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Exploratory Study on the Workability, Specific Gravity and Ultra Pulse Velocity of Replaced Foundry Sand Concrete

Paul Eloke and Yahaya Atolagbe
School of Computing, Engineering & Digital Technologies, Teesside University, Middlesbrough, United Kingdom

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ABSTRACT
This research undertakes a study on the use of foundry sand as a partial substitute to natural sand in the production of concrete. This was to test its impact on workability, strength and structural performance in general. Laboratory work Foundry sand instead of natural sand was used to substitute natural sand at 0, 20, 40, 60, and 100 by weight in a 1:2:4 concrete mixture with a water-cement ratio of 0.6 in the University of Benin Foundry Workshop. The tests that were done in experiment were sieve analysis, specific gravity, slump and ultrasonic pulse velocity (UPV). Analysis of particle size revealed that the foundry and natural sands are well-graded whereby 64.12% and 67.05% of the foundry and natural sand respectively pass 0.6 mm sieve, which is slightly coarser foundry sand. Slump values were lower at the 0% replacement (59 mm) and higher at 100% replacement (18 mm), showing that the higher the foundry sand content, the lower the workability. The UVP values of 3.63km/s decreased to 3.15km/s over the curing ages; while replacement increased indicating that the quality of concrete was diminishing to a medium one. Nevertheless, the 60% replacement level gave a working and structurally sound concrete with just a 2.05% cut in the cost of production. This study proves that foundry sand can also be successfully employed to a 60 per cent replacement in structural work, which is a more ecological and cost-effective alternative of natural sand as a concrete component.

Keywords: Foundry Sand, Concrete, Workability, Specific Gravity, Ultra Pulse Velocity.

I. INTRODUCTION

Concrete is among the most essential and commonly utilized materials in the civil engineering field and a major material in the construction of constructs, buildings, roads, bridges, pavements, and other infrastructures. It is an essential component to developing and developed countries, and it is at the center of the development and upkeep of infrastructural facilities. Concrete is a composite material which is mainly made out of cement, fine and coarse aggregates, water and in some cases also chemical admixtures, and each material plays a major role in the strength, durability and workability of concrete. The fine aggregate sand used in concrete production has been in high demands globally and this has resulted in most developing countries not being able to satisfy the increasing infrastructural demands. To counter such an obstacle, scientists and industry practitioners have been exploring the right substitutes to natural sand [21]. The most promising alternative is foundry sand, which is an off-product of metal casting industries and is produced in large amounts; it is disposed of upon reaching the end of several reuse cycles. The use of such waste material in building can minimize the environmental stress and encourage green behavior in the construction. Foundry sand consists primarily of high-silica sand covered with burnt carbon, the remnants of the binders, e.g., bentonite, sea coal or resin and coarse dust particles. It is mostly finer than natural sand and has homogenous physical characteristics, as well as, has good thermal conductivity, thus a good possible substitute material in the production of concrete [2].

Some sources have cited that, addition of foundry sand assists in enhancing concrete properties particularly, workability, specific gravity, ultrasonic pulse velocity at some levels of replacement [18]. Khatib and Herki [9] studied the concrete that was obtained by substituting the fine aggregates with 0, 30, 60 and 100 percent waste foundry sand (WFS). The water content, coarse aggregate, cement and water- cement ratio were

kept constant. The properties that were researched during 7, 28, and 90 days of curing times showed that there was an increase in water absorption through capillary action, a decrease in compressive strength, and a decrease in ultrasonic pulse velocity with an increase in WFS content. They also mentioned that sufficient strength can be attained through proper replacement level of foundry sand. Guney et al. [7] examined how waste foundry sand (WFS) influenced slump of concrete. The 0%, 5%, 10 and 15% WFS were used in the place of fine aggregates. It was noted that the waste foundry sand reduced the fluidity and the slump value of the fresh concrete. This was attributed by the fact that the waste foundry sand contains clayed fine materials that are good in reducing fluidity. Although such results were found, the analysis has identified that there is a possibility of using foundry sand under control in order to sustain the workability within reasonable limits. Singh et al. [20] discovered that over replacement of natural sand with foundry sand could lower the workability because of augmented fines and augmented water requirement. The paper has highlighted that it is important to find the best replacement percentage which is a balance between strength and workability. Their work also indicated that although foundry sand enhances the packaging of particles, it has high silica content which boosts surface absorption and hence low slump and pulse velocity. Etxeberria et al.[5] investigated the mechanical behavior of concrete which utilized green and chemically bonded foundry sands. They found out that concrete with a foundry sand content up to 30 percent retained high workability and steady ultrasonic pulse velocity measurements. Above 40, slump values decreased drastically and this is a pointer of poor flow properties. Specific gravity also decreased with more porosity and fines as this indicated that foundry sand can effectively substitute natural sand controlled with reasonable limits. The article by Sohail et al. [21] compared the behavior of various types of fine aggregates in concrete in the context of sustainable concrete in terms of how they varied the important properties of concrete. This investigation showed that the foundry sand replacement of up to 40 percent produced concrete with good workability and density. Nevertheless, the increased replacement levels led to reduced values of slump and pulse velocity. Specific gravity was gradually reducing which was due to the fine and irregular particle texture. Their findings favored moderate replacement because it is economical and sustainable. A study conducted by Basar and Aksoy [4] involved the research on the effect of waste foundry sand on the physical and mechanical properties of mortar and concrete. Findings indicated that the slump and pulse velocity were lower in the case of the use of foundry sand because the material texture was fine and dusty. The values of specific gravity were lower than the control samples, and it is indicative of a light density. The blend with 20 percent WFS was the most successful in terms of strength and workability which provoked the partial replacement in order to be used sustainably. A study of the leachate and structural performance of waste foundry sand concrete was carried out by Siddique et al. [19]. In their work, it was reported that with more foundry sand content, slump and pulse velocity decreased because of locked up air voids and smaller grains. The specific gravity also decreased and demonstrated lower density than conventional sand concrete. The best tradeoff between workability and quality was identified to be at 30-40 percent replacement rates and thus it was concluded that WFS could be safely reused in non-structural work. In investigating mechanical behavior of concrete with alternative fine aggregates, Akinwumi [1] used foundry sand. The paper has found that slump and pulse velocity decreases with the increase in WFS content. Also, the decrease of specific gravity was modest because of lightweight silica traces that were in foundry sand. Nevertheless, the maximum replacement of 50 percent ensured an acceptable level of density and strength to emphasize foundry sand as a potential substitute that can improve resource use in construction. Yadav and Tiwari [23] examined the use of industrial wastes such as foundry sand as a component of concrete. Their findings indicated that foundry sand decreased the workability because it had large surface area and was of irregular particle shape. The values of specific gravity were in the acceptable level to make concrete. The pulse velocity results indicated medium quality concrete with 40% replacement. The authors came to the conclusion that the controlled replacement levels of WFS can enhance sustainability without any considerable decrease in quality. The study by Paul et al. [16] was a detailed characterization of spent chemical foundry sand that can be used in concrete. In their research, replacement of foundry sand by a slightly lower specific gravity and slump-sensitive material did not affect uniform ultrasonic pulse velocity measurements to the 40% replacement point. Workability and pulse velocity decreased drastically at higher levels because of the formation

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of more voids. The authors came to the conclusion that controlled replacement does not decrease sustainability and avoids structural performance. Barde et al. [3] examined the effect of the foundry sand waste on concrete workability and mechanical properties. The experiment indicated that the addition of foundry sand reduced the slump but enhanced the consistency of the distribution of particles. The specific gravity was slightly decreased because of less density of the sand grains. Ultrasonic pulse velocity tests indicated a steady reading to 30% replacement. Authors proposed the maximum level of replacement 30-40 percent of durable concrete. Monosi et al. [11] studied the rheological and mechanical behaviour of the waste foundry sand concrete. Their study revealed that workability was lower with high degree of replacement because of binder-coated grains in the foundry sand. Specific gravity was a little low and the quality of the concrete was medium grade as suggested by ultrasonic pulse velocity. Their results formed the basis of introduction of 40 percent foundry sand since it guaranteed structural integrity and contributed to sustainability. Naik et al. [13] evaluated engineering characteristics of concrete prepared using foundry sand as partial substitute of fine aggregate. They found that specific gravity and ultrasonic pulse velocity had similarity in controlling mixes up to 30 percent replacement. But above 50 workability greatly dropped. The authors came up with the conclusion that natural sand could be effectively replaced with foundry sand in moderate ratios to form concrete to be used in construction. Patil and Sangle [15] examined the mechanical and durability performance of the concrete in case of waste foundry sand substitution. It was revealed that substitution rates of 2040 per cent provided acceptable workability, specific gravity, and pulse velocity. Out of this range, the properties diminished as a result of finer nature of material. They came to the conclusion that the gradation control is a must in case of using foundry sand in concrete. Kaur and Rajor [8] researched on how foundry sand can be used to develop sustainable concrete. Their results showed that slump and specific gravity decreased gradually with increased content of foundry sand. The velocity of ultrasonic pulse also decreased slightly which demonstrated that too much foundry sand may cause microstructural discontinuities. The research suggested the use of partial replacement to compromise cost and performance. Meenakshi et al. [10] conducted experimental research on the effects of foundry sand on the properties of workability and strength. The findings indicated that replacement of 30% provided the best slump and density. The velocity of ultrasonic pulse at this level was a sign of good-quality concrete and the increased contents decreased both density and homogeneity. Structural applications were suggested by the authors to be replaced at 30-40%. Thomas and Cabrera [23] examined the self-compacting concrete, in which foundry sand was completely or partially substituted. Their research established that workability and pulse velocity reduced gradually with increased replacement. There was slight difference in specific gravity amongst mixes. They came to the conclusion that foundry sand was usable up to 50% replacement of medium grade concrete without significant loss in performance. García Del Angel et al. [6] made a comparison between the effects of recycled foundry sand on the workability and mechanical properties of mortar and concrete. The findings indicated that foundry sand reduced the workability and still retained the same value of ultrasonic pulse velocity even when it was substituted by 40 percent. The paper has highlighted the importance of the fact that with minimal performance loss, foundry sand can be used to promote the sustainability of the concrete production process.

Regardless of the achievements made during the past studies, it has been revealed that the substitution of natural sand with more than the required amount of foundry sand can have a detrimental impact on the workability due to the increased fines content and water demand [20]. It is thus very important to determine the optimum ratio of foundry sand which will improve strength but not workability. In this study, the mechanical and workability of concrete are being investigated as a result of the partial replacement of natural sand with foundry sand. The study specifically analyzes workability, homogeneity and ultrasonic pulse velocity with different levels of replacement of 0, 20, 40 and 60 which are all under controlled laboratory conditions in order to assure accuracy and dependability of findings.

II. MATERIALS AND METHODS

2.1 Materials

Ordinary Portland Cement (OPC), natural sand, granite, water, and foundry sand form the materials to be used in this study. Moreover, the following material and equipment were used in the course of the experiments: complete set of sieves, mechanical shaker, cylindric bowl made of steel, tamping rod, sieves (2.36 mm, 10 mm and 14 mm), Aggregate Impact Value (AIV) machine, universal

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crushing machine, digital weighing balance, oven, slump cone and base, measuring tape, and hand towel.

2.1.1 Foundry Sand

The collected sand used in the foundry was found at the Foundry Workshop of the Faculty of Engineering, University of Benin (Ugbowo Campus), Edo State, Nigeria. The sample was carried to the Civil Engineering Laboratory of the same university where drying was done in air to eliminate the moisture before testing and use in production of concrete.

2.1.2 Cement

The cement product was that of Dangote 3X Ordinary Portland Cement (OPC) 42.5 grade which was acquired in Ibese Plant. The type of cement is appropriate to the standards employed in the application of structural concrete and was employed in the whole research to achieve homogeneity.

2.1.3 Natural Sand and coarse Aggregate

The natural sand and rough aggregate (granite stones) were procured at Isihor, Benin City.The granite aggregates were hard, clean and devoid of any deleterious organic substances. In the case of the experiment, coarse aggregates included aggregates that were retained in the 3.75 mm sieve and fine aggregates included those that were retained in the 2.75 mm sieve.

2.1.4 Water

The mixing and curing water was the borehole water taken at the Civil Engineering Laboratory, University of Benin. Water was fresh, and it did not contain any impurities which might influence the process of cement hydration or concrete strength.

2.1.5 Granite

The fineness of the coarse aggregate was crushed granite of nominal maximum size of 20 mm.

2.2 Methods

The maximum numbers of concrete cubes (150 mm × 150 mm × 150 mm) and concrete beam (100 mm × 100 mm × 500 mm) were manufactured and cured in the clean water tanks. It was mixed in the ratio of 1: 2: 4 (cement: sand: aggregate) and a water-cement ratio of 0.6. Natural sand was substituted with foundry sand in different weight ratios of 0, 20, 40, and 60 per cent and tests on compressive strength, flexural strength and ultrasonic pulse velocity were carried out after 7, 14 and 28 days of curing.

2.2.1 Batching of Materials

The constituent materials were well weighed according to the mix ratio (1:2:4) with the help of a digital weighing balance. The batching was done on a flat, clean surface in order to achieve uniformity, workability and consistent strength development of the hardened concrete.

2.2.2 Concrete Mixing

The batches of cement, foundry sand, natural sand, granite, and water were placed in a mechanical concrete mixer to a full load and until combined. It was completely dried with water added in proportion to the water-cement ratio (0.6).It was repeated in each case of the replacement of foundry sand (0, 20, 40 and 60 percent).

2.2.3 Concrete Curing

The beams and moulded cubes were demoulded after 24 hours and marked well to identify them. The specimens were then placed in a curing tank with clean water so as to maintain hydration, lessen the shrinkage, and enhance strength. A curing period of 7 days, 14 days and 28 days respectively before testing was practiced.

2.2.4 Sieve Analysis of Foundry Sand, Natural Sand and Granite

The sieve analysis has been done according to BS 812 Part 1 at the Civil Engineering Lab, University of Benin to find out the size of the particle distribution. Sieves were stacked downwards and swirled after 10 minutes on a mechanical shaker. The procedure are as follows:

A. Fine Aggregate (Sand)

- The sample was dried in the air to avoid the lumps.
- Sieves were used with 2.36 mm, 2.00 mm, 600 mm, 425 mm, 300 mm, 212 mm, 150 mm and 75 mm.
- The weight that had been retained in each sieve was measured and expressed as a percentage of the entire sample weight.
- Grading curves on BS 882: 1983 were plotted using the cumulative percentage passing.

B. Coarse Aggregate

The process was of a similar type except that sieves with the dimensions 20 mm, 14mm, 10mm, 5mm, 3.35mm, 2.36mm, and 1.18mm were

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used. The largest aggregate size to be used in this project was 12mm.

2.2.5 Aggregate Impact Value (A.I.V) Test:

This test identified the sudden impact resistance of aggregates as per BS 812 Part 112: 1990. The aggregates that made the 14 mm sieve and others that remained on the 10 mm sieve were dried in an oven at 100 110 F and allowed to cool then subjected to an AIV machine test. The drop load of a 14 kg hammer is made to drop through a height of 380 mm 15 blows, and the mass of the crushed material that has gone through the 2.36 mm sieve was weighed. Aggregated Impact Value AIV =

$$AIV = \frac{M_2}{M1} X\ 100\% \qquad (1)$$

Where; M_1 = mass of the test specimens, M_2 = mass of material passing the test sieve 2.36mm.

2.2.6 Aggregate Crushing Value (ACV) Test

The crushing resistance of aggregates under compressive load of 400 kN was tested in 10 minutes in the ACV test. The crushed material has been sieved using a 2.36 mm sieve and the weights that were retained and passed have been recorded and calculated.The ACV was determined as follows:

$$ACV = \frac{M_2}{M_1} \times 100\% \qquad (2)$$

Where; M_1= mass of the test specimens, M_2= mass of material which passes through the 2.36mm test sieve.

2.2.7 Concrete Mix Design

The concrete mix design was based on the M25 grade of concrete of British Standard BS 12/BS 4029.The water-cement ratio of 0.6 was used throughout the mix batches.

2.2.8 Specific Gravity

BS 812-2 (1995) was used to determine the specific gravity of the aggregates to measure relative density and void ratio. Procedures included:

- Weighing the empty bottle (W_1).
- Weighing again (W 2) of the sample.
- Adding distilled water filling, shaking and weighing (W 3).
- Adding water to the bottle only and weighing (W 4).

- The specific gravity was determined by the following expression;.

$$SG = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

W_1 = weight of bottle, W_2 = weight of bottle + sample, W_3 = weight of bottle + sample + water, W_4 =weight of bottle + water and W_1 =weight of sample = W_2 -W_1.

2.2.9 Workability

Slump test was used to determine workability of fresh concrete. Steps included:

- Lubricating the cone and base with oil.
- This is filled in three layers, tamped 25 times each.
- Ceil and uproot the top surface and raise the cone upwards.
- The concrete slump was measured to define the consistency and flowability of the concrete.

2.2.10 Ultrasonic pulse velocity Test

The test that was conducted to determine the quality of concrete was the UPV test which measured the pulse velocity as per IS 13311 (Part 1): 1992. Cubes were dried after curing and direct transmission was made. Steps included:

- TRAN and REC sockets of the V-meter were connected to transducers.
- The instrument was calibrated using a reference bar (52 u s).
- Proper contact between transducers and specimen was provided with grease.
- T was recorded and the pulse velocity (V) calculated as:

$$\text{Pulse Velocity} = \frac{\text{Path Length}}{\text{TravelTime}} \left(\frac{\text{Km}}{\text{S}}\right) \qquad (3)$$

The velocity is an indicator of higher concrete density, homogeneity and quality.

III. RESULTS AND DISCUSSIONS

3.1 Particle Size Analysis

Table 1: Table for Particle Size Distribution

Particle size for foundry sand	%Passing for foundry sand	Particle size for natural sand	%Passing for natural sand	Particle size for coarse aggregate	%Passing for coarse aggregate

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2.36	100.00	2.36	100.00	19.04	98.30
2	99.44	2	99.45	12.00	65.10
1.18	91.10	1.18	92.23	10.00	16.90
0.6	64.12	0.6	67.05	4.75	0.00
0.425	39.26	0.425	42.19	–	–
0.3	8.66	0.3	11.92	–	–
0.212	3.43	0.212	4.17	–	–
0.15	1.34	0.15	2.08	–	–
0.075	0.02	0.075	0.76	–	–

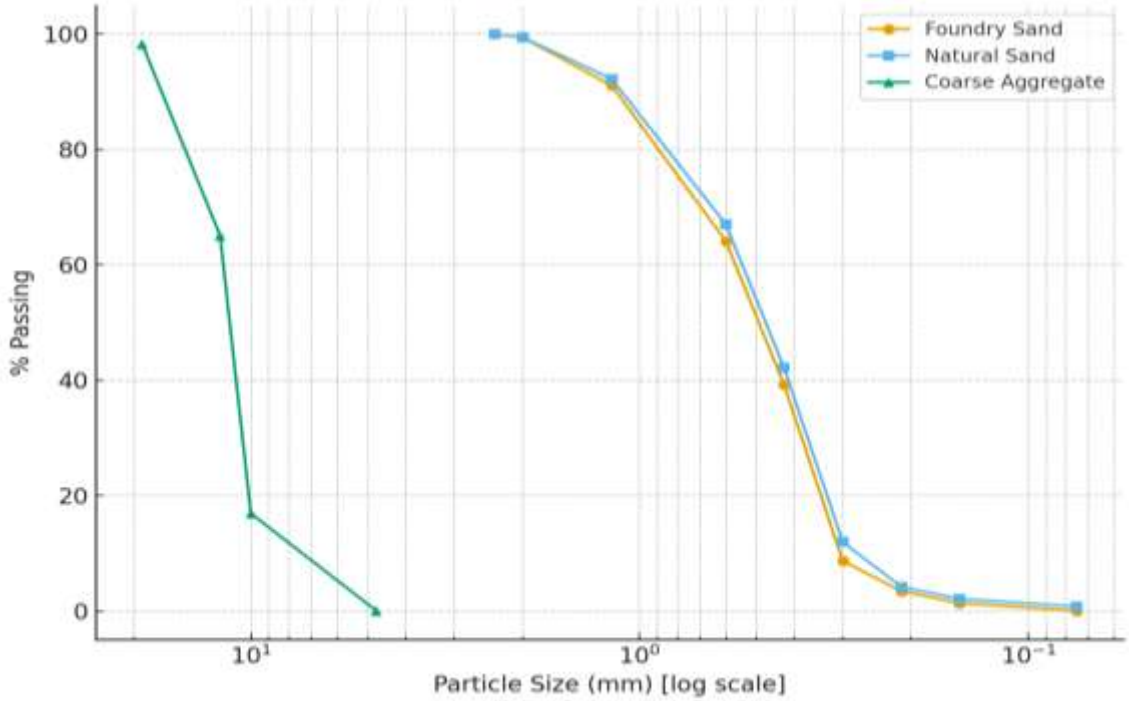

Fig 1: Graph of Particle Size Distribution Curve

The particle size distribution given in Table 1 and in Figure 1 gives an idea on the gradation characteristics of the foundry sand, natural sand and coarse aggregate used in this paper. The particle size distributions are both similar with both foundry and natural sands passing through the 2.36 mm sieve giving that both are within the fine aggregate range as defined in BS 812: Part 103.1 (1985) and ASTM C136 (2006) standards. But, the smaller the size of the sieve, the less percentage passes and there is a well-graded fine material distribution that can be used in concrete making. At 0.6 mm sieve, foundry sand passed 64.12% whereas natural sand passed 67.05, which indicated that foundry sand has slightly smaller particles. On the same note, at the 0.075 mm sieve, only 0.02 percent of foundry sand passed through as compared to 0.76 percent of natural sand which reaffirm foundry sand is a relatively coarse material. Such ruggedness communicates the reduction of the surface area that can reduce water requirements and better workability when incorporated in reasonable amounts of concrete [19]. In the figure of the coarse aggregate, the percentage passing drops to 0 at 4.75 mm although this value is still low compared to the original values of 98.30% at 19.04 mm which means that the material is uniformly graded and is in line with the specifications of the coarse aggregates used in concrete. The clear distinction between fine and coarse particles implies equal distribution of particle sizes that increases the density of the packing and minimizes the number of voids in the mix [14]. The curves of particle size distribution of

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foundry and natural sands are smooth and continuous with a characteristic gradation of well-graded fine aggregates as indicated in Figure 1. The strong correspondence between the two curves indicates that foundry sand is a good partial replacement of natural sand without any major changes involving the grading profile and behavior of the fine aggregate fraction. In general, the findings prove that all materials meet the standard grading requirements, and foundry sand has sufficient physical properties to be used in the production of structural concrete.

Table 2: Table for Quantity of materials required for the concrete production for one beam.

Foundry sand content	Water/cement Ratio	Mixing water (kg)	Cement (kg)	Natural sand (kg)	Granite (kg)	foundry sand (kg)
0%	0.6	1.028	1.714	3.429	6.857	0.00
20%	0.6	1.028	1.714	2.743	6.857	0.686
40%	0.6	1.028	1.714	2.057	6.857	1.372
60%	0.6	1.028	1.714	1.372	6.857	2.057
100%	0.6	1.028	1.714	0.00	6.857	3.429

Table 3: Table for Quantity of materials required for the concrete production for one cube sample.

Foundry sand content	Water/cement Ratio	Mixing water (kg)	Cement (kg)	Natural sand (kg)	Granite (kg)	Foundry sand (kg)
0%	0.60	0.694	1.157	2.314	4.629	0.00
20%	0.60	0.694	1.157	1.851	4.629	0.463
40%	0.60	0.694	1.157	1.388	4.629	0.926
60%	0.60	0.694	1.157	0.926	4.629	1.388
100%	0.60	0.694	1.157	0.00	4.629	2.314

Table 4: Specific gravity test for Natural and Foundry Sand

Parameters	Natural Sand	Foundry Sand
Weight of bottle (w_1)	18.97	20.20
Weight of bottle + sample (w_2)	60.37	60.50
Weight of bottle + b0ttle + water (w_3)	94.97	95.33
Weight of bottle+ water (w_4)	67.94	70.94
Mass of water used ($W_3 - W_2$)	34.6	34.83
Mass of soil used ($W_2 - W_1$)	41.4	40.20
Volume of soil (W4 – W1) – (W3 – W2)	14.36	16.08
$SG = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2}$	2.88	2.50

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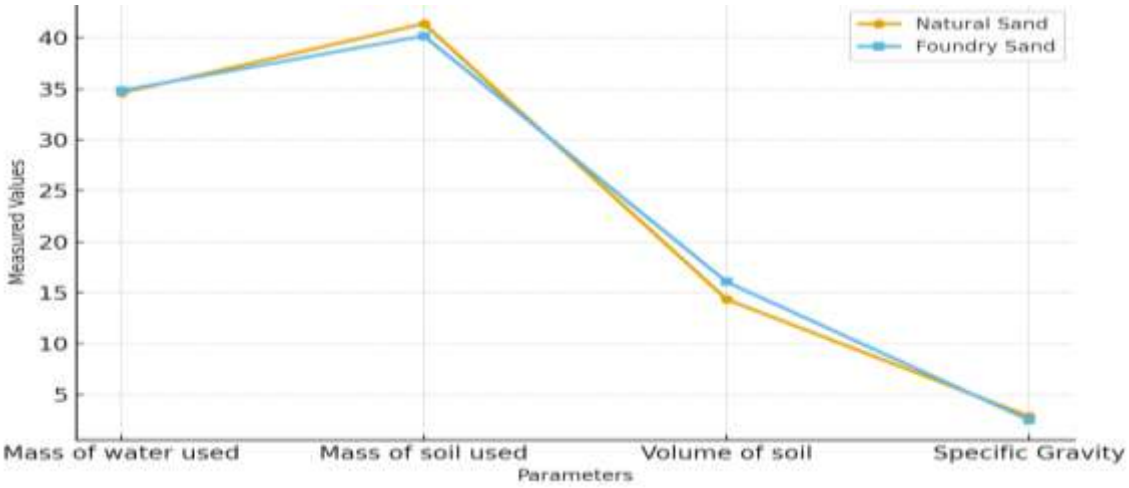

Fig. 2: Specific Gravity for Natural and Foundry Sand

Table 4 and figure 2 indicate that both samples (natural sand and foundry sand) have almost the same mass of water used and this suggests that the two materials exhibit similar behavior of displacement of water. Nevertheless, the weight of soil mass is a little less in foundry sand (40.20g) compared to natural sand (41.4g), which means that foundry sand is a little less dense in particles. The mass of the soil of foundry sand (16.08cm^3) is greater than the mass of natural sand (14.36cm^3), which proves the fact that the particles of foundry sand have more space owing to their roughness and the residual coating of the casting process. As a result, the specific gravity of the foundry sand (2.50) is lower than the natural sand (2.88), and the overall density is lower. Thus, the foundry sand is less dense and somewhat porous compared to the natural sand. These characteristics render it a good substitute of partial replacement of fine aggregate in concrete manufacturing to decrease the total weight of concrete without compromising the strength and workability of the concrete when well balanced.

Table 5: Table of Workability (Slump Test) Results

% FS	Slump (mm)
0	59
20	32
40	23
60	20
100	18

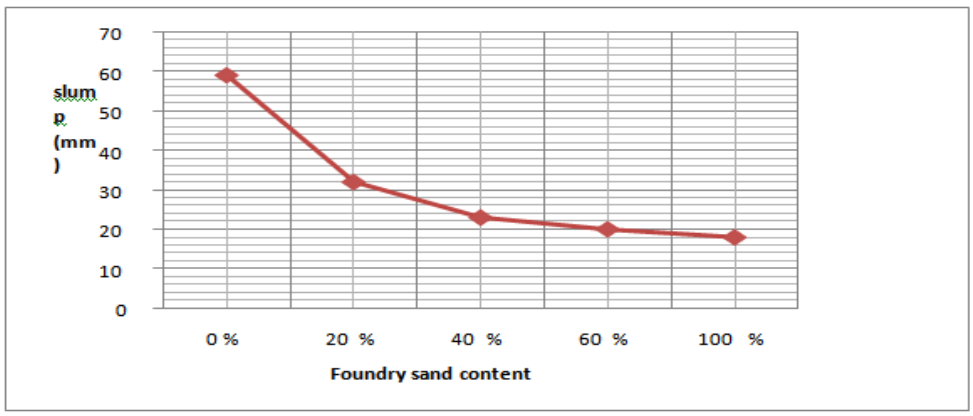

Figure 3: Graph of Workability (Slump) Test

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The table 5 and figure 3 above indicated the output of slump test on the concrete by partial substitution of foundry sand with natural sand in the proportions of 1:2: 4. The samples with foundry sand had an almost low workability when compared with the one with sand alone. The slump values decline as the content of foundry sand increases. This indicates that Foundry sand that demand more water has is higher compared to normal aggregates. As can be observed, 0% replacement level yielded a slump of 59 mm and hence the concrete generated by 0 percent replacement level will be concrete to be used on top of curb, slabs, piers and walls. A slump of 32mm was obtained at 20% replacement level (low workability) and concrete that was produced was suitable in foundations where light reinforcement was used and also as long as it was used in road vibrated by a hand operated machine. The concrete that is made using these is applicable in road making and road vibrated using power operated machine. The reduction in workability is explained by the fact that the foundry sand have been heated over a long period of time thus its water absorbing capacity is enhanced. It can also be reducing more likely than not because of the availability of the clayey type of fine materials in the foundry sand, which is good in reducing the fluidity of the fresh concrete. It also shows reduced free water present in the cementitious matrix as an effect of a finer particle and increased surface absorption properties of foundry sand. The roughness of the foundry sand texture composed of silica can also be the reason behind the increase in the frictional resistance among particles [17, 18]. The results are similar to those of Monosi et al. [12] who found that the reduction of slump was lower when foundry sand was employed because its content of fines was higher, and the residual binders were coated requiring more water to be lubricated. [23].

Table 6: Table of Ultrasonic Pulse velocity Test Results at 7, 14 and 28 days

Foundry Sand Content	UPV at 7days	UPV at 14days	UPV at 28days
0%	3.63	3.61	3.47
20%	3.58	3.59	3.45
40%	3.55	3.57	3.43
60%	3.50	3.50	3.42
100%	3.45	3.25	3.15

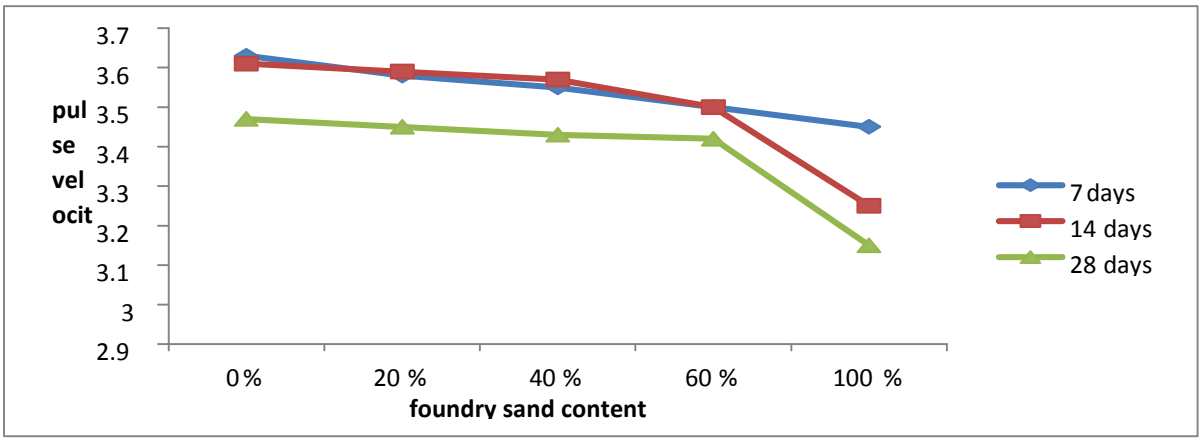

Fig 4: Graph of pulse velocity against foundry sand content at 7days, 14days and 28days.

Table 6 and Figure 4 provided the ultrasonic pulse velocity test at the end of the various curing periods 7 days, 14days and 28 days with various replacement levels of foundry sand contents (0%, 20%, 40%, 60% and 100%) in the test. The values are tabulated in figure 4 depicting the change in pulse velocities with fine aggregate replacements in the various curing ages respectively. The pulse velocities of concrete mixtures that had sand as 20,40,60 and 100 percent sand replacement were obviously lower than control mixture (0) at all the ages. It also demonstrated that pulse velocities go down as the quantity of foundry sand goes up. One will notice that at 7days, the quality grading was good (3.5 to 4.5km/s) at every replacement level except the 100 percent replacement level which was 3.45km/s which belongs to the medium quality range.

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However, the quality rating of concrete at 14 and 28 days curing was 3.0 to 3.5km/s, which is ranked medium in all replacement levels. The fact that concrete is of medium quality grading means that the concrete will have a rough surface. A reduction in the values of ultrasonic pulse velocity could probably be due to fine particles of metals pigments in the sand used in preparation of the foundry as a consequence of the use of the sand by the metal cast. It was discovered that a percentage decrease in cost was experienced as concrete generated per m3 when 60 percent of the mass of natural sand was substituted by foundry sand. The cost decrease was at 2.05 percentage. The reason is that the 60 percent replacement illustrated viable characteristics that are applicable in the structural application of vibration putting methods using larger water-cement ratios or admixtures to ensure the placement is not hard.These results resonate with Akinwumi (2014) who mentioned that a higher waste-sand substitution requires a higher water-cement percentage or alterations in admixtures to ensure the placement is not tedious.

Table 7: Table of Overall performance assessment indicates

Property	Effect of Foundry Sand	Optimum Behavior
Workability	Decreased	Requires admixture adjustments
Specific Gravity	Less dense and slightly more porous	Suitable as a partial fine aggregate replacement
Density	Slight reduction	Still acceptable structurally
UPV	Good structural quality	Up to 60% FS

IV. CONCLUSION

This paper found out that foundry sand could effectively replace natural sand in the concrete production process to a level of 60 percent replacement without material reduction in strength or durability. Particle size distribution showed well graded aggregates and specific gravity results proved that concrete had enough density to be used. The slump test showed that with higher content of foundry sand, lower workability was expected, but still the values obtained were such that they met the specifications of the use of vibrated concrete. The results of ultrasonic pulse velocity showed a progressive decrease in concrete quality with an increase in the content of foundry sand, but all of the mixes provided a structural integrity that was appropriate to medium-quality construction. The 60 percent replacement level was the best, as it produced good compressive strength, satisfactory pulse velocity, and the reduction of the production cost by 2.05 percent. After 60, the concrete had a very low workability and medium strength properties. The foundry sand texture that is fine, silica based and porous was observed to cause the decrease in the workability and density of the foundry sand due to the high demand of water. Generally, the study finds that foundry sand can be used as a sustainable material in the partial replacement of fine aggregates, which can help to reduce wastes, protect the environment, and save on the production of concrete in the civil engineering industry.

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