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Comparative Analysis of Strength of Concrete Produced from Different Fine Aggregates

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Abstract:

The high cost of river sand may be attributed to the significant expenses incurred during its transportation from its natural sources. Additionally, the substantial depletion of these sources results in environmental issues. Additionally, factors such as environmental transportation limitations and other limits contribute to the diminished desirability of using river sand. Consequently, it is imperative to actively seek alternative or replacements for river sand. The outcome of the sieve analysis conducted indicated that the aggregates met the grading criterion, as they fell within the specified upper and lower ranges. The specific gravity of the river sand used was measured to be 2.6, but the specific gravity of the grit was established via two separate experiments, resulting in values of 2.23 and 2.45. The average specific gravity of the grit was calculated to be 2.34. The measured bulk density of river sand was determined to be 1550kg/m3, whereas the bulk density of grit was recorded as 1650kg/m3. The slump measurements obtained from specimens with varying water-to-cement ratios (W/C) of 0.35, 0.45, and 0.60 exhibited a range of 51 to 86mm. The concrete specimens made with 100% grit as the fine aggregate and a water-cement ratio of 0.45 exhibited a maximum compressive strength of 29.56 N/mm3 at the longest curing age tested. In contrast, the concrete specimens made with sand alone as the fine aggregate showed the lowest compressive strength of 17.33 N/mm3. Therefore, the exploitation of grit in construction is seen as a more cost-effective approach due to its ability to maximize efficiency and its widespread availability across various quarry locations.

Keywords: River sand, Strength of Concrete, aggregates, bulk density of river sand

1.0 Introduction

Concrete is widely acknowledged as the predominant artificial material used globally, ranking second only to water in terms of its extensive utilization [1]. Concrete is considered a very significant building material because to its several advantageous characteristics. It is relatively cost-effective, simple to produce, and provides both stability and continuity. Additionally, concrete exhibits rapid binding capabilities with other materials. The composition of this material consists of cement, fine aggregate (sand), coarse aggregate (crushed or uncrushed stones), and water, all proportioned appropriately. The raw materials used for the production of

concrete are crucial in determining the quality of the final product. Previous studies have shown that the mechanical properties of concrete are primarily influenced by many factors, including the water-cement ratio, slump, cement aggregate ratio, cement quality, aggregate gradation, and the effectiveness of the curing method [2-8]. Furthermore, it should be noted that the specific gravity, particle size analysis, shape, and surface texture of aggregates play a crucial role in influencing the properties of both wet and hardened concrete. Similarly, the mineralogical composition, toughness, and elastic modulus are key factors that significantly contribute to the hardened state of concrete [9]. In an effort to examine the fluctuations in water needs for mixing as it pertains to aggregate, Wills (10) conducted a study on the particle morphology of both fine and coarse aggregate in relation to the sufficient hydration of concrete. The influence of fine aggregate form on water need was shown to be more significant compared to that of coarse aggregate. Based on the preceding information and within the confines of permissible limitations, it was determined that the particle size distribution of the fine aggregate has a more significant impact on the characteristics of concrete compared to those of coarse aggregates [11]. The selection of the suitable fine aggregate for concrete production is a matter of significant importance due to the increasing cost and limited availability of river sand, which is the predominant fine aggregate used in concrete production. Therefore, there exists a significant need for alternative materials derived from industrial waste, namely grit, also known as quarry dust, which may be readily obtained from several quarry locations within the surrounding vicinity.

2.0 Materials and Method

2.1 River Sand

The fine aggregate employed in this pilot investigation was river sand sourced from the Choba river in Rivers State, Africa.

2.2 Grit (Quarry Dust)

The quarry dust used in this study was sourced from the ample deposits located in the Akamkpa quarry site within the Akamkpa Local Government Area of Cross Rivers State, Nigeria. Quarry dust is a finely grained rock fragment characterized by its gray coloration.

2.3 Coarse Aggregate

In this field experiment, coarse material in the form of gravel was used.

2.4 Water

The water used in the experiment was uncontaminated tap water that was devoid of contaminants that may potentially hinder the chemical interaction between the cement and the water. The density and pH value of water were measured to be 1000 kg/m^3 and 6.9, correspondingly.

2.5 Cement

The acquisition of ordinary Portland cement was made in the construction material market in Port Harcourt via local wholesalers. The cement exhibited excellent protection against moisture and has a mass of 50 kg.

2.6 Sieve Analysis

The fine aggregates underwent a sieve examination, and the findings are shown in Table 1 below.

Table 1 presents the results of the sieve analysis.

Sieve Size	Grit (%passing through)	Sand (% passing through)
4.75mm	100	100
2.36mm	100	100
1.18mm	81	93
0.60mm	44	60
0.30mm	6	18
0.15mm	1	4

2.7 Specific Gravity

The specific gravity test was conducted on the grit sample and the results are shown in Table 2 below.

Table 2: Specific Gravity Analysis.

BOTTLE/TEST NUMBER	1	2	3
Weight of Bottle only	28.45	28.5	(g).....M3
Weight of Bottle and Dry Sample	78.5	80.26	(g).....M3
Weight of Bottle, sample and water	158.4	161	(g).....M3
Weight of bottle and water	113.7	111.5	(g)......M4
$G_s = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$	2.23	2.45	
Average(Gs)		2.34	

2.7 Mix Design, Casting and Curing

The development of mixes encompasses the quantitative determination of the constituent ingredients required for the production of a certain volume of concrete. This study used three cubes measuring 150mm x 150mm x 150mm to achieve optimal concrete production. Therefore, it is important to do a thorough examination of the design in order to determine the optimal composition in accordance with the guidelines outlined in BS 1881 part 125:1986. The production of concrete was carried out in three distinct rounds.

- **The first lot utilizes river sand only as the fine aggregate, constituting 100% of the total aggregate content.**
- **The second lot incorporates 100% grit, specifically quarry dust, as the fine aggregate.**

- **The third lot consists of a mixture of 50% river sand and 50% grit.**

The concrete cubes were produced using conventional molds with a mix design ratio of 1:2:4 and water-to-cement ratio (w/c) values of 0.35, 0.45, and 0.60. The measurement of the slump of the wet concrete was conducted in accordance with the requirements provided in the BS 1881: Part 102 (1983). Three cubes (150x150mm) were cast for each kind of fine aggregates, following the guidelines outlined in BS 1881: Part 108 (1983). Following a single day of casting, the concrete cubes were extracted from the mold and then placed in a water tank for the purpose of curing until the specimens are deemed suitable for the test of compression.

Figure 1: Sample of Grit

Figure 2 displays a sample of a concrete mix.

Figure 3 illustrates the process of placing concrete into cube moulds.

Figure 4 illustrates the presence of cubes inside a curing tank.

2.8 Compressive Test Testing

The cubes of concrete underwent a curing process and were subjected to compression measurements at intervals of 3, 7, 14, 21, and 28 days. Three cubes were subjected to testing for each water cement ratio, and the resulting average value was considered as the compressive strength of the concrete.

3.0 Results and Discussion

3.1 Properties of Aggregates

The findings of the conducted sieve analysis indicate that the aggregates conform to the specified upper and lower limits of the grading envelope, suggesting their high suitability for use in building projects.

3.2 Gravity Specification

The specific gravity, or the density, of river sand was estimated to be 2.6, whereas the specific gravity of grit was measured as indicated in table 2.The findings from two outcomes were 2.23 and 2.45, with an average of 2.34 discovered. This was chosen as the grit specific gravity, and it falls within the typical range for fine aggregates.

3.3 Bulk Density

River sand had a bulk density of 1550kg/m3, whereas grit had a density of 1650kg/m^3. Because of its tightly packed structure and suitable gradation, this signaled a lower void to be filled by cement and water.

3.4 Porosity and Absorption

The absorption values for concrete specimens of 0.35, 0.45, as well as 0.60 were measured. The range of permeability observed in the small aggregates was among 0.70 and 1.2, which may be attributed to their tightly packed highly fine character.

3.5 Slump and Workability

The outcomes of the slump test conducted on the wet concrete sample were also acquired. The slump measurements obtained from various water-to-cement ratios of 0.35, 0.45, and 0.60 exhibited a range of 51 to 86mm. The droop observed at a water-to-cement ratio (w/c) of 0.60 exhibited a comparatively greater magnitude than that of the specimens with w/c ratios of 0.35 and 0.45. This suggests that the concrete displayed improved workability as the absorption and w/c ratio rose. A lower water-cement ratio necessitates an increased quantity of paste to enhance the cohesiveness of the mixture and provide improved workability.

3.6 Compressive Strength

The compression measurement results for the concrete specimens under consideration are shown in Table 3. The observed trend indicated a general rise in compressive strength as the duration of curing increased. The concrete with just grit as fine aggregate exhibited the maximum strength, followed by the concrete constructed from an equal blend of river sand and grit as fine aggregate. The concrete sample that had 100% river sand as its fine aggregate exhibited the lowest strength. On the other hand, the concrete sample that had 100% grit as its fine aggregate and a water cement ratio of 0.45 achieved the highest compressive strength of 29.56 N/mm3 at the longest curing age in days. Additionally, one of the concrete mixes that solely used sand as its fine aggregate resulted in the lowest compressive strength of 17.33 N/mm^3.

Table 3 illustrates the results of the compressive strength tests conducted on various concrete specimens.

Concrete	Age in Days	Compressive Strength (N/mm2)
Cement, River Sand and Gravel	3	7.56
	7	9.33
	14	11.11
	21	12.5
	28	17.33

Cement, Grit and Gravel	3 7 14 21 28	11.56 15.11 23.56 26.15 29.56
Cement, River Sand, Grit and Gravel	3 7 14 21 28	9.33 10.67 17.34 19.95 23.60

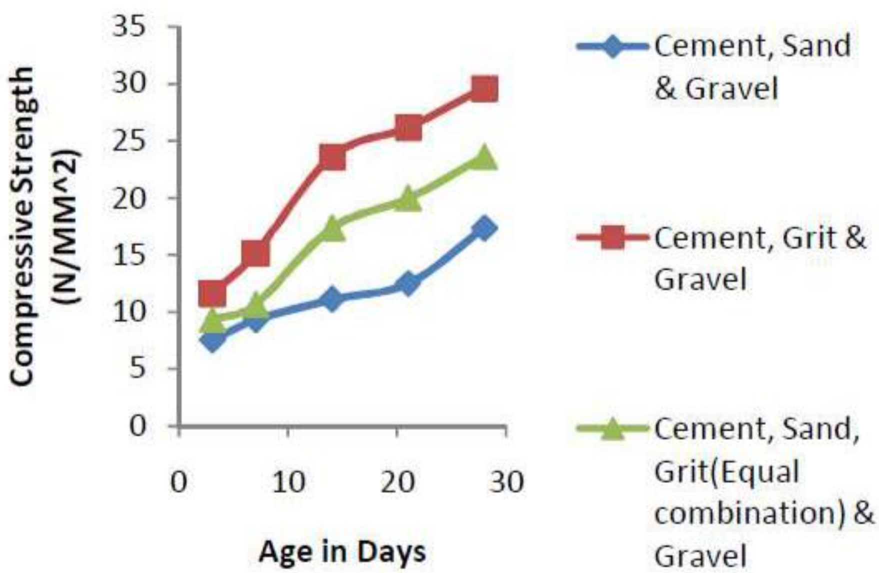

Figure 1: Graph of Concrete Compressive Strength versus Age in Days

4.0 Conclusion

Based on the findings and analysis presented in this research, it is possible to reach the following conclusion:

The greatest compressive strength was established for the three concrete samples after a curing period of 28 days.

The test specimen of concrete mixture consisting of cement, grit, and gravel had the highest compressive strength.

The research results demonstrate that the compressive strength of concrete, a secondary and contingent attribute, is influenced by the packing density of the mixture. This relationship remains unaffected by the grading and particle shape of coarse aggregate employed in the construction of concrete.

The utilization of grit in construction is often regarded as a cost-effective approach due to its ability to be optimally utilized. It is worth mentioning that grit is readily accessible, but typically seen as an industrial waste product.

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