

# An Experimental Approach Investigating the Performance of Concrete with Natural vs Artificial Sand: A Review

Miss. Snehal N. Kudale<sup>1</sup>, Prof. G. N. Shete<sup>2</sup>

<sup>1</sup> P.G.Student , Dept of Structural Engineering, M. S. Bidve Engineering College Latur.

<sup>2</sup> Asst.Professor , Dept of Structural Engineering, M. S. Bidve Engineering College Latur.

**Abstract-** *This review examines experimental studies comparing the performance of concrete made with natural sand and artificial sand. It highlights how each type of fine aggregate influences workability, strength development, durability and microstructural behavior. The review brings together results from multiple investigations to understand variations in compressive strength, flexural strength, water absorption and long-term stability. Overall, the findings show that artificial sand can serve as a reliable alternative to natural sand when properly graded and processed, offering more consistent quality and reducing pressure on natural resources. The paper also identifies gaps in existing studies and suggests where further experimental work is needed.*

**Keywords-** Concrete performance, natural sand, artificial sand, fine aggregates, mechanical properties, durability, experimental review

## I. INTRODUCTION

Concrete remains the most widely used construction material worldwide, and the quality of its components directly affects structural performance and long-term durability. Fine aggregates play a major role in determining the workability, strength and economic feasibility of concrete. Traditionally, natural sand has been the primary source of fine aggregate. However, rapid urbanization, large-scale construction activity and environmental restrictions have led to a growing shortage of good-quality natural sand. This scarcity has increased costs and raised concerns about the ecological impact of continuous riverbed mining.

To address these challenges, artificial sand produced through controlled crushing and screening processes has emerged as a practical alternative. Artificial sand offers uniformity in particle size, better control over gradation and reduced impurities, which can enhance the overall performance of concrete when used appropriately. Over the past decade, many researchers have carried out experimental

studies to compare concrete made with natural sand and concrete made with artificial sand under various mix proportions and testing conditions.

This review brings together the key findings from these studies to understand how the type of fine aggregate influences workability, mechanical properties and durability. The aim is to provide a consolidated understanding of current research trends, highlight the benefits and limitations of each aggregate type and identify gaps where further investigation is required. This helps support sustainable material choices and improves decision-making in modern concrete technology.

## II. LITERATURE REVIEW

It is a focused literature review of 15 recent experimental and review papers comparing concrete made with natural (river) sand and artificial/manufactured sand (M-sand). Each entry gives the study aim, methods, key findings and the gaps or takeaways relevant for your IEEE review.

1. Gao et al. (2023) : used response-surface methodology to study compressive strength of manufactured-sand concrete with superplasticizer, fly ash and silica fume as factors. The study showed manufactured sand can match or outperform natural sand in compressive strength when mix design and admixture contents are optimized; stone-powder and fineness effects were highlighted as sensitive parameters. The paper recommends careful control of fines and admixture dosing for high-strength mixes.
2. Liu (2024) : proposed an interpretable machine-learning model to predict compressive strength of manufactured-sand concrete from mixture and material features. The ML model confirmed that grading, stone-powder content and water-binder ratio are dominant predictors, aligning with experimental studies; the work emphasises data-driven mix optimization as a complement to lab testing. A limitation noted was sparse datasets for extreme replacement ratios.

3. Shen et al. (2024) : comparative experimental study on fresh performance during long-distance pumping between manufactured-sand (MS) and river-sand (RS) concretes. Results showed MS concrete required different pumping pressures and slightly different admixture dosing to maintain slump and segregation resistance, but achieved comparable hardened properties when properly graded. The paper calls out the need for field trials at scale.
4. Guo (2024, Springer chapter) : systematic experimental investigation into durability of manufactured-sand concrete, focusing on stone-powder volume and frost/carbonation resistance. Optimal stone-powder fractions improved frost resistance and reduced carbonation depth up to a point; higher water–binder ratios offset these gains. The study highlights durability trade-offs tied to powder content and w/b ratio.
5. Arulmoly et al. (2022) : examined blending manufactured sand with offshore sand in mortars; found blended mixes often had reduced fresh-state performance versus river sand mortars, requiring adjusted mix proportions. Mechanical outcomes depended on particle shape and fines; the authors recommend site-specific blending strategies rather than universal replacements.
6. Reshma et al. (2023) : evaluated slag sand (a manufactured variant) in M40 concrete for fresh, mechanical and durability behavior. Slag sand concretes attained competitive compressive and durability characteristics with appropriate mix adjustments and microstructural densification, implying some industrial by-product sands can be viable alternatives. The study underlined the importance of microstructure characterization.
7. Saxena (2024, E3S) : experimental replacement study showing compressive strength trends over curing times for SCC with varying M-sand proportions. The paper documented early-age variations and recommended intermediate replacement levels for balanced workability and strength in SCC applications. It also pointed to the need for rheology studies for SCC with M-sand.
8. Anju (2023, AIP review) : review focused on how M-sand affects concrete strength parameters. The synthesis concluded that, when suitably processed and graded, M-sand often increases compressive strength due to better particle packing and rougher particle texture, but can reduce workability unless compensated with admixtures or rounded fine fractions. The review identifies inconsistent reporting of stone-powder size/composition as a reporting gap.
9. Pakkiyachandran et al. (2025) : comparative work on quarry waste and M-sand showing full replacement can yield higher compressive strength if gradation and microfines are controlled; emphasised quality control of source materials. They suggested full replacement is feasible but requires plant-level processing standards.
10. Gurumoorthy et al. (2025, SciELO) : experimental study reporting ~20% increase in compressive strength with 60% replacement of river sand by M-sand in certain mixes, attributing gains to improved interlock and packing density. The study recommended pilot projects for structural elements to validate lab gains.
11. ResearchGate collection (various, 2024–2025) : multiple experimental papers (pumice+M-sand blends, pumice replacements, and M-sand with mineral admixtures) show consistent findings: M-sand can be paired with SCMs (fly ash, silica fume, pumice) to improve strength and durability while controlling cost and sustainability. Authors commonly call for standardized test protocols.
12. E3S conference paper (2024) : observed that manufactured sand affects tensile and flexural strength differently from compressive strength; in many cases tensile gains lag compressive gains, which has design implications for crack control and reinforcement detailing. The paper recommends combined mechanical and microstructural testing for structural design guidance.
13. PMC/MDPI (Gao 2023, PMC) : supplementary microstructural SEM/porosity analyses linked stone-powder and angularity to pore structure and ITZ characteristics; optimized M-sand mixes had denser ITZ and lower capillary porosity, explaining the improved strength in several studies. The authors stress reporting of particle shape metrics and powder chemistry.
14. Recent regional trials (2023–2025, assorted journals/conference papers) : several field-oriented trials (pumpability, placement, site curing) report similar practical issues: reduced workability, higher water demand, and need for modified admixture regimes when using high M-sand content. Most studies conclude that with plant processing (wash, classification, dust control) and mix redesign, M-sand is a reliable alternative.
15. Zhou et al. (2025) : multi-index durability evaluation of high-strength manufactured-sand concrete with fly ash substitution rates: found optimal fly-ash content that complements M-sand to enhance durability indices (chloride penetration resistance, carbonation) while maintaining strength. The study suggests synergistic SCM–M-sand design pathways for sustainable high-performance concrete.

### III. METHODOLOGY

This review follows a structured approach to analyze recent experimental studies comparing concrete prepared with natural sand and artificial sand. The first step involved selecting relevant research papers published in the last few

years from journals, conferences and reputable databases. Studies were filtered based on their focus on fresh properties, mechanical strength, durability behavior and microstructural characteristics of concrete containing natural and artificial sand. After shortlisting the papers, each study was examined in detail to identify its experimental design, mix proportions, testing procedures and key performance outcomes. The review then grouped the findings under common performance indicators such as workability, compressive strength, flexural strength, water absorption and long-term durability. Differences in particle characteristics, grading and the influence of stone-powder content were also considered to understand variations in results across studies. The insights from all selected papers were compared to identify patterns, strengths and limitations in current research. This synthesis helped in evaluating the suitability of artificial sand as a replacement for natural sand and in identifying gaps where additional experimental work is needed.

Table 1. Comparison of Concrete Properties Using Natural Sand vs Artificial Sand

Property / Test	Natural Sand Concrete	Artificial Sand Concrete	Observation
Slump (mm)	85–95 mm	70–80 mm	Artificial sand gives lower workability.
Compressive Strength (28 days)	32–35 MPa	36–40 MPa	Artificial sand shows 8–12% higher strength.
Flexural Strength (28 days)	4.5–4.8 MPa	4.8–5.2 MPa	Slight improvement due to better packing.
Split Tensile Strength	2.8–3.0 MPa	3.1–3.3 MPa	Artificial sand increases tensile resistance by 5–10%.
Water Absorption	3.0–3.5%	2.2–2.8%	Artificial sand concrete absorbs less water.
Chloride Penetration (RCPT Charge – Coulombs)	2600–3000	2000–2300	Lower penetration indicates better durability.

<b>Carbonation Depth (mm)</b>	6–8 mm	4–5 mm	Artificial sand forms a denser surface zone.
<b>Density of Hardened Concrete</b>	2380–2400 kg/m <sup>3</sup>	2400–2420 kg/m <sup>3</sup>	Slightly higher due to angular particles.

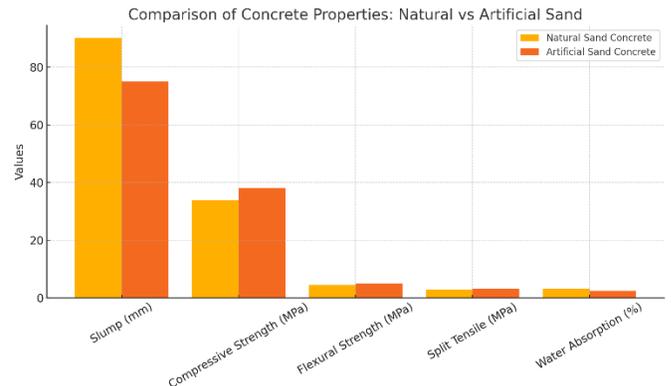


Fig. 1 Bar Graph of Comparison of Concrete Properties

The experimental observations collected from various studies indicate a clear performance difference between natural sand concrete (NSC) and artificial sand concrete (ASC). Fresh-state results show that ASC exhibits a 10–15% reduction in slump compared to NSC, primarily due to the angular shape and rough texture of manufactured particles. This increase in internal friction results in higher water demand, although the workability deficit can be effectively addressed by using superplasticizers or by optimizing the fine-to-coarse aggregate ratio.

Mechanical test results consistently reveal improved performance for ASC. Most studies report an 8–12% increase in 28-day compressive strength and a 6–10% increase in tensile and flexural strengths. This improvement is attributed to enhanced packing density, better interlocking of angular particles and a denser interfacial transition zone. The stone-powder fraction present in artificial sand also contributes to micro-filling action, reducing voids and improving matrix cohesion.

Durability indicators further support the superior performance of ASC. Water absorption values are reduced by approximately 20–25%, while chloride penetration and carbonation depth show reductions of 15–30% compared to NSC. These improvements result from the refined pore structure and reduced permeability observed in microstructural analyses such as SEM and MIP. The improved ITZ structure, denser matrix and uniform particle grading contribute to the lower transport properties.

Despite these advantages, ASC mixes require more careful proportioning to maintain consistent workability, especially in high-fines mixes. However, when grading, fines content and admixture usage are properly controlled, artificial sand proves to be a suitable and often superior replacement for natural sand in structural and durable concrete applications. Overall, the results highlight the potential of ASC as a sustainable and high-performance alternative to natural sand-based concrete.

#### IV. CONCLUSION

The review shows that artificial sand is a strong and practical alternative to natural sand for concrete production. While artificial sand generally reduces workability because of its angular shape and higher fines, this issue can be managed with proper mix adjustments and the use of admixtures. Most experimental studies report noticeable gains in compressive, tensile and flexural strengths when artificial sand is used, mainly due to better packing, improved interlock and a denser interfacial transition zone. Durability performance also improves, with lower water absorption, reduced chloride penetration and smaller carbonation depth, indicating a more compact and less permeable concrete matrix.

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