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Assessment of Concrete Produced with Foundry Waste as Partial Replacement for River Sand

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Abstract The assessment in this research is targeted at determining the percentage of foundry waste suitable to be used as a partial replacement for fine sand aggregate. Experimental result reveals that 15% of foundry sand is appropriate as partial replacement of fine sand aggregate for preparation of grade 20 concrete by application of compressive strength equation as targeted strength of concrete were established at 28 days. The mathematical tools known as least square model was also applied to simulate the best equation of the curve for the purpose of prediction of compressive strength for the design of WFS concrete. The equation of best fit is given as $\sigma = 13.77wfs + 13.65$ for 7 days and 28 days and $\sigma = 1.303wfs + 17.49$ for 21 days. The developed equation illustrates the usefulness of least square model in monitoring the compressive strength of concrete upon the variation of percentage replacement with waste foundry sand.

Keywords Concrete, Waste Foundry Sand, Fine Sand and Compressive Strength

1. Introduction

The evaluation of engineering aggregate materials as good alternative replacement or partial replacement of aggregate in concrete production that will be affordable and durable is of global interest. Aggregates are the significant constituents in concrete. They give weight to the concrete and reduce shrinkage [1-3].

Assessment of foundry sand as a replacement for fine aggregate on fresh and hardened characteristics of concrete revealed that compressive strength of concrete decreases with increase in foundry sand [4-5]. Research conducted on fresh and hardened properties of grade 20 concrete, by substituting waste ferrous and non-ferrous foundry sand revealed that the compressive strength increased normally at 7days, however the strength gradually decrease as waste foundry sand content increased at 21 and 28 days, which is similar for other kind of replacements [6-14]. In terms of flexural strength, concrete strength increased with the increased in founding sand content at 28 days.

This research is centered at investigating the foundry sand as an alternative for partial replacement of fine sand aggregate in the production of concrete, thereby making the waste founding sand in Nigeria a useful waste by applying the empirical formula for compressive strength for adequate mix design.

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2. Materials and Method

2.1. Cement

R Dangote 3x Portland cement were used for batching and mixing of all specimens

2.2. Standard Grading Curve

The grading patterns of aggregate can be shown on tables or charts. Expressing grading limits by means of charts gives a good pictorial view. The correlation of grading pattern of a number of samples can be made at one glance. This is the reason, often grading of aggregates is shown by means of grading curves. Practical knowledge has revealed that in practice it is difficult to get the aggregate to conform to any one particular standard curve exactly where concrete of high strength and good durability is required, time aggregate zones may be used, but the concrete mix should be properly designed. If the fine aggregate grading becomes progressively finer, that is from aggregate to coarse aggregate should be progressively reduced. The most suitable fine to coarse rating of aggregate to be applied for any particular mix will depend on the grading particle shape and surface texture of both fine and coarse aggregates.

2.3. Water

The quantity and quality of water used during the batching of the concrete is of good one and based on water / cement adopted as water is a significant ingredient of concrete as it actively participates in the chemical reaction with cement.

2.4. Moulds

The moulds used were cleaned and oiled properly in order to remove the concrete from the mould easily after casting is done. The cube moulds size is 150 x 150mm and are used for the preparation of the concrete specimens in accordance with BS: 12390 part 1.

2.5. Mix Design of Concrete

In this research selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible is based on specification of BS:1881: part 125 – 1986. Hence, 1:2:4 design mix was used, where the river fine sand content were partially replaced with foundry sand aggregate at a constant water-cement of 0.5.

Three number of concrete cubes were cast for control mix (0% Foundry sand, tagged M-0) and design mixes at each replacement level. Fine aggregate were partially replaced with foundry sand at 5,10,15,20 and 25% replacement and specimens tagged M-1, M-2, M-3, M-4 and M-5 respectively.

3. Results and Discussion

3.1. Aggregate Grading Curve

River Sand (Fine Aggregate)

Sieve analysis investigation on fine aggregate was carried out using BS 410-2000. The analysis reveals that the fine aggregate conforms to the grading pattern of zone 3 as illustrated Figure 1. The bulk density, specific gravity and the percentage passing of the fine sand aggregate is presented in Table 1 and 2.

Table 1. Physical Properties of Fine Aggregate

S/N	Properties	Observed values
1	Bulk density (kg/m^3)	1639
2	Specific gravity	2.68

Table 2. Sieve Analysis of Fine Aggregate

Weight of sample taken = 500gm

Particle Description		Sieve Mm	Total Wt. (g)	Wt. Retained	% Retained	% Passing	Specification
GRAVEL	Cobbles	100.00					
		90.00					
	Coarse	75.00					
		63.00					
		50.00					
		31.80					
		25.00					
		19.00					
	Fine	12.50					
		10.00	0.0	0.0	0.00	100.00	
		5.00	14.00	14.0	2.80	97.20	**90-100**
SAND	Medium	2.36	30.00	16.0	3.20	94.00	**85-100**
		1.18	92.00	62.0	12.40	81.60	**75-100**
		0.60	166.00	74.0	14.80	66.80	**60-79**
	Fine	0.300	394.00	228.0	45.60	21.20	**12- 40**
		0.150	478.00	84.0	16.80	4.40	**0-10**
		0.075					
FINES	Clay or Silt	<0.075					

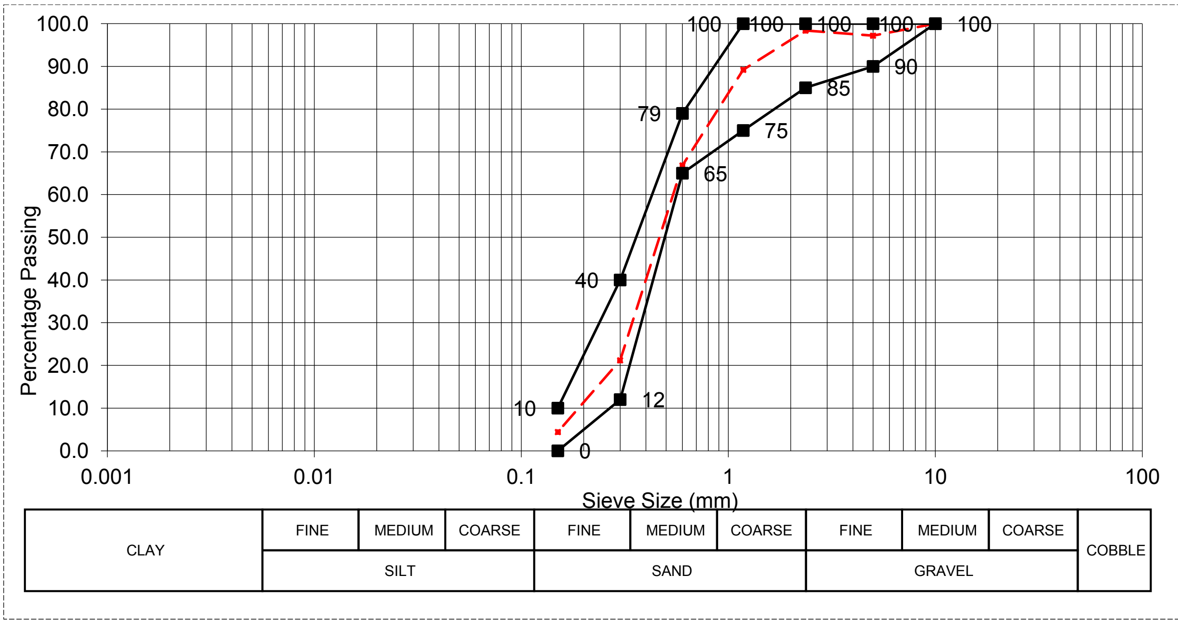

Figure 1. Particle size distribution curve of fine aggregate

Coarse Aggregate

The available coarse aggregate in Nigeria having the maximum size of 20mm were used in this research investigation for the preparation of the concrete specimens. Figure 2 shows the pattern of the particle size distribution of the coarse aggregate. The Maximum size, bulk density, specific gravity and percentage passing are presented in Table 3 and 4 as shown below.

Table 3. Physical Properties of Coarse Aggregate

S/N	Properties	Values
1	Maximum size	20mm
2	Bulk density (kg/m^3)	1850
3	Specific gravity	2.74

Table 4. Sieve Analysis of Coarse Aggregate

Particle Description		Sieve Mm	Total Wt. (g)	Wt. Retained	% Retained	% Passing	**Specification Grading limit**
	Cobbles	100.00					
		90.00					
GRAVEL	Coarse	75.00					
		63.00					
		50.00					
		31.80					
		25.00				100.00	**100**
	Fine	20.00	168.00	168.0	16.80	83.20	**85-100**
		14.00	850.00	682.0	68.20	15.00	**0-70**
		10.00	945.00	95.0	9.50	5.50	**0-25**
		5.00	995.00	50.0	5.00	0.50	**0-5**
SAND	Medium						
	Fine						
FINES	Clay or Silt						

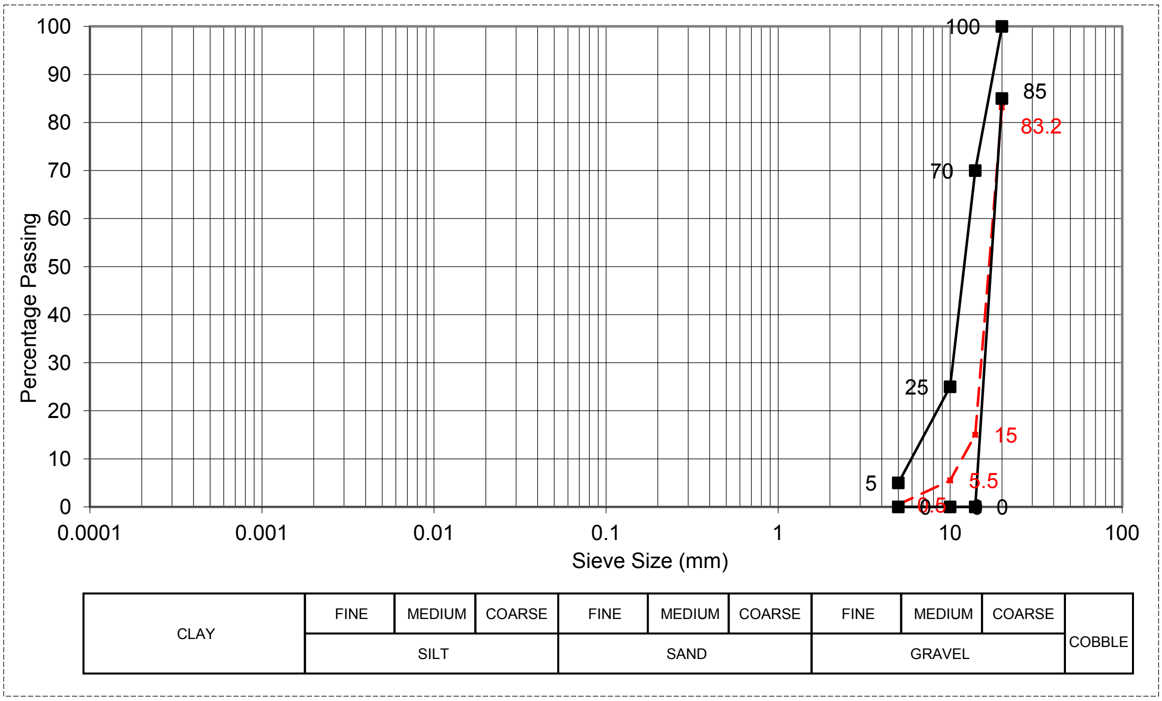

Figure 2. Particle Size Distribution Curve of Coarse Aggregate

Foundry Sand (Fine Aggregate)

Table 5. Physical Properties of Foundry Sand

S/N	Properties	Values
1	Color	Gray (blackish)
2	Bulk density (kg/m³)	1598
3	Specific gravity	2.61

Table 6. Sieve Analysis of Foundry Sand

Weight of sample taken = 500gm

Particle Description		Sieve mm	Total Wt. (g)	Wt. Retained	% Retained	% Passing	Specification
	Cobbles	100.00					
		90.00					
		75.00					
		63.00					
	Coarse	50.00					
		31.80					
GRAVEL		25.00					
		19.00					
	Fine	12.50					
		10.00	0.0	0.0	0.00	100.00	
		4.75	4.00	4.0	0.80	99.20	**90-100**
		2.36	30.00	26.0	5.20	94.00	**85-100**
	Medium	1.18	72.00	42.0	8.40	85.60	**75-100**
SAND		0.60	136.00	64.0	12.80	72.80	**60-79**
		0.300	334.00	198.0	39.60	33.20	**12- 40**
	Fine	0.150	406.50	72.5	14.50	18.70	**0-10**
		0.075		56.0	11.20	11.62	
FINES	Clay or Silt	<0.075			0.00	7.29	

Foundry waste was collected from stemma gray-iron, Asaba-street off Afikpo street in Ebonyi State, Nigeria. The characteristic of the particle size distribution is illustrated in Figure 3. The color, bulk density, specific gravity and percentage passing and presented in Table 5 and 6 for the waste foundry sand.

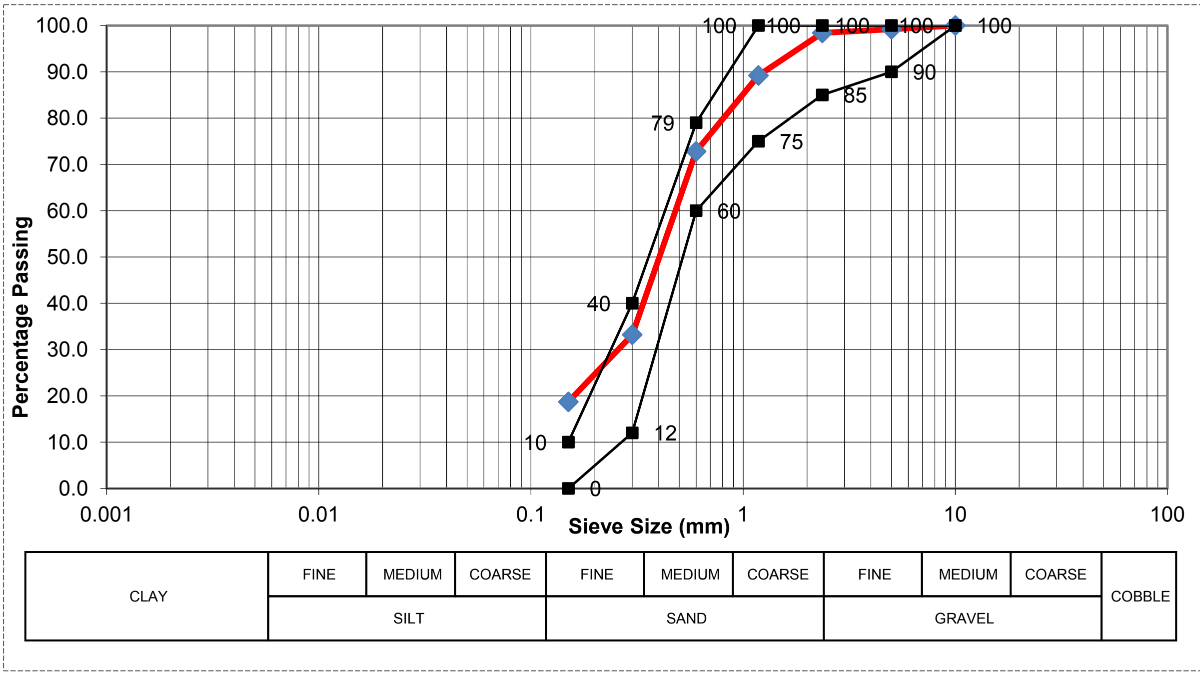

Figure 3. Particle Size Distribution Curve of Foundry Sand

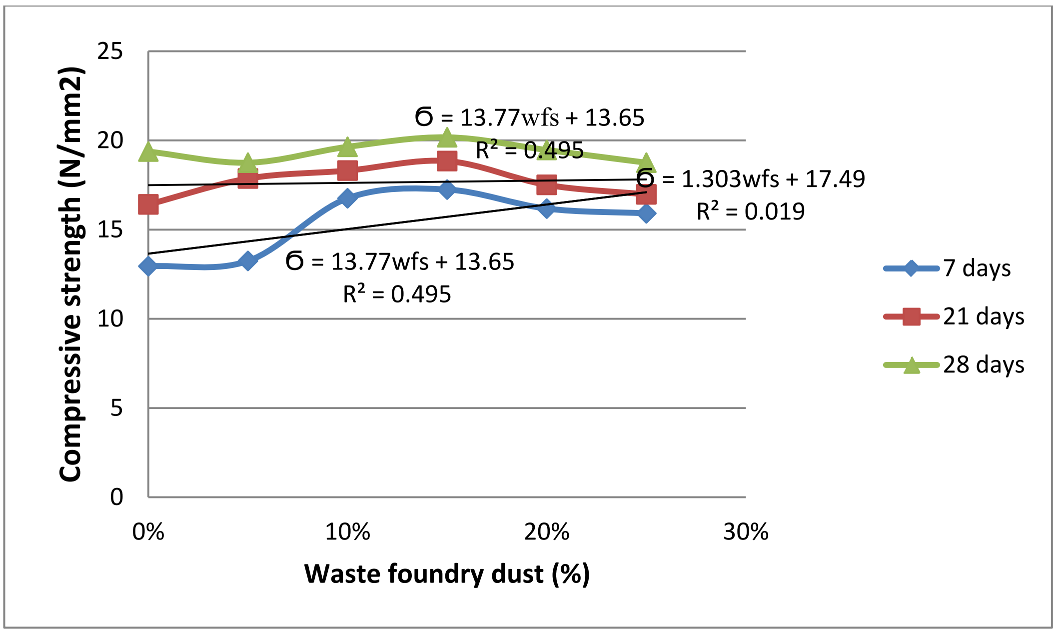

Figure 4. Plot of Compressive Strength against Foundry Sand Replacement Level

3.2. Compressive Strength

The evaluation of the compressive strength of the concrete made containing waste foundry sand at different replacement levels (0%, 5%, 10%, 15%, 20% and 25%) at the end of different curing period (7days, 21days, and 28days) as presented in Table 7. The results were obtained by application of compressive strength equation, given as

$$б = \frac{P}{A} \quad (1)$$

Where; б = compressive strength (N/mm^2), P = maximum load (N), A = cross-sectional area of cube (mm^2).

Figure 4 illustrate the relationship between compressive strength (б) of concrete and waste foundry sand for various partial replacement of fine sand aggregate with waste foundry sand (WFS) proportion. The linear regression model for 7 days reveals that the compressive strength relates to the WFS by the equation, $\sigma = 13.77WFS + 13.65$ and coefficient of correlation R = 0.70. Similarly both parameters are related by the same equation at the 28th day while the 21th day was related by, $\sigma = 1.303WFS + 17.49$ with R = 0.14.

Also from Figure 7, it was seen that the concrete produced with varying percentages of foundry sand showed higher compressive strength than the control specimen (0% WFS) up to a 15% replacement level after which there was a gradual decrease in strength from the 20 to 30% replacement level.

Table 7. Compressive Strength (N/mm^2) of Concrete at Different foundry sand Replacement Level

Foundry sand content (%)	Designation	Compressive strength, N/mm^2		
		7 days	21 days	28 days
0%	M-0	12.95	16.41	19.38
5%	M-1	13.24	17.87	18.76
10%	M-2	16.76	18.31	19.64
15%	M-3	17.24	18.84	20.18
20%	M-4	16.18	17.51	19.47
25%	M-5	15.91	16.98	18.76

4. Conclusions

The compressive strength of concrete can be investigated for further percentage of waste foundry sand as a partial replacement of fine sand aggregate by application of least square model as addressed by this paper. The following specific conclusion are drawn from the results obtain from the investigation;

1. The use of foundry sand as partial replacement of fine aggregates in making concrete increases the compressive strength at all replacement levels.
2. A maximum compressive strength is achieved at 15% replacement level.

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