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Original Research Article

Comparison of Strength of Concrete Produced from Different Sources of Fine Aggregate in Ihiala Town

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Abstract

The need to ascertain the engineering properties of locally sourced fine aggregate in Ihiala town necessitated this study. The laboratory investigation carried out on the fine aggregate samples from Ogboro-Isiala, Okohia, and Umuezeawala provided insight into their engineering behavior in terms of natural moisture content, particle size distribution, slump test and compressive strength development. The sieve analysis results revealed that Ogboro-Isiala sample contained a higher proportion of fines and clay fraction, Okohia sample showed a sandy profile with fewer fines, while Umuezeawala sample with a balanced sand–silt composition. The natural moisture content values showed that Ogboro-Isiala had the highest water retention (14.8%), followed by Umuezeawala (13.2%) and Okohia (11.5%). This indicates that Ogboro-Isiala sample is relatively wetter and more clayey, while Okohia sample is drier and sandier in composition. The compressive strength results indicated significant variation across the samples. Ogboro-Isiala sample showed an appreciable strength with curing age, Okohia exhibited moderate strength performance, Umuezeawala performed best overall, recording the highest compressive strength at 28 days (24.29MPa), and the Response Surface modeling of Umuezeawala fine aggregate demonstrating that well-graded fine aggregate respond more favorably in concrete strength development. The findings established a clear link between fine aggregate, gradation, moisture content, and concrete strength development. Ogboro-Isiala sample, due to its high plasticity and fines, is least suitable for concrete; Okohia shows moderate suitability; while Umuezeawala emerges as the most stable and reliable fine aggregate for engineering applications within the study area.

Keywords: Concrete, Fine Aggregate, Ihiala, Sieve Analysis, Compressive Strength, Moisture Content.

1.0 INTRODUCTION

Concrete is a fundamental material in the construction industry, composed primarily of cement, water, fine aggregates (such as sand), and coarse aggregates (like gravel or crushed stone). The quality and characteristics of these constituent materials significantly influence the properties of the resulting concrete, including its strength and workability (Bhagath, *et al*., 2025). Among these, fine aggregates play a crucial role in determining the concrete's performance (Rifa, *et al*., 2023; Donza, *et al*., 2002). Fine aggregates, typically comprising natural sand or crushed stone with particle sizes smaller than 4.75 mm, contribute to the concrete's workability, good finishes, and overall strength. The source and nature of these fine aggregates can lead to variations in concrete properties due to differences in particle size distribution, shape, texture, and mineral composition (Maina, *et al*., 2022). Therefore, understanding how fine aggregates from different sources affect concrete strength is essential for optimizing material selection and ensuring structural integrity. Several studies have investigated the impact of fine and coarse aggregate sources on concrete properties (Abdallah & Fan 2014; Ogunjiofor, *et al.,* 2023a; Ogunjiofor & Ayodele, 2023; Ogunjiofor and Ezeani, 2025; Obi, *et al*., 2023). Similarly, Ogunjiofor, *et al.*, 2023b examined the compressive strength of concrete produced using fine aggregates sourced from Onitsha, Uli (both in Anambra State), and Njaba (Imo State). The findings indicated that all tested aggregates yielded concrete with average strengths exceeding 20 N/mm² after 28 days of curing. Notably, the fine aggregate from Uli resulted in the highest mean compressive strength of 33.2 N/mm², suggesting that the source of fine aggregate plays a pivotal role in the strength development of concrete.

In the context of Ihiala Town, located in Anambra State, Nigeria, local construction practices predominantly utilize fine aggregates sourced from nearby riverbeds and sand deposits. These sources often vary in their physical and chemical properties due to differences in geology, weathering processes, and extraction methods. Despite the critical role of fine aggregates in concrete production, there is limited information regarding the suitability and performance of fine aggregates from different sources in Ihiala Town. Builders and contractors often rely on convenience or cost rather than data-driven decisions about the quality of aggregates. This can lead to substandard concrete, structural failures, and increased maintenance costs, potentially compromising the safety and durability of buildings and infrastructure.

However, there is a paucity of empirical data comparing the strength characteristics of concrete produced with fine aggregates from different local sources within this region. Given the potential variability in aggregate properties due to geological and environmental factors, it becomes imperative to assess how these local sources influence concrete strength. This study identified the variations in aggregate quality and their corresponding effects on concrete strength, providing recommendations for the most suitable sources for construction purposes in the area.

Understanding how the source of fine aggregate affects concrete strength ensures that only high-quality aggregates are selected for construction projects, enhancing the durability and reliability of structures (Liu, *et al*., 2020; Sada, *et al*., 2013). The study helps to evaluate locally available aggregates in Ihiala Town, promoting the use of cost-effective and readily accessible materials, which can reduce construction costs and dependence on external supplies. By identifying the best sources of fine aggregate, the study contributes to sustainable construction practices by minimizing waste, reducing transportation costs, and encouraging the use of locally sourced materials.

This study focused on comparing the strength of concrete produced using fine aggregates sourced from three specific locations in Ihiala Town: Ogboro-Isiala, Okohia, and Umuezeawala. The research will evaluated the physical and mechanical properties of the fine aggregates from these locations, including their particle size distribution and silt content.

1.1 Types of Fine Aggregates:

i. **River Sand**: River sand is one of the most commonly used fine aggregates in concrete production. It is obtained from riverbeds and banks and is generally clean, free from clay, and has rounded particles. These properties make it ideal for concrete mixes, as it improves workability and reduces the water requirement in the mix. River sand often provides good strength and durability for concrete but can be affected by the region's environmental regulations on extraction (Ozioko & Ohazurike, 2020).

ii. **Pit Sand**: Pit sand is another type of fine aggregate sourced from pits dug in the ground. This sand is typically angular, unlike river sand, and may have a slightly higher content of clay particles. Due to its angularity, pit sand often provides a rougher texture, which can influence the bonding of the cement paste, potentially improving the strength of the concrete. However, excessive silt and clay content can reduce the quality of the concrete (Tulashie, *et al*., 2017).

iii. **Sea Sand**: Sea sand is derived from beaches and sea shores. It is generally finer than river sand but often contains impurities such as salts. The presence of salt can negatively affect the durability of concrete by promoting corrosion of reinforcement bars. Thus, when used, sea sand must be thoroughly washed and treated to remove salts and other harmful substances before mixing with cement (Ge, *et al*., 2023).

iv. **Manufactured Sand (Crushed Sand)**: Manufactured sand, also known as crushed sand, is produced by crushing rocks to create sand-sized particles. It has angular shapes and sharp edges, which can improve the bond between the aggregate and cement paste. However, it may affect the workability of the concrete, requiring adjustments in water content or the use of plasticizers. Crushed sand is often used as a substitute for natural sand when the latter is scarce (Arulmoly, *et al*., 2021).

v. **Masonry Sand**: Masonry sand is fine sand specifically used for masonry work. It has a smooth texture and uniform particle size. While it is typically not used in standard concrete production, it can be used for mixes requiring finer sands. Masonry sand may not provide the best compressive strength compared to other types due to its uniformity and smoothness.

vi. **Artificial Sand (Manufactured Aggregates)**: Artificial or manufactured sand refers to sand-like materials made by crushing rocks, stones, or other aggregates. The size and shape of artificial sand particles can be controlled to meet specific concrete requirements. It is often preferred when natural sand is in short supply. This type of sand can provide good compressive strength and durability, but its properties are heavily dependent on the source material (Jagadeesh, 2022).

2.0 MATERIALS AND METHOD

2.1 Selection/Collection of Fine Aggregate and other materials

Samples of fine aggregate were obtained from three major fine aggregate site within Ihiala Town which are Ogboro-Isiala, Umuezeawala and Okohia. The selection was based on availability and the predominant sources used in construction within the town. Coarse aggregate was sourced from Uturu quarry site, Bua cement was sourced from a cement seller at Ihiala building material shop, water was obtained from Civil Engineering Laboratory, located at Department of Civil engineering, Chukwuemeka Odumegwu Ojukwu University Uli Campus.

The sampling and sample collections were done in accordance with standard procedures to ensure that the samples are truly representative of the material available from each source. The fine aggregate samples were collected using shovels, sample containers, and labeled sample bags.

2.2 Testing of Fine Aggregate Properties

Prior to the concrete mix preparation, the fine aggregates underwent several laboratory tests, including:

Sieve Analysis: To determine the particle size distribution of the aggregates.

Moisture Content Measurement: To determine the amount of water present in the aggregates, this will affect the water-to-cement ratio of the concrete.

2.3 Preparation of Concrete Mixes

Concrete mixes were prepared using the collected fine aggregates from each source. A standard mix design was followed, with careful measurement of cement, fine aggregate, coarse aggregate, and water. The concrete mix was designed to produce a uniform mixture for testing. The water-cement ratio, as well as the proportion of fine and coarse aggregates, was kept consistent across all mixes, with only the fine aggregate being variable.

2.4 Workability Test (Slump Test)

In order to ascertain the workability of the samples, a Slump Test was performed on the fresh concrete before placing it on the moulds to measure its workability. This test provided insights into the handling properties of the concrete made with different fine aggregates.

2.5 Casting of Concrete Specimens

Concrete specimens were cast in standard molds of 150mm x 150mm x 150mm cubes for each mix. The casting process was conducted in a controlled laboratory environment to minimize variables such as temperature and humidity. The specimens were cast in triplicates to ensure the accuracy of results and to account for any variability in the mix or casting process.

2.6 Curing of Concrete Specimens

After casting and initial setting, the concrete cubes were stored in curing tanks filled with water. The specimens were cured for a period of 7, 14 and 28 days to ensure the development of full strength. During the curing process, temperature and humidity were monitored to ensure optimal curing conditions. The curing was done according to the standard curing procedure to ensure that no external factors affect the strength development.

2.7 Compressive Strength Testing

After 7, 14 and 28 days of curing, the concrete cubes were subjected to compressive strength testing using a Compression Testing Machine. Each specimen was tested to failure under controlled conditions, and the maximum load it can withstand before crushing was recorded. The compressive strength was calculated as the load at failure divided by the cross-sectional area of the specimen. The average compressive strength of the three specimens for each fine aggregate source was calculated.

2.8 Data Recording and Analysis

Data on the compressive strength, workability (slump), and other properties of the concrete specimens were recorded systematically. The results were compared across the different fine aggregate sources to assess their impact on the strength of the concrete. Statistical analysis was performed to determine the significance of any observed differences in strength between the mixes using Response Surface Methodology (RSM).

3.0 RESULTS AND DISCUSSIONS

3.1 Natural Moisture Content

The results of the natural moisture content test presented in Table 1 show variations in the in-situ water content of fine aggregates collected from the three study locations: Ogboro-Isiala, Okohia, and Umuezeawala. The Natural Moisture Content (NMC) is an important geotechnical property, as it influences fine aggregate workability, compaction behavior, and response to stabilization.

Table 1: Natural Moisture Content of Fine aggregate Samples from the Study Areas

Location	Wet Weight of Fine aggregate (g)	Dry Weight of Fine aggregate (g)	Weight of Water (g)	Natural Moisture Content (%)
Ogboro-Isiala	120.6	105.1	15.5	14.8
Okohia	116.0	104.0	12.0	11.5
Umuezeawala	119.8	105.8	14.0	13.2

From Table 1, the Ogboro-Isiala fine aggregate sample recorded the highest moisture content at 14.8%, followed by Umuezeawala with 13.2%, while Okohia had the lowest value of 11.5%. These results suggest that the Ogboro-Isiala fine aggregate naturally retains more water compared to the other locations, which may be associated with its higher proportion of fines (silt and clay) observed in the sieve analysis. Fine aggregates with higher clay and silt content generally have greater surface area and stronger affinity for water, leading to higher moisture content. This characteristic, however, can negatively affect stabilization performance because excess water interferes with cement hydration, reduces bonding, and promotes shrinkage, which helps explain why Ogboro-Isiala exhibited the weakest compressive strength results.

The Umuezeawala fine aggregate recorded an intermediate natural moisture content of 13.2%, which balances between the clay-rich Ogboro-Isiala and the sandier Okohia. This moderate water content, combined with a higher proportion of sand, provides favorable conditions for strength development, allowing effective hydration without excessive moisture. This correlates with Umuezeawala's superior performance in compressive strength tests, where it attained the highest values at 14 days.

The table shows that the fine aggregates with lower natural moisture content (Okohia and Umuezeawala) performed better under stabilization, while the fine aggregate with the highest natural moisture content (Ogboro-Isiala) showed weaker strength characteristics. This reinforces the relationship between fine aggregate moisture, particle size distribution, and stabilization behavior.

3.2 Sieve Analysis Results

The sieve analysis results presented in Table 2 highlight the differences in particle size distribution among fine aggregates from Ogboro-Isiala, Okohia, and Umuezeawala, and these differences strongly influence their engineering behavior and suitability for stabilization.

Table 2: Sieve Analysis Results of Fine aggregate Samples from the Study Areas

Sieve Size (mm)	% Passing – Ogboro-Isiala	% Passing – Okohia	% Passing – Umuezeawala
4.75 (Gravel/Sand boundary)	87.5	81.7	89.6
2.00	79.2	75.6	83.1
0.425	61.3	58.4	65.7
0.075 (Sand/Silt boundary)	39.3	29.6	33.8
<0.002 (Clay fraction, est.)	16.9	11.0	13.7
Dominant Fraction	Sand + fines	Sand	Sand + fines
USCS Classification	CL (Low-plastic clay)	SC (Clayey sand)	SM (Silty sand)

The Ogboro-Isiala fine aggregate shows 87.5% passing the 4.75 mm sieve, with a steady reduction to 61.3% passing the 0.425 mm sieve and 39.3% passing the 0.075 mm sieve. This relatively high percentage of fines indicates that Ogboro-Isiala contains a significant proportion of silt and clay. The Okohia fine aggregate displays a coarser gradation compared to Ogboro-Isiala. About 81.7% passes the 4.75 mm sieve, reducing to 58.4% passing the 0.425 mm sieve, and only 29.6% passing the 0.075 mm sieve. The clay fraction is relatively low at 11.0%, meaning the fine aggregate is less plastic and better drained. The Umuezeawala fine aggregate demonstrates a well-graded sandy profile. About 89.6% passes the 4.75 mm sieve, 65.7% passes the 0.425 mm sieve, and 33.8% passes the 0.075 mm sieve, with an estimated clay content of 13.7%. While it has more fines than Okohia, the fine aggregate is still dominated by sand. This composition leads to its classification as SM (silty sand).

3.3 Workability (Slump) Test

The high degree workability results in Table 3 show that fine aggregate from the three locations Ogboro-Isiala, Okohia and Umuezeawala contains more sand, less fines and some clay fractions. Umuezeawala, which has a well-graded sandy-silty profile, demonstrates the best combination of properties for concrete, as reflected in its superior slump performance. These findings confirm that fine aggregate gradation strongly influences the effectiveness of concrete strength and the long-term strength of concrete.

Table 3: Workability (Slump) test

Sample	Slump (mm)	Degree of workability
Ogboro-Isiala	150	High
	155	High
	153	High
Okohia	130	High
	140	High
	135	High
Umudala	155	High
	154	High
	160	High

3.4 Compressive Strength

The compressive strength results presented in Table 4 provide valuable insights into the performance of the concrete produced using the fine aggregates from the three different locations (Ogboro-Isiala, Okohia, and Umuezeawala) at varying curing ages of 7, 14, and 28 days.

Table 4: Compressive Strength

Sample	Days	Strength (kN)	Strength (MPa)
Ogboro-Isiala	7	156.4	6.95
	14	257.1	11.43
	28	521.6	23.18
Okohia	7	198.2	8.81
	14	286.8	12.75
	28	530.3	23.57
Umuezeawala	7	187.4	8.33
	14	297.4	13.22
	28	546.5	24.29

The Ogboro-Isiala sample displayed an initial compressive strength of 156.4kN (6.95 MPa) at 7 days, suggesting that the concrete was able to develop a good level of early strength. The strength increased normally to 257.1 kN (11.44 MPa) at 14 days, and while the load capacity gainfully increased to 521.6 kN at 28 days, the corresponding strength was recorded as 23.18 MPa, which is higher than both the 7-day and 14-day results.

The Okohia sample showed relatively better strength behavior. At 7 days, it recorded 198.2 kN (8.81 MPa), which was the highest early strength value among the three fine aggregates. At 14 days, the compressive strength increased to 286.8 kN (12.75 MPa), indicating an appreciable increase, and at 28 days the strength rose again to 530.1 kN (23.57 MPa). The Okohia fine aggregate shows a moderate and stable increase in strength range over time. Its results suggest that the concrete mix maintains a reasonable degree of structural integrity over the curing period. This relative stability makes it more reliable than the Ogboro-Isiala fine aggregate, though there is a need for closer quality control in mixing, compaction, and curing.

The Umuezeawala sample as shown in Figure 1 produced the most promising results. Its compressive strength at 7 days was 2187.44 kN (8.33 MPa), which is comparable to the other samples, but by 14 days it showed a remarkable increase to 297.4 kN (13.22MPa). This sharp rise reflects proper hydration and strong bonding between the fine aggregate particles and cement paste. At 28 days, the strength increased to 546.5 kN (24.29 MPa). The value is higher than the corresponding results from Ogboro-Isiala and Okohia at 28 days, indicating superior performance overall. Nevertheless, the Umuezeawala sample clearly demonstrates the greatest potential for use in concrete and soil stabilization works, as its strength development pattern indicates compatibility with cement treatment.

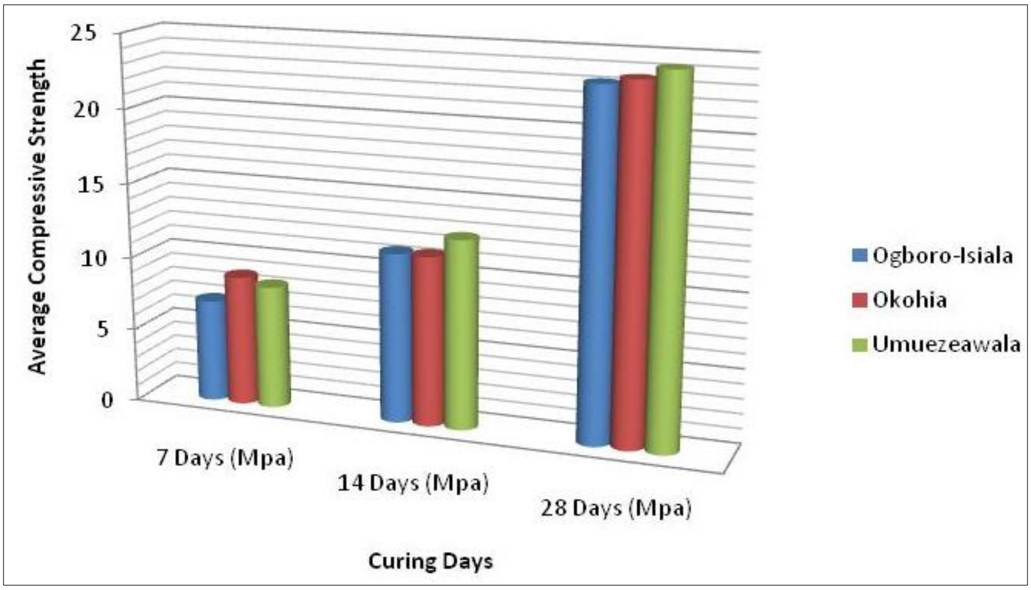

Figure 1: Chart representation of Compressive Strength

When benchmarked against conventional standard, all three fine, even in their lowest recorded values, far exceed this minimum specification. This implies that, in principle, each of the fine aggregates possesses sufficient strength to serve as fine aggregate in concrete production. They all indicated consistent strength development. Consistent strength gain is not only desirable but necessary to ensure the long-term durability of concrete structures.

The variations observed can be linked to the inherent properties of the fine aggregated. Factors such as the proportion of clay minerals, soil plasticity, organic matter content, and initial moisture condition can all influence the cement hydration process and, consequently, the strength development. Moreover, differences in curing conditions, such as exposure to air, temperature fluctuations, or insufficient moisture, could also contribute to the irregular trends noted in the results.

3.5 Modeling of Compressive Strength of Umuezeawala Sample

Comparing the three samples, it is evident that Umuezeawala fine aggregate exhibited the highest overall strength, reaching 24.29 MPa at 28 days, while Ogboro-Isiala fine aggregate showed the lowest performance, declining to as low as 6.95 MPa at 7 days. Okohia fine aggregate, on the other hand, displayed intermediate values with a relatively stability. The outstanding performance of Umuezeawala fine aggregate necessitated the need for its modeling as shown in Figure 2 and Table 5.

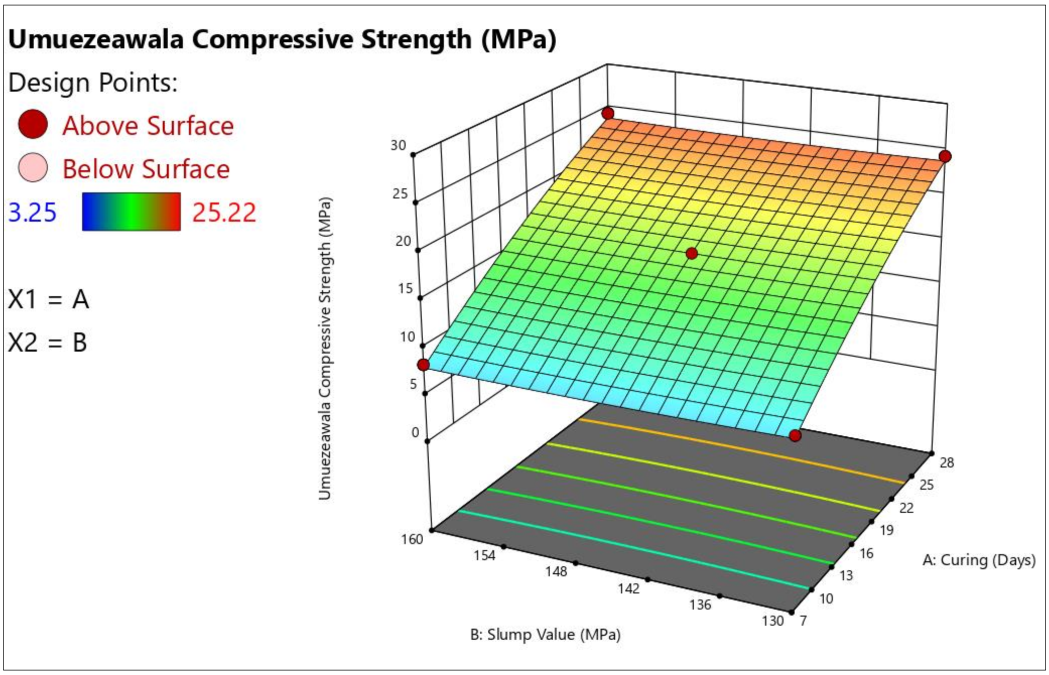

Figure 2: 3D Model of Umuezeawala Compressive Strength

Table 5: Umuezeawala Compressive Strength ANOVA model

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	504.43	5	100.89	480.82	< 0.0001	Significant
A-Curing	495.97	1	495.97	2363.76	< 0.0001	
B-Slump Value	0.0006	1	0.0006	0.0030	0.9580	
AB	0.0000	1	0.0000	0.0000	1.0000	
A^2	7.68	1	7.68	36.62	0.0005	
B^2	0.2618	1	0.2618	1.25	0.3008	
Residual	1.47	7	0.2098			
Lack of Fit	1.47	3	0.4896	24478.00	< 0.0001	Significant
Pure Error	0.0001	4	0.0000			
Cor Total	505.90	12				

Factor coding is Coded.
Sum of squares is Type III – Partial

The Model F-value of 480.82 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case A, A^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model. The Lack of Fit F-value of 24478.00 implies the Lack of Fit is significant. There is only a 0.01% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit is bad -- we want the model to fit.

The compressive strength equation of Umuezeawala fine aggregate is presented in equation (1). The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor.

$$Compressive\ Strength = 16.75 + 7.87A - 0.0088B + 0.00AB - 1.05A^2 + 0.1940B^2 \quad (1)$$

Where A is the curing time and B the Slump Value

By default, the high levels of the factors are coded as +1 and the low levels are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusions

This study investigated the characteristics and properties of fine aggregates obtained from the main sources of Fine Aggregate in Ihiala town which are Ogboro-Isiala, Okohia, and Umuezeawala with emphasis on natural moisture content, sieve analysis, Slump and compressive strength performance. The results revealed that fine aggregate characteristics vary significantly across the three locations and strongly influence their engineering behavior. Ogboro-Isiala fine aggregate, with high fines and plasticity, demonstrated slight weak performance characteristics and strength with curing age. Okohia sample, characterized as clayey sand, showed moderate stability and strength development. Umuezeawala sample, classified as silty fine aggregate with a balanced sand–silt profile, exhibited superior compressive strength, peaking at 13.22MPa and 24.29MPa at 14 and 28days of curing. In conclusion, Umuezeawala sample is the most suitable for engineering applications among the study areas, while Ogboro-Isiala is the least favorable.

4.2 Recommendations

Based on the results, the following recommendations are made:

Umuezeawala fine aggregate should be prioritized for engineering construction within the region due to its superior performance under concrete works. Okohia-type fine aggregate may be used for construction projects provided that the concrete mix ratio and production process are carried out professionally. Ogboro-Isiala-type fine aggregate should be avoided for critical construction works that requires high grade of concrete but can be used for minor engineering works that requires less strength of concrete unless subjected to advanced treatment.

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