PERFORMANCE ANALYSIS OF CONCRETE MADE WITH RIVER AND LOCAL SANDS FOR HIGHWAY CONSTRUCTION PROJECTS IN NIGERIA

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ABSTRACT

The type and quality of fine aggregates significantly affect the strength and durability of concrete. Although river sand has been the preferred choice due to its smooth texture and consistent grading, its dwindling availability and associated environmental issues have led to increased interest in using local sand as a substitute. This study compared concrete made with river sand from the River Niger and local sand from Akazi, Ihiala LGA, Anambra Sate, Nigeria, using a 1:2:4 mix with a 0.50 water–cement ratio. Cubes were cured for 7, 14, and 28 days and tested for compressive strength, while sieve and slump tests assessed grading and workability. Results showed both sands are well-graded and produce medium-workability concrete. River sand concrete consistently achieved higher strength (23.81 N/mm² at 28 days) than local sand (21.78 N/mm²), due to finer particle size and better packing. Local sand remains a viable, cost-effective alternative for non-structural applications. River sand is recommended for critical structural elements, while local sand is suitable for less demanding applications, with potential benefits from blending both.

Key words: Concrete, River Sand, Local Sand, Fine Aggregate, Curing, Compressive Strength

1.0 INTRODUCTION

Concrete is a fundamental construction material known for its strength, durability, and versatility (Bhattacharjee *et al*., 2018). It is composed of various ingredients, including cement, water, aggregates, and additives. Among these components, aggregates, particularly sand, play a crucial role in determining the properties of concrete. Sand acts as a filler material, providing volume and stability to the mixture. According to Adetunde *et al*. (2015), river sand has traditionally been the preferred choice as a fine aggregate in concrete production due to its desirable characteristics such as smooth texture, round shape, and well-graded particle size distribution. These qualities contribute to good workability, improved bonding with cement paste, and higher strength of the resulting concrete.

However, Begum *et al*. (2019) highlighted that the escalating demand for construction materials has led to the depletion of river sand resources. Additionally, river sand extraction often causes environmental issues, including riverbed erosion, habitat destruction, and ecological imbalances. Consequently, there is an increasing need to explore alternative sources of sand for sustainable construction practices. Studies have shown that local sand, including sand from inland areas, quarries, or crushed stone screenings, is gaining attention as a viable substitute for river sand (Nounu *et al*., 2017; Sanusi *et al*., 2026; Hamada *et al*., 2025). Local sand is often more readily available, cost-effective, and can mitigate environmental impacts associated with river sand mining. Recycled concrete aggregates and manufactured sands have also been explored as sustainable alternatives, showing promising mechanical and environmental performance (Saurabh Singh *et al*., 2024; Wang *et al*., 2025).

In Nigeria, concrete remains the predominant construction material, yet a significant number of structural failures are linked to the use of substandard concrete (Ayininuola and Olalusi, 2004; Ede, 2010; Ede, 2011). Deodhar (2009) emphasized that concrete strength primarily depends on the water-cement ratio, while workability is influenced by the aggregate-to-water ratio, and construction cost is impacted by the aggregate-cement ratio. The evolution of concrete spans from plain concrete through reinforced concrete, precast concrete, pre-stressed concrete, to contemporary high-performance concretes.

Recent research has explored the use of supplementary and alternative materials to improve concrete performance while promoting sustainability. Studies by Anene *et al*. (2025, 2026a, 2026b), Mmonwuba *et al*. (2025), Muñoz-Pérez *et al*. (2024), and Al-Naghi *et al*. (2025a, 2025b) investigated rice husk ash, cassava starch, fibers, fly ash, silica fume, and local sand in concrete production. These studies demonstrated enhancements in compressive strength, durability, and environmental performance. For instance, Mmonwuba *et al*. (2025), reported that incorporating rice husk ash and cassava starch in concrete produced from petroleum-contaminated sand significantly improved mechanical properties. Similarly, Al-Naghi *et al*. (2025a, 2025b) and Mohd Abu Bakr *et al.* (2025) showed that integrating industrial byproducts, agricultural waste, and nano-additives can further enhance the performance of recycled aggregate concrete.

Building upon earlier studies such as “Comparison of Strength of Concrete Produced from Different Sources of Fine Aggregate in Ihiala Town” and “Spatial Distribution and Characteristics of Soil Particles of Ihiala Localities, Anambra State, Nigeria,” this research critically examines the influence of locally sourced sand on the strength properties for field work, with the aim of establishing a clearer basis for selecting suitable fine aggregates in construction. The findings shows that variations in particle size distribution of fine aggregates significantly influence concrete strength (Ogunjiofor *et al*. 2026a; Ogunjiofor *et al*. 2026b)

Reducing reliance on river sand and promoting alternative fine aggregates contributes to natural resource conservation and ecosystem preservation (Akinyemi *et al*. 2020; Sanusi *et al*. 2026). Understanding the comparative strength and durability of concrete produced with river sand, local sand, and recycled aggregates is crucial for sustainable construction practices (Singh *et al.* 2024; Wang *et al*. 2025). Concrete strength is influenced not only by aggregate properties but also by the interfacial bond with cement paste (Shetty, 2006; Gao, 2013). High-performance and eco-friendly concretes employing alternative materials can maintain structural integrity while reducing environmental impact (Kim *et al.* 2018; Zhang *et al*. 2025; Al-Naghi *et al.* 2025a).

Concrete, a synthetic stone-like material, finds application across diverse construction endeavors and remains one of the most extensively used human-made materials, second only to water in global usage (Gambhir, 2005). The integration of sustainable fine aggregates, recycled materials, and supplementary binders represents a promising pathway for modern construction, balancing structural performance, cost-effectiveness, and environmental responsibility (Sanusi *et al*. 2026; Hamada *et al*. 2025; Saurabh Singh *et al*., 2024).

2.0 MATERIALS AND METHODS

Fine Aggregates

Sand used as fine aggregate was locally sourced and free from coarse materials. The sand was sieved through a 5.00 mm test sieve to remove larger particles and air-dried to achieve saturated surface dry (SSD) condition. Two types of sand were used:

- River sand, collected from the beddings of the River Niger sand beach located in Onitsha, Anambra State, Nigeria.
- Local sand, obtained from Uli, Ihiala Local Government Area, Anambra State, Nigeria. The bulk density and moisture content of the fine aggregate were determined using the following equations:

$$\text{Bukl Density} = \frac{\text{Mass of SSD Sand}}{\text{Volume of Container}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .. (1)$$

$$\text{Moisture Content} = \frac{\text{Mass of Wet Sand} - \text{Mass of Dry Sand}}{\text{Mass of Dry Sand}} \times 100\% \dots\dots\dots .. \dots .. (2)$$

Cement

Cement serves as the binding agent in concrete, providing strength and adhesion to other materials. BUA Cement Type, an Ordinary Portland Cement (OPC), was used. The cement was sourced from the Uli Timber and Building Material Market, Umuoma, Uli, Anambra State. The water–cement ratio (w/c), a critical factor affecting strength and workability, is given by:

$$W/_{o} \text{ ratio} = \frac{\text{Mass of Water(kg)}}{\text{Mass of Cement(kg)}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (3)$$

Water

The water used in the concrete mix was obtained from the Civil Engineering Concrete/Soil Laboratory, Chukwuemeka Odumegwu Ojukwu University, Uli Campus. It was potable and free from impurities, ensuring proper hydration of the cement.

Batching

Concrete batching involves measuring the constituent materials (cement, fine aggregate, coarse aggregate, and water) prior to mixing. Volume-based batching was adopted in this study due to the relatively small-scale nature of the concrete works. The mix proportions for a 1:2:4 mix (Cement:Fine aggregate:Coarse aggregate) were calculated as:

Cement: Sand: Coarse Aggregate = 1:2:4

The total mass of concrete can be expressed as:

$$M_{\text{concrete}} = M_{\text{cement}} + M_{\text{sand}} + M_{\text{coarse aggregate}} + M_{\text{water}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (4)$$

The percentage of each component in the mix is:

$$\text{Percentage of Component} = \frac{\text{Mass of Component}}{M_{\text{concrete}}} \times 100\% \dots\dots\dots\dots\dots\dots\dots\dots . (5)$$

This batching method ensures the proper proportioning of materials, although it is less suitable for large-scale concrete works where weight-based batching is preferred for accuracy

Concrete Placing and Compaction of Concrete

The processes of laying and compacting are interconnected and executed concurrently. This synchronization is crucial to ensure that the enforced concrete within the real structure attains the required levels of strength, durability, and impermeability.

Curing

The curing process commenced immediately after demoulding of the concrete specimens. The concrete cubes and cylinders were carefully removed from the moulds after 24 hours and subsequently immersed in a water curing tank containing clean potable water obtained from the Civil Engineering soil/concrete laboratory. Water curing was maintained for a period of 28 days to ensure adequate hydration of cement, which is essential for strength development and durability of concrete. The hydration reaction responsible for strength gain can be generally expressed as:

$$\mathrm{C_3S + H_2O \rightarrow C - S - H + C_a(OH)_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (6)$$

$\mathrm{C_3S}$ = Tricalcium silicate

C − S − H = Calcium silicate hydrate (strength − giving compound)

$\mathrm{C_a(OH)_2}$ = Calcium hydroxide

Concrete Compressive Strength Test.

The primary objective of this test is to determine the compressive strength of concrete cubes using a Universal Testing Machine (UTM). The apparatus used includes the UTM, standard concrete cube specimens, and a weighing balance. The compressive strength of concrete is calculated using the formula:

$$\mathrm{F_c} = \frac{\mathrm{P}}{\mathrm{A}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (7)$$

Where, F_c = Compressive strength of concrete ($\mathrm{N/mm^2}$)

P = Maximum load applied at failure (N)

A = Cross − sectional area of the specimen ($\mathrm{mm^2}$)

3.0 RESULTS AND ANALYSIS

The laboratory test results obtained in this study are systematically presented in Tables 2 to 5 and illustrated in Figures 1-6. Figure 6 indicates the progression of average compressive strength of concrete with curing age for two types of fine aggregates: river sand and local sand. Table 1 is showing proportion of mix design. These tables and figures were critically discussed below

Table 1: Mass of Aggregates Mix/Water Content

Mass	**Volume (kg)**
Mass of cement	7kg
Mass of fine aggregate	14kg
Mass of coarse aggregate	28kg
Water content	3480 (ml)

The 1:2:4 mix (7 kg cement: 14 kg fine aggregate: 28 kg coarse aggregate) with 3.48 L water achieves a water-cement ratio of 0.50, providing good workability and moderate strength. The proportions ensure effective binding, adequate void filling, and sufficient load-bearing capacity, making it suitable for general structural concrete applications.

Table 2: Sieve Analysis

Sieve Size (mm)	**% Passing Local Sand**	**% Passing River Sand**
4.75	100	100
2.36	95	97
1.18	80	85
0.6	65	70
0.3	40	50
0.15	20	25

Both Local sand and River sand are well-graded fine aggregates, with 100% passing the 4.75 mm sieve. River sand is slightly finer than local sand, especially in smaller fractions (0.3-0.15 mm), which may improve workability, while local sand's coarser particles could enhance strength. Both are suitable for concrete, with minor differences in texture and water demand

Table 3: Slump Test Results

Fine aggregate	**Height of cone (mm)**	**Height of collapse (mm)**	**Slump value (mm)**
Local sand	300	250	70
River sand	300	225	75

Both local sand (70 mm) and river sand (75 mm) produced medium workability concrete, suitable for general construction. Although river sand shows a slightly higher slump, the difference is minimal (5 mm) and has little practical impact. Importantly, local sand remains adequately workable while offering significant cost advantages due to its availability and lower transportation requirements. It also reduces risks of segregation due to its slightly lower slump. Local sand provides a cost-effective and sufficiently workable alternative to river sand, making it suitable for most construction applications.

3.1 Compressive Strength Test

Compressive strength is employed to assess the potency of a provided concrete cube. This measurement is obtained by subjecting the concrete to crushing within a Universal Testing Machine (UTM). A typical observation indicates that the compressive strength augments as the curing period extends. The evaluation is conducted at intervals of 7, 14, and 28 days. Specifically, two cubes using local sand as fine aggregate and two cubes using river sand as fine aggregate are crushed at each of these time points following curing. The compressive test values are shown below.

Table 3: A 7 Days Compressive Strength Results.

Fine Aggregate	**Age in days**	**Weight of Concrete (kg)**	**Crushing load (kn)**	**Compressive Strength (n/mm^2)**	**Average compressive strength (n/mm^2)**
RIVER SAND	7 DAYS	8.30 8.10	339.27 336.85	14.2 14.0	14.10
LOCAL SAND	7 DAYS	8.12 8.12	336.73 333.50	13.8 13.5	13.65

The 7-day compressive strength results show that concrete made with river sand achieved a slightly higher average strength (14.20-14.00 N/mm²) compared to local sand (13.50-13.80 N/mm²). This indicates a marginal advantage of river sand in early strength development, likely due to its finer and more uniform particle distribution, which enhances packing density and reduces voids. The consistency of the test results suggests proper casting and compaction for both mixes. Despite the slight strength difference, local sand still demonstrates adequate performance for many construction applications.

In practice, river sand is preferable where higher early strength is required, while local sand remains a cost-effective and viable alternative, especially in areas with limited access to river sand.

Table 4: A 14 Days Compressive Strength Results.

FINE AGGREGATE	AGE IN DAYS	WEIGHT OF CONCRETE (KG)	CRUSHING LOAD (KN)	COMPRESSIVE STRENGTH (N/mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)
RIVER SAND	14 DAYS	8.13 8.10	415.50 405.75	21.50 20.90	21.20
LOCAL SAND	14 DAYS	8.25 8.14	401.8 403.33	19.70 19.85	19.78

The results of the 14-day compressive strength test reveal that concrete made with river sand consistently exhibited higher strength values than that produced with local sand. River sand concrete recorded strengths ranging from 20.50N/mm² to 21.50N/mm² while local sand concrete ranged between 19.70N/mm² to 19.85 N/mm², showing River sand concrete has approximately **6.2% higher compressive strength** than local sand concrete.

This improved performance is attributed to the better grading, cleaner texture, and lower impurities in river sand, which enhance bonding and overall concrete density. Despite this, local sand still demonstrates satisfactory strength and remains suitable for many applications.

In practical terms, river sand is more appropriate for structural works requiring higher strength and durability, although it is often more expensive due to processing and transportation. Conversely, local sand provides a more economical and readily available alternative, making it suitable for non-structural or lightly loaded applications. Ultimately, the choice depends on the required strength performance and cost considerations.

Table 5: A 28 Days Compressive Strength Result

FINE AGGREGATE	AGE IN DAYS	WEIGHT OF CONCRETE (KG)	CRUSHING LOAD (KN)	COMPRESSIVE STRENGTH (N/mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)
RIVER SAND	28 DAYS	8.26 8.24	534.10 537.31	23.73 23.88	23.81

LOCAL SAND	28 DAYS	8.17 8.21	529.73 526.13	21.67 21.89	21.78

After the 28-day curing period, the compressive strength results provided clear insight into the performance and durability of the concrete mixes. Concrete produced with river sand attained an average compressive strength of 23.81 N/mm², which is approximately 14-15% higher than that of local sand concrete, recorded at 21.78 N/mm².

This superior performance of river sand concrete can be attributed to its better quality, higher crushing load capacity, and improved aggregate characteristics, which enhance bonding and overall strength development. The consistency observed in the test results for both mixes indicates that the variation in strength is primarily due to the properties of the fine aggregates rather than differences in specimen preparation.

While river sand demonstrates clear advantages for structural applications requiring higher strength and durability, the performance of local sand remains commendable. Its 28-day strength falls within acceptable limits for many construction purposes, making it a practical and more economical alternative, particularly in areas where river sand is scarce or environmentally restricted.

Generally, the results highlight the importance of fine aggregate selection in achieving desired long-term strength and durability. Although river sand offers superior performance, local sand remains a viable option where slightly lower strength is acceptable, with potential for further optimization in concrete mix design.

4.0 CONCLUSION

1. Workability and Mix Design: The 1:2:4 concrete mix with a water–cement ratio of 0.50 produced good workability and moderate strength. Both river sand and local sand yielded medium-slump concrete (70-75 mm), suitable for general construction applications. River sand showed slightly higher slump, indicating marginally better flow, while local sand remains adequately workable.
2. Aggregate Characteristics: Sieve analysis confirmed that both river and local sands are well-graded, with 100% passing the 4.75 mm sieve. River sand is finer in the smaller fractions (0.15-0.3 mm), which contributes to better packing, reduced voids, and slightly improved workability. Local sand, being coarser, may enhance early-age strength and reduces the risk of segregation.
3. Compressive Strength Development: At the age of 7 Days, River sand concrete averaged 14.10 N/mm², slightly higher than local sand at 13.65 N/mm². At 14 days of age, River sand concrete reached 21.20 N/mm², about 7 to 8% higher than local sand at 19.78 N/mm². At the age of 28 days, River sand concrete achieved 23.81 N/mm², approximately 14 to 15% higher than local sand at 21.78 N/mm². The superior strength of river sand concrete is primarily due to its finer and more uniform particle size, which improves packing, reduces voids, and enhances bonding. Both concrete types displayed consistent test results, confirming reliable casting and compaction.
4. Cost-Effectiveness: Local sand offers significant economic advantages due to its availability and lower transportation costs, making it suitable for projects with budget constraints or non-critical structural applications. River sand, although slightly more expensive, provides higher strength and durability, making it preferable for structural elements requiring greater load-bearing capacity.

5.0 RECOMMENDATIONS

Material Selection: River sand should be used for critical structural elements, where higher strength and durability are required to ensure safety and long-term performance. In contrast, local sand is suitable for non-structural elements or low-load applications, particularly in projects where cost-effectiveness is a key consideration, as it is more readily available and less expensive than river sand.

Concrete Production: Proper mixing and compaction should be maintained during concrete production to achieve consistent strength, regardless of whether river or local sand is used. The 1:2:4 mix with a water–cement ratio of 0.50 is recommended for general-purpose concrete, providing good workability and adequate strength for most construction applications.

Further Considerations:

Blending local and river sand in appropriate ratios can be considered to achieve an optimal balance between cost and strength. Additionally, slump and workability should be carefully monitored during mixing to prevent segregation, particularly when using river sand, which ha finer particles and higher flowability.

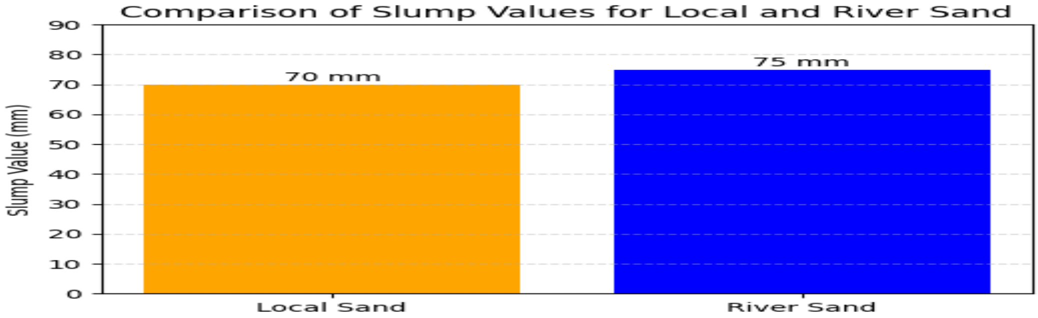


Figure 1: Slump test for River and Local Sand

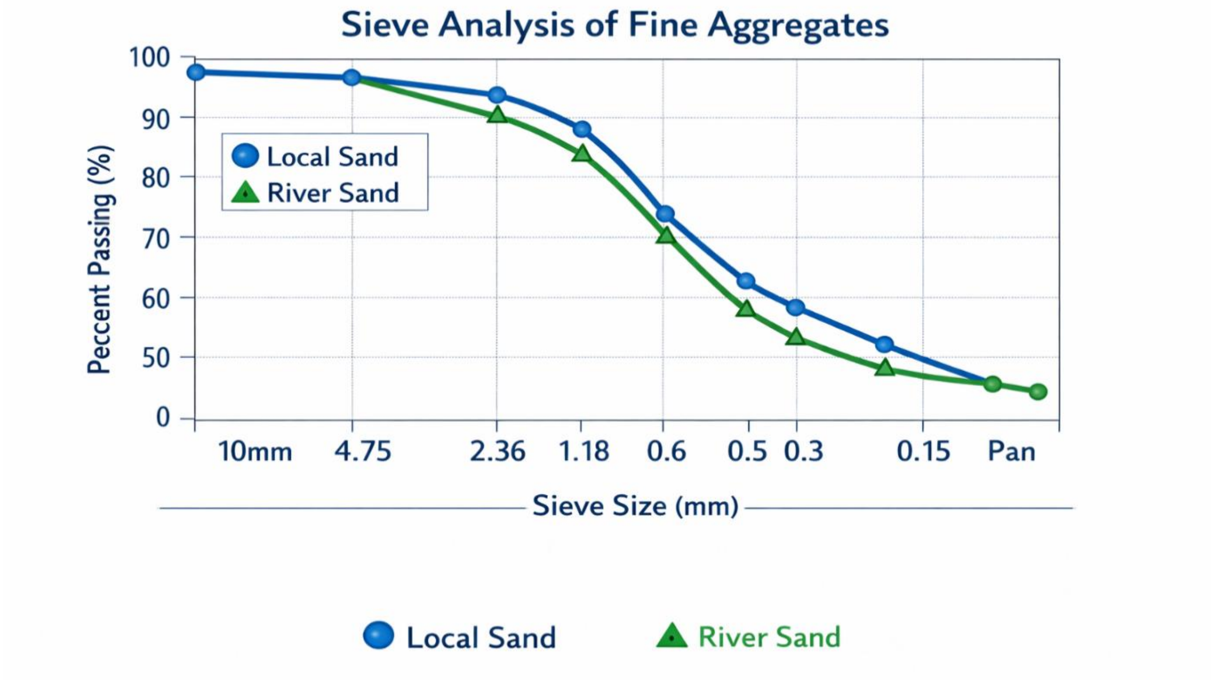


Figure 2: Sieve Analysis of Fine Aggregates

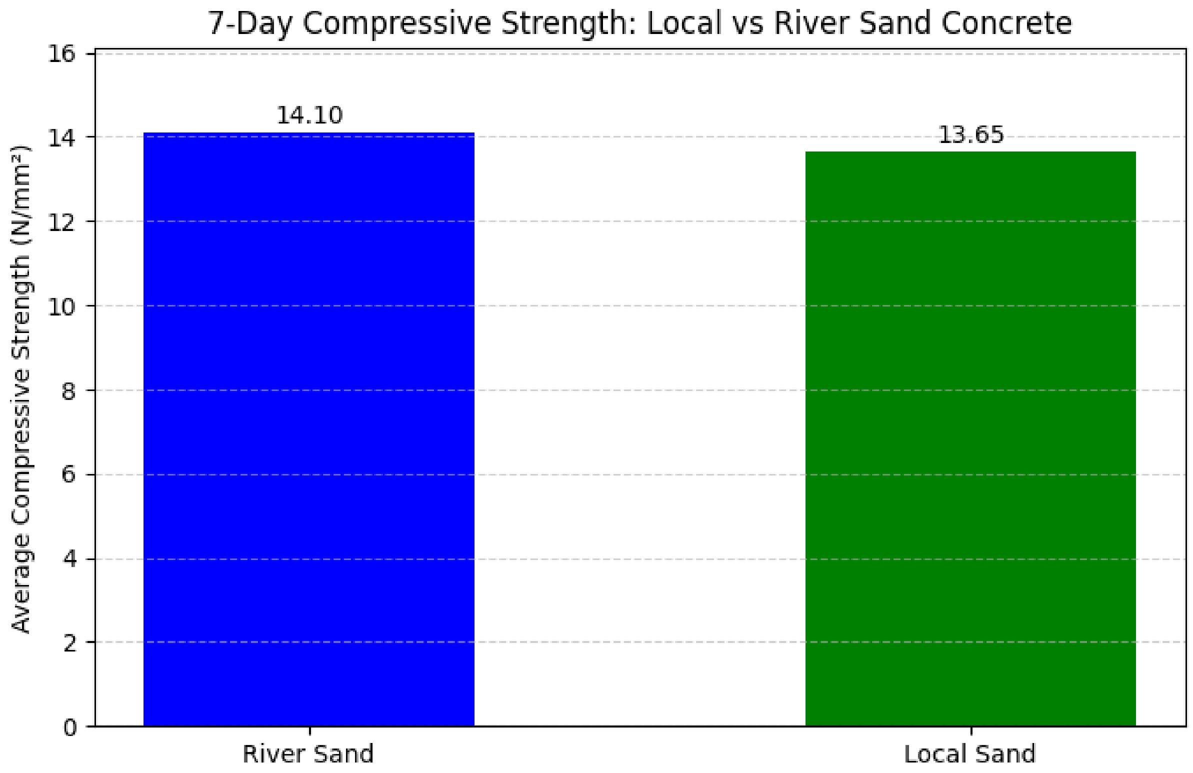


Figure 3: A-7 Day Compressive Strength of Local and River Sands Concrete

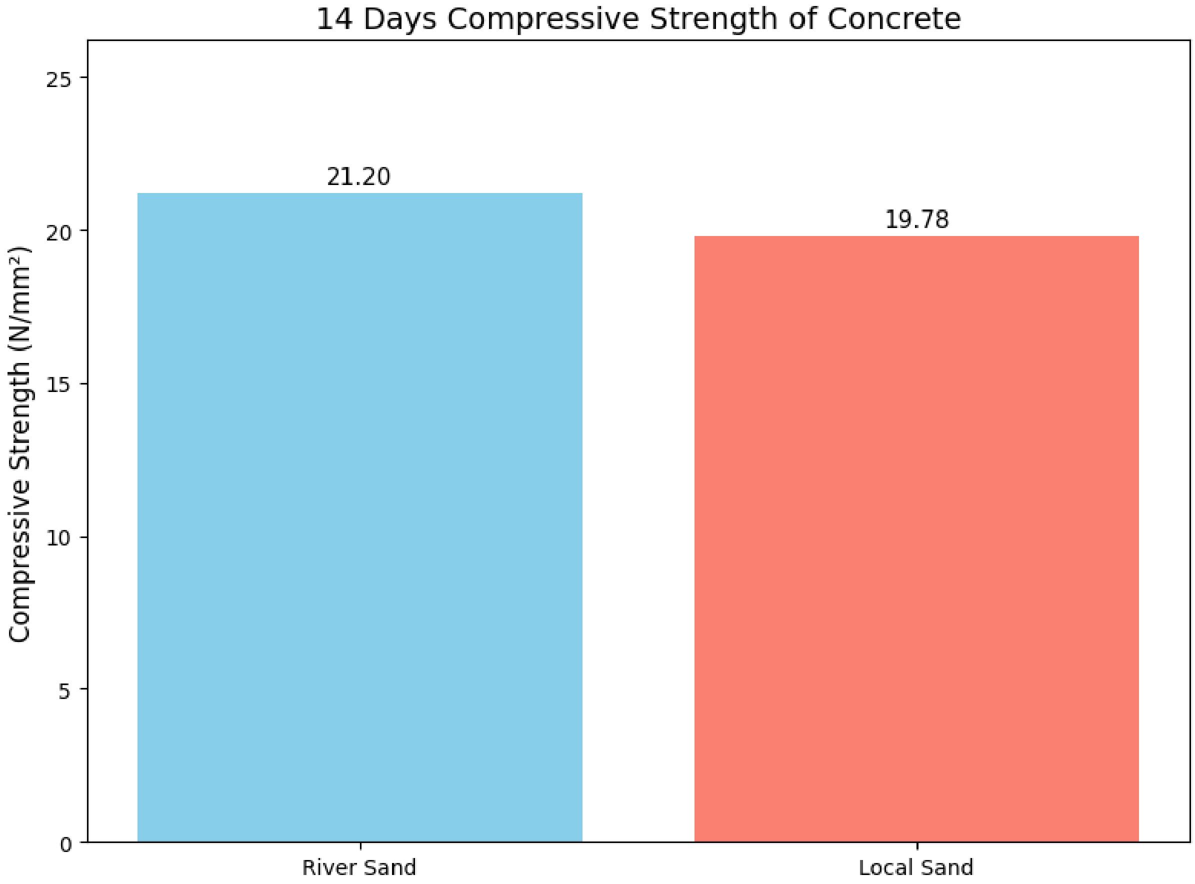


Figure 4: A-14 Day Compressive Strength of Local and River Sands Concrete

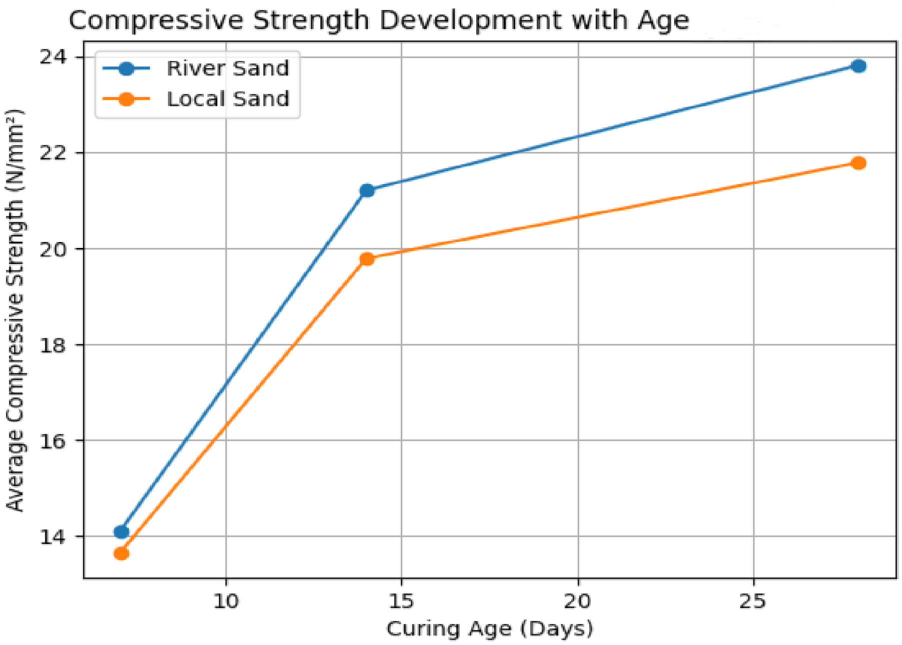
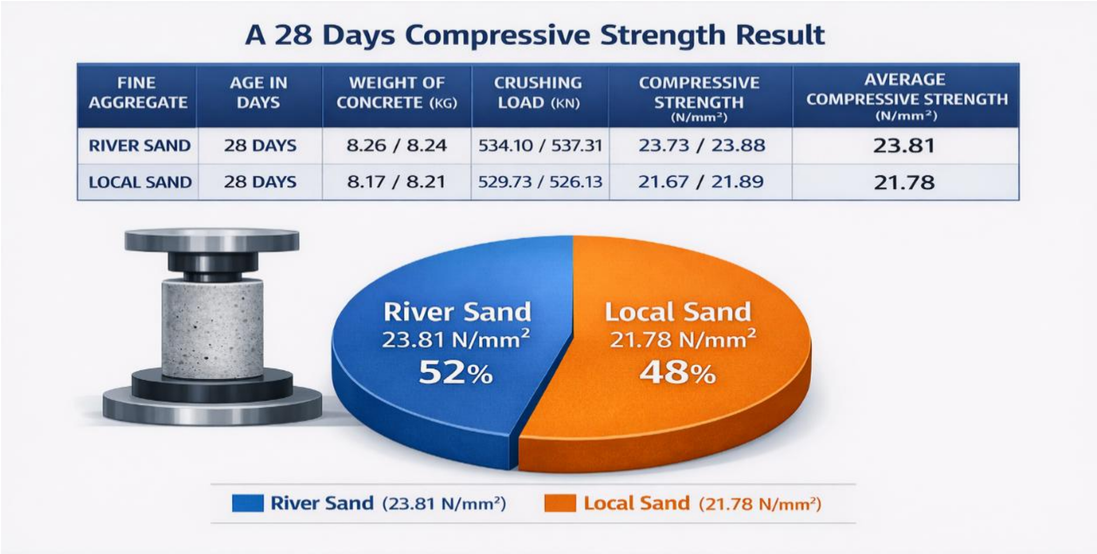


Figure 5: A-28 Day Compressive Strength of Local and River Sands Concrete


A 28 Days Compressive Strength Result

FINE AGGREGATE	AGE IN DAYS	WEIGHT OF CONCRETE (KG)	CRUSHING LOAD (KN)	COMPRESSIVE STRENGTH (N/mm²)	AVERAGE COMPRESSIVE STRENGTH (N/mm²)
RIVER SAND	28 DAYS	8.26 / 8.24	534.10 / 537.31	23.73 / 23.88	23.81
LOCAL SAND	28 DAYS	8.17 / 8.21	529.73 / 526.13	21.67 / 21.89	21.78

Figure 6: Graph Representation of Compressive Strength of concrete Development with Age 7, 14 and 28

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