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Experimental investigation on the compressive and flexural properties of replaced natural sand with foundry sand in concrete development

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Abstract

The paper identifies the compressive and flexural strength of concrete when foundry sand is used instead of natural sand. The proportion of mix ratios in the experiment was 1:2:4 and water-cement ratio 0.6 concrete cubes. Substitute 0, 20, 40, 60, and 100 percent of natural mass sand by foundry sand in compressive strength test and concrete beam flexural test. Compressive and flexural strength were boosted by the percentage composition of foundry sand. The compressive strength increased to 26.27 N/mm^2 (60 percent replacement) after seven days as compared to 24.64 N/mm^2 (0 percent replacement). The strength increased at 14 days noted to be 26.22 N/mm^2 in 0% replacement to 29.10 in 60 replacement and 31.11 in 28 days. This resulted in compressive strength of 28.00 N/mm^2 when foundry sand was used as a substitute of all natural sand. The flexural strength rose to 60 percent replacement level, and then decreased. At 0, 60, and 100 replacements, flexural strength was 2.20 N/mm^2, 3.10 N/mm^2, and 2.50 N/mm^2, respectively. This indicates that the mild foundry sand enhances the tensile and bending strength of concrete with the enhancement of cement matrix-aggregate interfacial bonding. Analysis of sieves revealed that the two materials are within acceptable grading limits though, foundry sand exhibits a smaller particle spread in the pack and therefore is more efficient in packing density and less void at the optimum replacement level, making it a good partial replacement of natural sand in concrete manufacture.

Keywords: Compressive Strength; Flexural Strength; Foundry Sand; Concrete

1. Introduction

In the construction business, concrete is mostly utilised for the creation of buildings, roads, bridges, pavement, and other similar structures due to its versatility and significance as a civil engineering material. Whether a country is expanding or already established, concrete will be used as a building material for new or existing infrastructure. In its most basic form, it consists of cement, aggregates, water, and an admixture that, when combined, give the finished product its intended physical characteristics. The material that makes up the aggregates includes both fine and coarse particles. "Concrete" is a composite substance in which each ingredient plays an important role. Sand is a very popular fine aggregate in concrete, but its supply has been under pressure in some emerging nations that have been trying to keep up with the rising demand for infrastructure development in recent years. Researchers and professionals in the building industry have discovered several alternatives to natural sand in order to alleviate its stress and high demand [16]. The foundry sand used in metal casting is currently mass-produced and then discarded after several recycling cycles. One way to lessen our impact on the environment would be to use this garbage as construction material [1]. The main ingredients in foundry sand are silica sand and a thin layer of carbon that has been burned, together with any remaining binder (such as bentonite, sea coal, resins, or dust). It is sand with a high silica content, is finer than regular sand, and has consistent physical properties. For millennia, people have relied on foundry sand a byproduct of both ferrous and nonferrous casting processes as a moulding medium due to sand's excellent heat conductivity [1].

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Research has shown that the mechanical qualities of concrete, particularly its compressive strength, may be enhanced by including foundry sand into the mix [10]. Preetkaur [11] studied the effects of using foundry sand in a 1:1.45:2.20:1.103 ratio as a fine aggregate substitute on the compressive strength, modulus of elasticity, and split tensile strength of concrete. Foundry sand made up around 75% of the mixture instead of fine aggregates. This replacement rate was 10% by weight of fine aggregate, 20% by volume, and 30% by volume, respectively. All levels of foundry sand replenishment had their modulus of elasticity, compressive strength, and split tensile strength evaluated at both the 28-day and 56-day curing periods. Using foundry sand as a proportion of fine particles in concrete improved the compressive strength, split tensile strength, and modulus of elasticity. This demonstrates that foundry sand is a risk-free and efficient addition for enhancing the material's strength and longevity. In [2], Basar and Nuran investigated the feasibility of incorporating foundry sand (WFS) into RMC. Every one of the concrete mixes was made using the solidification/stabilization (S/S) method, with weight-based replacements of WFS for regular sand in increments of0%,10%,20%,30%, and 40%. In order to validate WFS-based-RMC, researchers looked at its microstructural, leaching, and mechanical characteristics. Adding WFS as a partial sand replacement had a detrimental effect on the strength performance and density of concrete mixes, but the water absorption ratio was positively influenced, according to the results of many physical and mechanical performance tests performed on the solidified products. But the results for both the control and the concrete with 20% WFS were almost identical. This study found that using WFS in place of some of the fine aggregates in RMC improved the material's quality without changing its microstructural, mechanical, or environmental qualities. But the proportion of WFS shouldn't go beyond 20%. Compressive strength improves and split tensile strength diminishes when the fraction of rejected foundry sand increases. This result is based on the tests performed by Patel et al. [9] with M-25 grade concrete (PPC) containing 0%, 20%, 40%, and 60% waste foundry sand by weight. There was manufacturing, testing, and comparing to standard concrete strength measurements. These tests were performed on a typical 150*150*150 mm cube for 7, 14, and 28 days to determine the mechanical characteristics of the concrete. In [6], Khatib and Herki investigated four different percentages of water-blown sand (WFS) as a substitute for fine aggregate in concrete: zero, thirty percent, sixty percent, and one hundred percent. All of the ingredients—cement, water, coarse aggregate, and cement—maintained their original quantities. In order to examine the characteristics, a range of curing periods, from 7 days to 90 days, were used. In conclusion, the results show that when the levels of WFS in concrete increase, the water absorption rate by capillary action increases, but the compressive strength and ultrasonic pulse velocity decrease.

The results show that with the right amount of foundry sand, it is possible to obtain sufficient strength. Siddique and Kadri [12] examined the impact of foundry sand (FS) and metakaolin (MK) on the near-surface properties of concrete. With a water/cement ratio of 0.45 and a cement content of 450 kg/m^3, the design team created the control concrete. At that point, foundry sand accounted for 20% of the fine particles, whereas metakaolin made up 5%, 10%, and 15% of the cement weight, respectively. The initial surface absorption, sorptivity, water absorption, and compressive strength were determined by a series of studies carried out at 35, 56, and 84 days of age. In [4], Guney et al. investigated the effects of waste foundry sand (WFS) on slump concrete. We used 0–5%, 10%, and 15% WFS as partial fine aggregate substitutes. Adding used foundry sand to fresh concrete lowers its slump value and makes it less fluid, according to the research. Because the remaining foundry sand contains small particles of a clayey variety, the fresh concrete might not be as fluid as it could be. When three different kinds of foundry sand were used in place of fine aggregate in concrete for 90 days, Khatib and Ellis [5] looked examined how it affected the compressive strength of the material. Foundries typically made use of three different kinds of sand: blended sand, waste sand, white fine sand. Class M, the common sand, had a variety of sand percentages added to it, including 0, 25, 50, 75, and 100%. I. Compared to utilising more ordinary sand; the strength of concrete was lowered when additional foundry sand was used. II. At all levels of replacement, the strength of concrete made with white sand and waste sand was almost identical. III. A large quantity of mixed sand weakens the mixture, in contrast to concrete that uses white sand or waste sand. IV. When replacement levels were low, below 50%, there was no strength improvement. Naik et al. [7] examined the compressive strength of several building materials, including bricks, blocks, and paving stones, using materials such as Class F fly ash, coal-combustion bottom ash, and waste foundry sand. There was a 35% bulk replacement rate for unprocessed sand and a 25% rate for waste foundry sand. The compressive strength of the blocks was measured after 7, 14, 28, and 91 days of cure. At5,28,56,91, and 288 days post-curing, the bricks and paving stones were evaluated. According to what they found, paving stones lost a lot of their strength when they used WFS in place of some sand. With the exception of one block combination, every single one of them exceeded the minimum compressive strength requirement of 13 MPa stipulated by ASTM C 90. You can use either WA or BA for up to 25% of the sand when making blocks in colder areas. In areas where frost action is not an issue, you can use BA or WFS in place of up to 35% of the sand in bricks and blocks. When tested according to ASTM C 936, the standard for solid concrete pavement units, none of the stones could withstand compressive loads greater than 55 MPa. Siddique et al. [13] looked at how foundry sand (FS) affected the modulus of elasticity and compressive strength of concrete. In place of some of the fine aggregate, FS can be used. At 7, 28, 56, 91, and 365 days after curing, the modulus of elasticity and compressive strength of concrete mixes with and without foundry sand were measured. Their research led them to the following conclusions: (i) Using foundry sand in place of part of the ordinary sand in the mix increased the compressive strength of the concrete. Within 28 days, Control Mixture M-1 (0% FS) was strengthened by4.2%, Control Mixture M-3(20% FS) by5.2%, and Control Mixture M-4(30% FS) by 9.8%. The viscosity of Control Mixture M-1, which included no FS, was 28.5 MPa. The compressive strength of concrete mixes also rises with time. There was an 8-18% increase in compressive strength for the control mixture (0% FS) as the samples aged (56-365 days), a 11.4-18.8% increase for combination M-2, a 12-20% increase for Mixture M-3, and a 12.4-20% increase for Mixture M-4. Because it increased the compressive strength of concrete mixes, foundry sand may be utilised in part as a substitute for fine aggregate in the manufacturing of concrete. First, the inclusion of foundry sand raises the density of the concrete matrix, which in turn increases the compressive strength of the finished product. Second, the presence of silica in the sand further enhances this effect. Over the course of 28 days, Etxeberria et al. [3] investigated the impact of two types of foundry sand on compressive strength. There were two types of foundry sand used: chemical and environmentally friendly. The concrete that was made utilising chemical foundry sand had 1150 kg of coarse aggregates, 300 kg of cement, 447.5 kg of foundry sand, 399.6 kg of natural sand, and a water-cement ratio of 0.61. In contrast, concrete that included green foundry sand had a water-cement ratio of 0.69 and included 300 kg of cement, 326 kg of foundry sand, 458 kg of natural sand, and 1150 kg of coarse aggregates. In comparison to concrete made using chemical foundry sand, which had a 28-day strength of 28.4 MPa, the results demonstrated that green foundry sand concrete had a strength of 25 MPa. The flexural strength of concrete was studied by Siddique et al. [13] when fine aggregate was partially replaced with foundry sand (FS). The flexural strength of concrete mixes was evaluated at 7, 28, 56, 91, and 365 days of age, regardless of whether foundry sand was included or not. Figure 2.6 shows the outcomes of the concrete mixes' flexural strength testing. Mixtures of concrete with varying amounts of foundry sand showed a small but noticeable shift in flexural, compressive, and splitting-tensile strengths. A strength increase of 2.0%, 5.6%, and 9%, respectively, was seen in the Control Mixture M-1 (0% FS) after 28 days when Mixtures M-2 (10% FS), M-3 (20% FS), and M-4 (30% FS) were added to it. The third and final combination achieved a strength of 3.41 MPa and 4.18 MPa, correspondingly. Research like this also shows that flexural strength increases with age. During the span of one year, the following combinations demonstrated improvements: There was a 7.3% to 13.2% increase in M-1 (control) without FS, a 7.8% to 10.8% increase in M-2 (10% FS), a 7.1% to 12.3% increase in M-3 (20% FS), and a 7.1% to 12.3% increase in M-4 (30% FS).

Even though there have been advancements, research has shown that replacing too much could actually increase the material's compressive and flexural strengths [15]. Finding the sweet spot for foundry sand % that improves strength performance is, hence, crucial. The mechanical characteristics of concrete made with foundry sand as a partial or full replacement for natural sand are the subject of this investigation. The study encompasses compressive and flexural strengths under controlled laboratory circumstances at 0%, 20%, 40%, and 60% replacement levels.

2. Materials and methods

2.1. Materials

In order to make concrete, a number of ingredients are mixed together. These include water, sand from a foundry, sand from nature, granite, and ordinary Portland cement (OPC). The following equipment is required in addition to the aforementioned: An oven, a cone, a base, a set of sieves (2.36mm, 10mm, and 14mm), a tamping rod, a cylindrical steel bowl, a shaker, and a hand towel are all needed.

2.1.1. Foundry Sand

Collecting the foundry sand sample from the stock dump at the University of Benin's Faculty of Engineering's Foundry workshop on the Ugbowo campus in Benin City, Edo State, Nigeria, allowed it to air-dry.

2.1.2. Cement

Ordinary Portland Cement (OPC) was the cement that was utilised from the Ibese factory in Dangote 3x packaging, with a grade of 42.5.

2.1.3. Natural Sand and coarse Aggregate

Ishihor, Benin City was also the source of the coarse aggregate and natural sand utilised in this study. Granite stones were utilised as the coarse aggregate. Both the coarse aggregate (retained on a 3.75 mm filter) and the fine aggregate (retained on a 2.75 mm sieve) were of excellent quality and devoid of harmful organic materials.

2.1.4. Water

The University of Benin's civil engineering laboratory provided the borehole water.

2.1.5. Granite

Coarse aggregate consisted of granite not exceeding 20 mm in nominal dimension.

2.2. Methods

In a curing tank filled with clean water, fifteen 100mm×100mm×500mm concrete beams and forty-five 150mm×150mm×150mm concrete cubes were poured and allowed to cure. Using a 1:2:4 ratio, the concrete was mixed using a water-cement ratio of 0.6. Foundry sand was used to replace 0%, 20%, 40%, and 60% of the natural sand by mass fraction. Concrete cube specimens were crushed and tested for flexural and compressive strengths after7,14, and 28 days of curing, respectively.

2.2.1. Batching of Materials

To ensure a reasonable level of consistency in the fresh concrete and to obtain a reliable development of its hardened form's strength, the concrete's constituent materials were accurately measured according to the 1:2:4 mix ratio on a large, level surface using a standard digital weighing balance.

2.2.2. Concrete Mixing

In accordance with the calculations, the several components of the concrete foundry sand, cement, sand, granite, the mixture was completely mixed with water using a concrete mixer. The specific amount of clean water was injected at regular intervals during the mixing procedure to provide a constant blend, following a water/cement ratio of 0.6. All of the various percentages of spent foundry sand replenishment were appropriately replaced using this process.

2.2.3. Concrete Curing

After 24 hours, the concrete examples, which included cubes and beams, were removed from their moulds to allow them to solidify. Before demoulding, each item was tagged for identification. The next step was to submerge the specimens in a big water tank to boost the concrete's strength, accelerate hydration, prevent shrinkage, and retain the heat of hydration until the test's age. The concrete specimens were initially available for testing after 7, 14, and 28 days of cure.

2.2.4. Sieve Analysis of Foundry Sand, Natural Sand and Granite

In the University of Benin, Nigeria's Civil Engineering department's Civil Laboratory, foundry sand, fine sand, and granite were used for the sieve analysis. Seated firmly on a frame, the sieves were agitated for ten minutes. Sieve Analysis for fine and coarse aggregate. The aggregate was manufactured to meet the standards laid out in BS812 part 1. Here are the things you need to do.

Preparation of Coarse Aggregate;

- To prevent the formation of big particles that are lumpy, the sample of fine aggregate is air dried.
- To ensure thorough filtering, set up a sieve shaker with a timer and set the test sieve arrangement on top. The sieve will be arranged using the following sizes: 2.36mm, 2.00mm, 600μm, 425μm, 300μm, 212μm, 150μm, and 75μm, in decreasing order from top to bottom.
- Take a weight reading from each filter to find out how much fine aggregate was retained.
- The weight that was measured is then expressed as a proportion of the total sample mass, starting with the smallest size and working our way up. According to BS882: 1983, the aggregate can be better classified by using the cumulative percentage to build a grading curve.

Preparation of Coarse Aggregate;

The coarse aggregate was prepared in accordance with the first part of BS812. The process is the same as in the above, only the test sieves will be arranged in decreasing order from 20mm to 1.18mm, rather than in the usual sequence of 10mm, 5mm, 3.35, 2.36mm, etc. Coarse aggregate used in this project must be larger than 12 mm.

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

One comparable way to evaluate an aggregate's shock or impact resistance is by looking at its aggregate impact value. The aggregates that are used for testing are those that stay on a 10 mm sieve after passing through a 14 mm filter. The aggregates were oven-dried for another day after being heated to 100–110 degrees Celsius for four hours. The aggregates were compacted in the steel bowl by using the tamping rod 25 times, after it was filled approximately three quarters of the way. The second and third levels were constructed by repeating the processes stated earlier with the other two parts. After the machine's base was equipped with a cylindrical steel cup, the net weight of the aggregate was calculated. Next, the entire sample was transferred to the cup. The 14-kilogram (0.14-newton) hammer was set to fall freely on the aggregates after being raised 380 millimetres above the material in the container. Fifteen of them were administered to the test group, with a one-second interval between each. After crushing the aggregates, they were removed from the container and screened through a 2.36 mm mesh. We took precise measurements and noted the percentage that made it through the filter, down to the milligramme. The proportion that was left on the 2.36 mm sieve was likewise given equal weight. Following the guidelines laid down in BS812: part 112:1990, the aggregate impact value test was carried out. Following that, the AIV was calculated with the help of the following formula.

$$AIV = \frac{M_2}{M_1} X\ 100\%$$

A substance's mass M_2 is equal to its mass after passing through a 2.36 mm test sieve, and mass M_1 is the mass of the test specimens.

2.2.6. Aggregate Crushing Value (ACV) Test

This test included standardising the process of compacting the specimen into three layers within a steel cylinder that had a freely moving plunger. After that, the specimen was plunged under a normal force of 400KN for a duration of 10 minutes. The crushing resistance of the material determines the extent to which this motion crushed the aggregate. Afterwards, a 2.36 mm sieve test was run on the crushed specimens to ascertain the degree. The weigh of passing and retaining were determined.

$$ACV = \frac{M_2}{M_1} \times 100\%$$

Compared to the mass of the test specimens, which is M_1, the mass of the material that passes through the 2.36mm test sieve is M_2.

2.2.7. Concrete Mix Design

The concrete mix was designed that is in line with the British Standard Recommended Guidelines (BS 12 or BS 4029). A weight-to-water-cement ratio of 0.6 was specified for the M25 grade concrete, which was mixed according to the specified proportions of 1:2:4.

2.2.8. Specific Gravity

Soil specific gravity at a set temperature may be calculated by dividing the mass of gas-free distilled water per unit volume by the volume of soil. The vacancy ratios and relative densities of the materials may be found using this test, which is conducted by the civil laboratory at the University of Benin. Here is how it is done:

1. Using the weighing balance, the empty density bottle's weight was measured as W_1. 2. The weight of the sample was recorded as W_2 when it was placed into the density bottle.

The sample in the bottle was then filled up by adding distilled water. We measured the weight of the full bottle and recorded it as W_3 after shaking it and letting it sit for 24 hours.

Weighing the distilled water after emptying the density bottle and recording it as W_4 allowed us to compute the specific gravity using this formula.;

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

The formulas provide the following results: weight of water = W_4 - W_1; weight of sample = W_2 - W_1; weight of the bottle + sample = W_3; weight of the bottle + water = W_4; and weight of the bottle + water = W_1 - W_2. The procedures followed here were those of BS 812-2 (1995).

2.2.9. Compressive Strength Test

In order to measure the compressive strength, a machine with a 2,000 KN capability was utilised. Each batch was tested using three 150*150*150 mm cubes. Using zero, twenty percent, forty percent, and one hundred percent waste foundry sand as a fine aggregate replacement, we analysed the concrete's characteristics before and after. Curing the concrete cubes in a water tank for seven, fourteen, and twenty-eight days was the proper procedure at the structural section of the civil laboratory at the University of Benin, Nigeria's civil engineering department before they were crushed using compression testing equipment. While taking the test, make sure you follow these steps: Specimens were taken out of the water and left to dry for three hours following the curing time. Stage two involved cleaning the testing machine's bearing surfaces. After that, you had to make sure the specimen was lying perpendicular to the machine's base plate. Finally, the top-moving portion of the apparatus was meticulously spun by hand until it touched the surface of the object. The fifth step was to power up the machine. In the end, we recorded the loads that caused each cube to collapse and determined their compressive strengths using the standard relation. The results are displayed below:

$$\text{Compressive Strength} = \frac{\text{Failure Load}}{\text{Area of Cube}} \; (N/mm^2)$$

Table 5 and picture 3 show the results of the compression strength test after7,14, and 28 days of curing. According to BS 1881-116 1983, the test is conducted.

2.2.10. Flexural Strength Test

Also, the University of Benin, Nigeria's structural unit and civil engineering laboratory performed the flexural test. The test was conducted following the test procedure specified by BS 1881-118 1983. Before the test, the concrete beams were removed from the water and left to dry after curing for the specified periods of time. We used a flexural testing equipment with two points of load to do the test. At intervals of one third of the beam's length, the point loads were positioned 166.67 mm from each edge. The machine's strengths and maximum load upon failure were documented. After the curing period was over, the specimen was taken out of the water and left to dry for three hours. We cleaned the testing machine's bearing surface. The specimen was set up in the machine with a 50 mm distance between each edge and a support within the machine. So that the point loads strike the specimen's upper surface at a third of its length, the movable component on top of the machine was gently turned by hand. A record was made of the load at which the beam broke. Using the beam size and failure load, the flexural strength was then determined, as shown below.

$$\text{Flexural Strength} = \frac{\text{Failure Load}}{\text{Area of beam}} \; (N/mm^2)$$

3. Results and discussion

3.1. Particle Size Analysis

Both table 1 and picture 1 below display the results of the particle size distribution. It clarified the gradational behaviour of the study's materials, including foundry sand, natural sand, and coarse aggregate. Based on the requirements set by BS 812: Part 103.1 (1985) and ASTM C136 [17], both foundry and natural sands are considered fine aggregates since they have identical distribution patterns, and all of the particles pass through the 2.36 mm screen. The percentage of material passing through a sieve drops as its size lowers; this indicates that the fine aggregate is well-graded and acceptable for use in concrete. It appears that the natural sand is marginally finer than the foundry sand, as it passed through the 0.6 mm screen with a percentage of 67.05% compared to 64.12%. The results showed that foundry sand is noticeably coarser than natural sand at the 0.075 mm sieve, with just 0.02% passing and 0.76% for natural sand. In modest amounts, this coarser gradation might replace some of the fine aggregate in concrete, which may improve workability and decrease water need due to its reduced surface area [14]. The passing percentage for the coarse aggregate dropped dramatically from 98.30% at 19.04 mm to 0% at 4.75 mm, showing that it is well-graded and meets the requirements for making concrete. An optimised particle packing that reduces voids and increases concrete mix density is a result of the distinct separation of the fine and coarse fractions [8]. In addition, well-graded materials are characterised by smooth and continuous patterns in the particle size distribution curves, which can be seen in both foundry and natural sands. The fact that the curves are so similar shows that foundry sand may partially substitute natural sand in concrete without compromising its performance or gradation characteristics. The results show that foundry sand has the right physical properties for structural concrete uses, and that all the ingredients meet the grading criteria of the applicable standards.

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
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	–	–

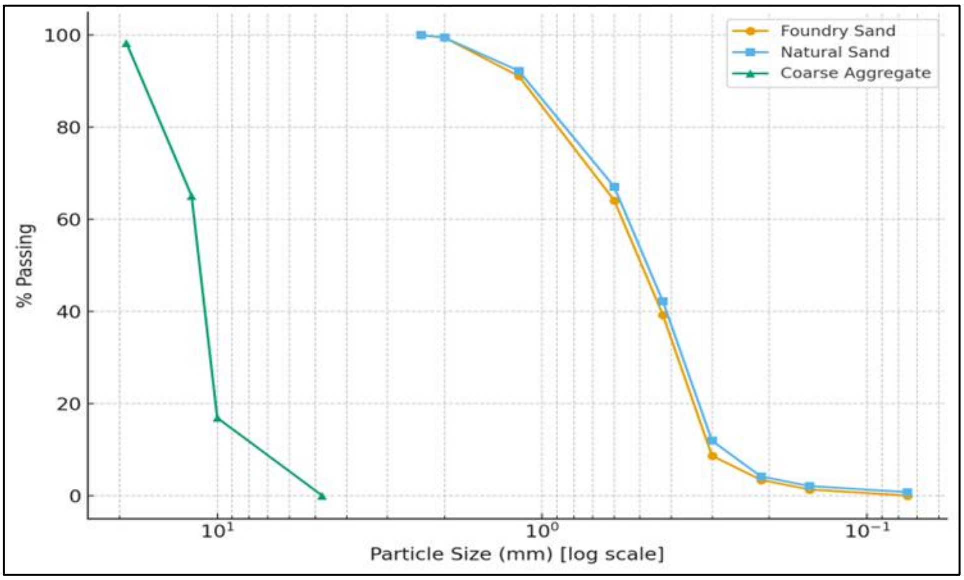

Figure 1 Graph of Particle Size Distribution Curve

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	Values for Natural Sand	Values for 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 (W3 –W2)	34.6	34.83
Mass of soil used (W2 – W1)	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

Table 5 Compressive strength of concrete cubes at 7, 14, and 28 days

Foundry sand content	Compressive Strength (N/mm^2) at 7days	Compressive Strength (N/mm^2) at 14days	Compressive Strength (N/mm^2) at 28days
0%	24.64	26.22	27.70
20%	25.26	26.37	28.15
40%	26.59	27.70	28.74
60%	26.27	29.10	31.11
100%	20.33	23.33	28.00

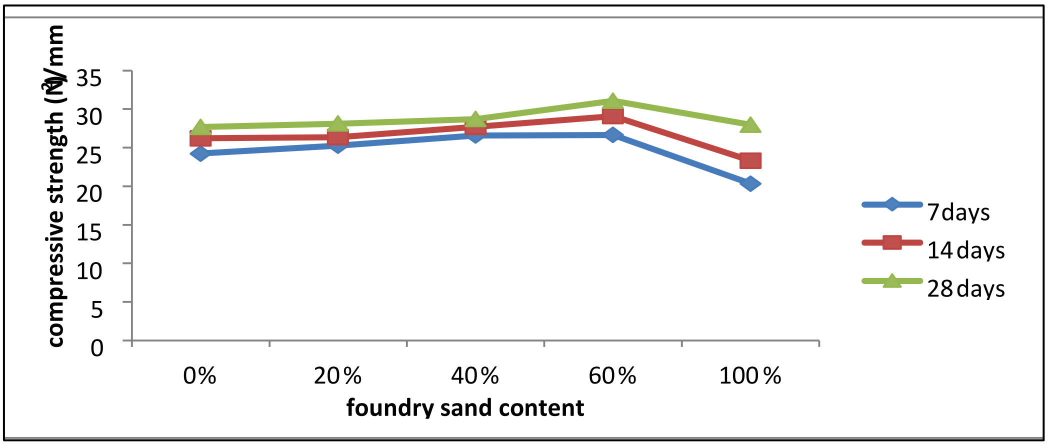

Figure 2 Graph of compressive strength against foundry sand content at 7, 14 and 28 days

Compressive strength of 0.6 water-to-cement mix concrete was measured at7,14, and 28 days after mixing. Table 5 and graphic 3 show the outcomes. After seven days of curing, the compressive strength of the concrete is measured, rose from 24.64N/mm² with no foundry sand replacement to 26.67N/mm² with 60% foundry sand replacement, according to the results. Nevertheless, the strength decreased to 20.33N/mm² when foundry sand was used in lieu of the original sand 100% of the time. But with zero replacement, the maximum compressive strength was 24.64N/mm², but with one hundred percent replacement, the value was lower. A steady trend was seen when the compressive strengths were compared at 7, 14, and 28 days. After 28 days of curing, the compressive strength of the 100% replacement group was 28 N/mm², just slightly higher than the 0% replacement group's maximum strength of 27.70 N/mm². The concrete grade M25 is ideal for reinforced bases and house foundations, and it is utilised for all levels of replacement except 60%. Foundations and pavements alike benefit from the M30 concrete grade, which comprises 60% of the mix.

Table 6 Table of Optimum Flexural Strength Test

Foundry sand content	Flexural Strength (N/mm²)
0%	2.20
20%	2.40
40%	2.60
60%	3.10
100%	2.50

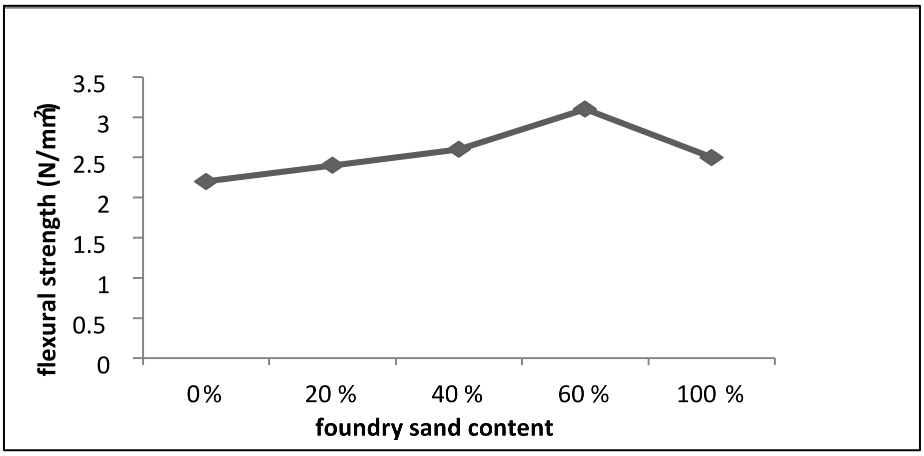

Figure 3 Graph of optimum flexural strength against foundry sand content

Substituting foundry sand for fine sand in concrete increased its flexural strength, but only up to a certain point. Here are the flexural strengths at the 28-day mark: Figure 4 and Table 7. The flexural strength evolves after 28 days when different proportions of fine aggregate are substituted for foundry sand. Results demonstrated that when 60% of the sand was sourced from foundries, the concrete's strength increased from 2.2 N/mm^2 at 0% to 3.1 N/mm^2. When using foundry sand in place of regular sand, the flexural strength usually decreased to 2.5 N/mm^2.

4. Conclusion

With a constant water-cement ratio of 0.6 and a mix ratio of 1:2:4, this experimental investigation tested concrete's compressive and flexural strengths with foundry sand and natural sand replaced in 0%, 20%, 40%, 60%, and 100% by weight. The use of foundry sand has a substantial effect on the compression and flexural strength development of concrete. Mechanical performance was improved up until the foundry sand was completely changed. Afterwards, its quality started to decline. Made by replacing 60% of the natural sand with foundry sand based on the findings of the compressive and flexural strengths, concrete of grade M30 is appropriate for heavy-duty structural components including pavements, foundations, and reinforced bases. M25 grade concrete, which includes additional replacement levels (0%-40%), is a suitable option for moderately heavy projects. The final product's strength and durability may be preserved when foundry sand is used in place of up to 60% of natural sand in concrete manufacturing. Its usage promotes eco-friendly construction practices by reducing waste and preserving natural sand resources. However, you shouldn't replace it totally due to the evident weakening of its strong properties. To confirm this concrete's structural and environmental performance, more research into its chemical resistance, shrinkage, permeability, and longevity is needed.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Attar, R., and Gupta, R. (2005). *Utilization of foundry sand waste in concrete production*. *Journal of Environmental Engineering and Construction*, 13(2), 57–63.

[2] Basar, H. M., and Nuran, G. (2012). *The effect of waste foundry sand (WFS) as partial replacement of fine aggregates on concrete properties*. *Construction and Building Materials*, 35, 508–515.

[3] Etxeberria, M., Pacheco, C., and Luna, J. (2010). *Effect of chemical and green foundry sands on concrete properties*. *Construction and Building Materials*, 24(9), 1916–1922.

[4] Guney, Y., Sari, Y. D., Yalcin, M., Tuncan, A., and Donmez, S. (2010). *Re-usage of waste foundry sand in high-strength concrete*. *Waste Management*, 30(8–9), 1705–1713.

[5] Khatib, J. M., and Ellis, D. (2001). *Mechanical properties of concrete containing foundry sand as partial replacement of fine aggregate*. *Journal of Materials in Civil Engineering*, 13(6), 442–449.

[6] Khatib, J. M., and Herki, B. (2013). *Effect of foundry sand replacement on concrete properties*. *Construction and Building Materials*, 47, 151–158.

[7] Naik, T. R., Kraus, R. N., and Siddique, R. (2003). *Use of foundry sand in manufacturing controlled low-strength materials and concrete*. *ACI Materials Journal*, 100(3), 208–215.

[8] Neville, A. M., and Brooks, J. J. (2010). *Concrete Technology* (2nd ed.). Pearson Education Limited.

[9] Patel, S., Shah, N., and Desai, D. (2013). *Effect of foundry sand on mechanical properties of concrete*. *International Journal of Engineering Research and Applications*, 3(4), 202–206.

[10] Prabhu, G., and Shanthappa, N. (2018). *Mechanical properties of concrete with waste foundry sand*. *Construction and Building Materials*, 172, 86–95.

[11] Preetkaur, S. (2006). *Influence of foundry sand as fine aggregate replacement in concrete*. *Indian Journal of Structural Engineering*, 3(2), 77–83.

[12] Siddique, R., and Kadri, E. H. (2011). *Effect of foundry sand (FS) and metakaolin (MK) on the near-surface characteristics of concrete*. *Construction and Building Materials*, 25(10), 3899–3905.

[13] Siddique, R., Aggarwal, P., and Aggarwal, Y. (2009). *Waste foundry sand in concrete: Strength and durability properties*. *Journal of Materials in Civil Engineering*, 30(6), 1–10.

[14] Siddique, R., Kaur, G., and Rajor, A. (2011). *Waste foundry sand and its leachate characteristics*. *Resources, Conservation and Recycling*, 55(9–10), 885–892.

[15] Singh, R., Gupta, S., and Pal, M. (2020). *Effects of partial replacement of sand with foundry sand on concrete*. *Journal of Materials in Civil Engineering*, 32(9), 76–84.

[16] Sohail, M., Khan, R., and Ahmad, S. (2008). *Alternative fine aggregates for sustainable concrete construction*. *Journal of Environmental Engineering*, 134(8), 674–682.

[17] ASTM C136. (2006). *Standard Test method for sieve analysis of fine and coarse aggregates*. ASTM International, West Conshohocken, PA.