of the falling weight is K_d times its static effect. Dynamic force is:

$$F_d = F_s \times K_d = K_d M_{wg} \quad \text{Eq. (19)}$$

Design analysis for ramming plunger/piston

Ramming plunger is required to fit into the specimen without squeeze out of sand mixture. Therefore, for fit and standard, the diameter of the plunger is made to 49.95±0.03 mm.

Design analysis for collar and shaft

The collar, which receives the impact, is supported on the vertical plunger with the latter step-turned. A small pin fixes the collar to the shaft to prevent movement.

Design analysis for cam for weight lifting

This rotates clockwise, and lifts the weight through a height of 50 mm and drops suddenly. The following specifications are given (Table 1):

Table 1. The specification for weight lifting.

Type of cam	Plate cam
Minimum diameter	24 mm
Maximum diameter	74 mm
Cam shaft diameter	12mm
Dwell angle	0° to 180°
Lift angle with uniform acceleration	180° to 360°

Procedures

The sand rammer was fabricated from various locally sourced materials, which include mild steel shaft (Φ95 x 150) mm for the ramming weight. Mild steel rod (Φ22 x 600) mm for ramming rod; mild steel shaft (Φ70 x 200) mm for specimen tube base; mild steel plate (290 x 255 x 10) mm for frame base and square steel section (900 x 40 x 4) mm for frame. Turning operations on the lathe machine produced the ramming weight, shaft, collar, and specimen tube. The frame was constructed by marking out, notch cutting and bending. The frame was then welded to the base plate by carefully aligning the plunger’s axis of movement to fit into the specimen tube. Figure 3 shows the basic components of the rammer.

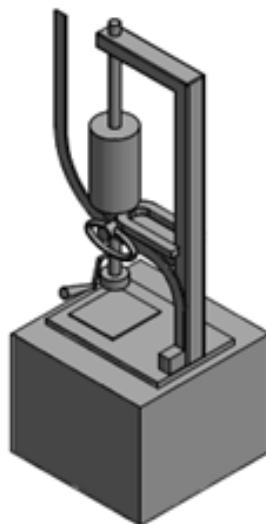


Figure 3. Isometric view of standard rammer.

Results and Discussion

Testing

In testing the sand rammer, flowability and permeability tests were carried out on standard specimens produced from the fabricated rammer as well as an imported rammer and the results compared. Sand mix of various compositions was weighed to the amount required to form a standard AFS specimen (0.145kg to 0.175kg) and filled into the specimen tube, which was fabricated along with the rammer. The specimens were transferred to the flowability tube and three blows (Nwakaire et al., 2015) were applied using the foreign and the indigenous rammers. Percentage flowability was calculated for the rammers. Similarly, the green permeability was determined using a permeability meter. *Figures 4* and *Figure 5* show the variation of percentage flowability and green permeability with fineness sieve numbers obtained from a sand mix of 75% silica, 20% clay content and 7% moisture content. From the results obtained, *Figure 4* shows that there is much closeness in the results of flowability for the indigenous rammer when compared with that obtained from the foreign rammer (*Table 2*). The graph is almost linear with a standard deviation of 0.954 and 0.947 for the foreign and indigenous rammer respectively. Coarser sand grains have a lower flowability than do the finer grains (Salihu et al., 2020). This is because greater force is required to rearrange the larger sand grains. The smaller grains flow together more readily. Similarly, *Figure 5* the comparison of the indigenous and the foreign rammers in terms of green permeability after ramming (*Table 3*). While the indigenous has a standard deviation of 0.966, the foreign has 0.995. This indicates that the indigenous rammer has more voids due to low impact force. Flowability and permeability of moulding sand are also influenced by moisture content. *Figure 6* indicates that at low and high moisture content, flowability is low than at the temper moisture content of 6% (*Table 4*). This is because the clay swells most at or near temper moisture. However, there is a close conformity between the values for indigenous and the foreign rammers when their trend lines are examined. *Figure 7* shows a much clearer difference of the results for the two rammers, although the pattern of variation is similar (*Table 5*).

Table 2. *Finess sieve and flowability.*

Finesness sieve numbers	Flowability (%)	
	Indigenous	Foreign
20	58	56
40	60	58
50	61	59
70	62	60
100	63	61

Table 3. *Finesness sieve and permeability.*

Finesness sieve numbers	Flowability (%)	
	Indigenous	Foreign
20	60	58
40	58	56
50	56	55
70	53	53
100	48	51

Table 4. *Moisture content and flowability.*

Moisture content (%)	Flowability (%)	
	Indigenous	Foreign

3	81	80
4	76	79
6	73	72
8	75	74
10	80	79

Table 5. Moisture content and permeability.

Moisture content (%)	Flowability (%)	
	Indigenous	Foreign
3	50	48
4	52	49
6	53	52
8	53	50
10	48	49

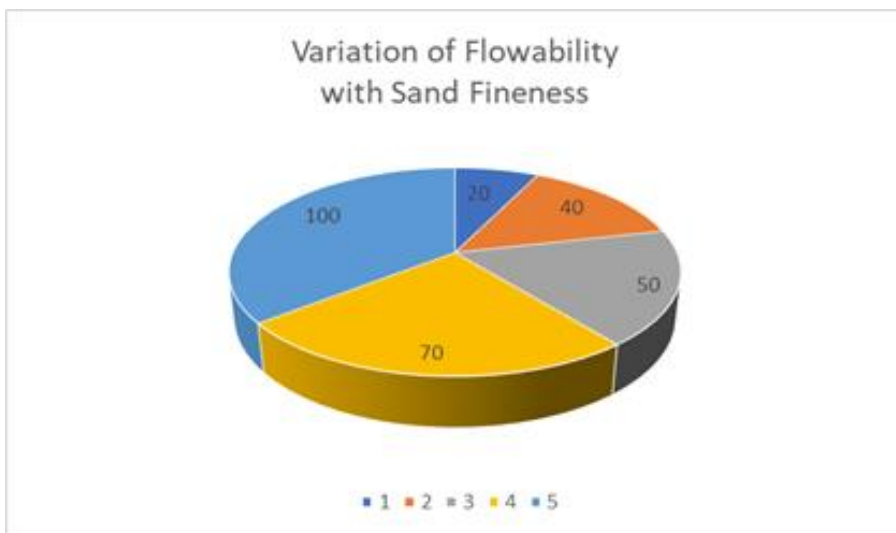


Figure 4. Variation of flowability with sand fineness.

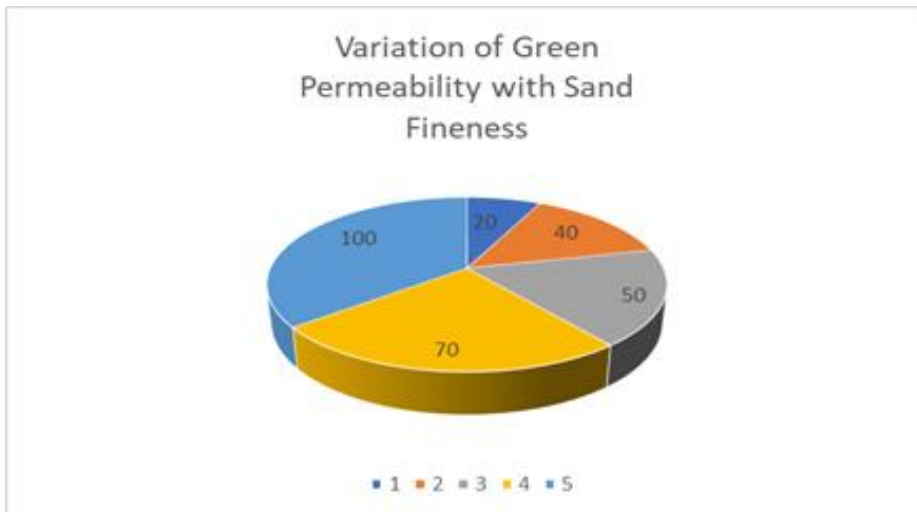


Figure 5. Variation of green permeability with sand fineness.

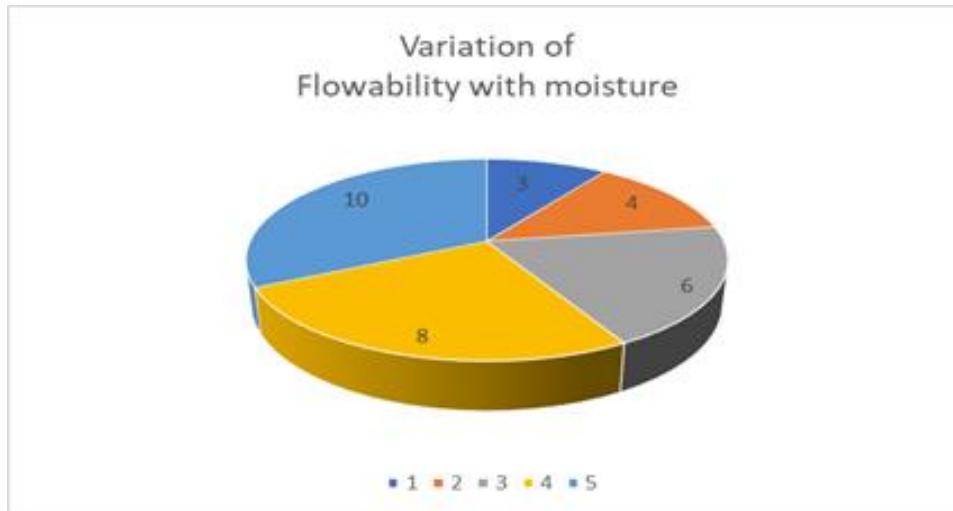


Figure 6. Variation of flowability with moisture.

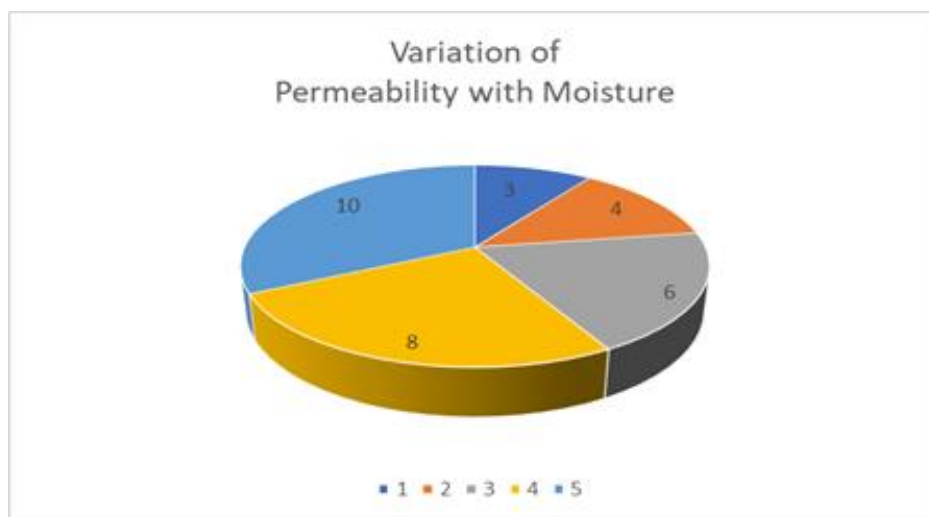


Figure 7. Variation of permeability with moisture.

Conclusion

The redesigning of the Standard Rammer presented in this work was to enhance indigenous development of Nigeria foundry industries by providing test equipment at minimal cost. The total cost of production amounted to N175, 600.00 (\$1,300.74) compared to that of Georg Fischer Disa Ltd. (Milberger and Dunlap, 1966), Switzerland of N 601,897.50 (\$4,458.5). From the results, it can be concluded that there is a close agreement between the flowability and green permeability values obtained from the foreign and indigenous rammers, within the limits of experimental errors, and fabrication defects, although several other tests could be carried out to test its validity. It can therefore, be concluded that the locally fabricated rammer is of good standard and can be used for various foundry tests. It is pertinent to bring therefore the design of this rammer to foundry industries for mass production and commercialization.

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Conflict of interest

The authors declare that there is no conflict of interest involve in this research study.

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