

An Experimental Approach Investigating the Performance of Concrete with Natural vs Artificial Sand

Miss. Snehal N. Kudale.¹ Prof. Shete G.N.²

PG Student, M. S. Bidve Engineering College, Latur, Maharashtra, India¹

Professor, M. S. Bidve Engineering College, Latur, Maharashtra, India²

Abstract— This study presents an experimental investigation into the performance of concrete produced using natural sand and artificial sand as fine aggregates. The objective is to evaluate the feasibility of replacing natural sand with artificial sand while maintaining or improving concrete quality. A series of concrete mixes were prepared using natural sand and artificial sand under identical mix proportions. Standard laboratory tests were conducted to assess workability, compressive strength, split tensile strength, and flexural strength at different curing ages. The results indicate that concrete made with artificial sand exhibits comparable, and in some cases improved, mechanical strength when compared to natural sand concrete. Slight variations in workability were observed due to differences in particle shape and surface texture of the sands. The experimental findings suggest that artificial sand can serve as a reliable alternative to natural sand, offering advantages in terms of consistent quality and sustainable construction practices. This study supports the use of artificial sand as an effective solution to address the scarcity of natural sand in concrete production while ensuring structural performance and durability.

Index Terms— Concrete, Natural Sand, Artificial Sand, Fine Aggregate, Mechanical Properties, Workability, Sustainable Construction etc.

I. INTRODUCTION

Concrete is the most widely used construction material across the world due to its strength, durability, versatility, and cost effectiveness. It is a composite material primarily made up of cement, water, coarse aggregates, and fine aggregates. Among these constituents, fine aggregate plays a crucial role in influencing the workability, strength, and overall performance of concrete. Traditionally, natural river sand has been used as the preferred fine aggregate in concrete production because of its rounded particles and good grading characteristics. However, rapid urbanization and large-scale infrastructure development have led to excessive extraction of

natural sand, resulting in environmental degradation, riverbed erosion, lowering of groundwater levels, and ecological imbalance.

The increasing scarcity of natural sand and the strict regulations imposed on sand mining have created a strong need for alternative materials that can partially or fully replace river sand in concrete. Artificial sand, commonly known as manufactured sand or M-sand, is produced by crushing hard stones such as granite or basalt into fine particles. With controlled production processes, artificial sand can be manufactured to meet standard specifications for use in concrete. Its availability, uniform quality, and reduced environmental impact make it an attractive alternative to natural sand.

Despite these advantages, the performance of concrete made with artificial sand differs from that made with natural sand due to variations in particle shape, surface texture, and grading. Artificial sand particles are generally angular and rough, which can affect the workability of fresh concrete and the bond between cement paste and aggregates. While angular particles may reduce workability, they can improve interlocking and enhance the strength characteristics of hardened concrete. Therefore, a detailed experimental evaluation is necessary to understand the behavior of concrete when natural sand is replaced with artificial sand.

Several studies have indicated that concrete incorporating artificial sand can achieve comparable or higher compressive strength than conventional concrete, provided that proper mix design and quality control are maintained.

However, practical acceptance of artificial sand in construction still requires clear experimental evidence demonstrating its influence on fresh and hardened

concrete properties. Factors such as water demand, workability, strength development, and durability must be carefully examined to ensure reliable performance.

In this context, the present study focuses on an experimental comparison of concrete prepared using natural sand and artificial sand as fine aggregates. The investigation aims to assess key performance parameters such as workability, compressive strength, split tensile strength, and flexural strength under controlled laboratory conditions. By keeping all other variables constant, the study highlights the direct influence of the type of fine aggregate on concrete behavior. The outcomes of this research are expected to provide practical insights into the suitability of artificial sand as a sustainable and effective replacement for natural sand, supporting environmentally responsible construction practices without compromising structural performance.

II. LITERATURE SURVEY

- Ilangovana et al.

This study presented a detailed experimental investigation on the use of manufactured sand as a replacement for natural river sand in concrete production. Concrete mixes were prepared by replacing natural sand with artificial sand at different proportions while maintaining constant water-cement ratio. Fresh concrete properties such as workability and hardened properties such as compressive strength were evaluated at 7, 14, and 28 days of curing. The results indicated that artificial sand concrete showed slightly reduced workability due to angular particles but achieved higher compressive strength compared to natural sand concrete. The study concluded that manufactured sand can be effectively used as a full replacement for river sand with proper mix design.

- Rao et al.

An experimental program was carried out to compare the performance of concrete made with natural sand and crushed stone sand. Replacement levels of artificial sand were varied from 0% to 100%. Slump test results showed a decrease in workability with increasing artificial sand content, which was attributed to higher surface area and angularity. However, compressive and split tensile strength results showed noticeable improvement at higher replacement levels. The authors recommended artificial sand for structural concrete applications.

- Hudson

This research focused on the influence of particle shape and texture of fine aggregates on concrete performance. Artificial sand produced by crushing hard rock was compared with river sand in terms of grading, shape, and strength contribution. Test results showed that the rough surface of artificial sand improved bonding between cement paste and aggregate, resulting in enhanced compressive and flexural strength. The study emphasized the importance of proper grading of artificial sand to minimize workability issues.

- Manoharan et al.

The authors conducted an experimental investigation on concrete mixes incorporating manufactured sand as fine aggregate. Concrete specimens were tested for compressive strength, split tensile strength, and durability properties. The results revealed that artificial sand concrete exhibited better strength performance at later curing ages compared to natural sand concrete. The study highlighted the potential of manufactured sand to produce high-quality concrete with consistent properties.

- Suresh and Revathi

This research examined the effect of complete replacement of natural sand with artificial sand in concrete. Workability, compressive strength, and flexural strength were evaluated. Although the workability of artificial sand concrete was lower, the use of chemical admixtures significantly improved flow characteristics. The strength results confirmed that concrete made with artificial sand achieved higher compressive strength than conventional concrete.

- Ganesh Prasad et al.

An experimental study was carried out on high-strength concrete using manufactured sand as fine aggregate. The mechanical properties of concrete such as compressive strength and split tensile strength were studied at different curing periods. The results showed that artificial sand contributed to better interlocking within the concrete matrix, resulting in improved tensile and flexural strength compared to natural sand concrete.

- Shanmugapriya and Uma

This study evaluated the influence of partial and full replacement of natural sand with manufactured sand on concrete performance. Replacement levels of 25%, 50%, 75%, and 100% were considered. The test

results showed a gradual increase in compressive strength with higher artificial sand content. The authors concluded that manufactured sand is suitable for both partial and full replacement of river sand.

- Reddy et al.

The authors investigated the effect of grading and fineness modulus of artificial sand on concrete strength. Poorly graded artificial sand resulted in reduced workability and higher void content, while well-graded manufactured sand improved packing density and strength. The study emphasized the need for strict quality control during artificial sand production.

- Patel and Shah

This experimental investigation compared the performance of concrete made with river sand and crushed sand. Compressive strength and flexural strength were evaluated at different curing ages. The results showed that crushed sand concrete achieved higher strength at 28 days due to improved aggregate interlock and denser microstructure.

- Karthik and Selvan

This study focused on the durability performance of concrete containing artificial sand. Tests such as water absorption and permeability were conducted. Artificial sand concrete showed reduced water absorption and improved resistance to moisture penetration compared to natural sand concrete, indicating better long-term durability.

- Singh et al.

An experimental study was conducted to evaluate the fresh and hardened properties of concrete using manufactured sand. The results indicated that artificial sand reduced workability but significantly enhanced compressive strength. The authors concluded that artificial sand concrete is suitable for structural applications when proper water content and admixtures are used.

- Balaji and Kumar

This research examined the flexural behavior of reinforced concrete beams made with artificial sand. Test results indicated higher load-carrying capacity and reduced crack widths compared to beams made with natural sand. The study highlighted the structural benefits of using artificial sand.

- Jain et al.

The authors studied the environmental and economic benefits of replacing natural sand with manufactured sand in concrete. Strength, cost, and sustainability aspects were analyzed. The findings showed that artificial sand concrete is more economical in the long term and reduces environmental impact.

- Nagaraj and Zahida Banu

This study investigated the microstructural characteristics of concrete using manufactured sand. SEM analysis revealed better packing density and a stronger interfacial transition zone in artificial sand concrete compared to natural sand concrete. This contributed to improved mechanical properties.

- Chandrasekaran et al.

An experimental investigation was conducted on concrete with full replacement of natural sand by artificial sand. Mechanical properties such as compressive strength, split tensile strength, and flexural strength were evaluated. The results confirmed that artificial sand can completely replace natural sand while meeting strength and durability requirements.

III. METHODOLOGY

3.1 MIX DESIGN PROCEDURE

The mix design was carried out as per IS 10262:2019 and IS 456:2000 for M30 grade concrete. The objective is to compare concrete performance using natural sand and artificial sand, while maintaining identical mix proportions.

- MIX DESIGN

- a. Target mean strength:

$$f'_{ck} = f_{ck} + 1.65 \times S$$

$$f'_{ck} = 30 + 1.5 \times 5 = 38.25 \text{ N/mm}^2$$

- b. Selection of water Cement ratio

From IS 456:2000,
Maximum W/C ratio = 0.45
Adopted W/C ratio = 0.42

- c. Selection of water cement ratio

From IS 10262 for 20 mm aggregate:
Water content = 186 liters/m³

d. Calculation of cement Content

$$\text{Cement content} = \frac{186}{0.42} = 442.85 \text{ kg/m}^3$$

Minimum cement content as per IS 456 = 320 kg/m³

e. Proportion of volume of CA&FA Content

For 20 mm aggregate and Zone II sand:

- Volume of CA at W/C = 0.5 → 0.60
- Adjustment for W/C = 0.42

$$\text{Increase in CA} = \frac{0.08}{0.05} \times 0.01 = 0.016$$
 Corrected CA volume = 0.616

Considering 10% reduction for workability:

$$\begin{aligned} \text{Final CA volume} &= 0.616 \times 0.9 = 0.55 \\ \text{FA volume} &= 1 - 0.55 = 0.45 \end{aligned}$$

f. Mix Calculation

$$\begin{aligned} \text{Volume of cement} &= \frac{442.85}{3.15 \times 1000} = 0.1406 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Volume of water} &= \frac{186}{1000} = 0.186 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Volume of aggregates} &= 1 - (0.1406 + 0.186) = 0.6734 \text{ m}^3 \end{aligned}$$

g. Mass of Aggregates:

$$\begin{aligned} \text{Coarse Aggregate} &= 0.6734 \times 0.55 \times 2.68 \times 1000 \\ &= 992.59 \text{ kg/m}^3 \end{aligned}$$

$$\begin{aligned} \text{Fine Aggregate} &= 0.6734 \times 0.45 \times 2.63 \times 1000 \\ &= 796.96 \text{ kg/m}^3 \end{aligned}$$

3.2 FINAL MIX PROPORTION

Material	Quantity
Water	186 kg
Cement	442.85 kg
Fine Aggregate	796.96 kg
Coarse Aggregate	992.59 kg
W/C Ratio	0.42

Table 4. Mix Proportion for 1 m³ Concrete

IV.RESULT AND DISCUSSION

The experimental investigation focused on evaluating the performance of M30 grade concrete incorporating natural sand and artificial sand (manufactured sand) as fine aggregate. The study aimed to compare the mechanical behavior of concrete prepared with varying proportions of natural sand and artificial sand through a series of standardized laboratory tests. Comprehensive testing was conducted, including compressive strength, flexural strength, and tensile strength tests, to assess the structural performance of the concrete mixes.

These experiments were essential to understand how the replacement of natural sand with artificial sand influences strength development, durability, and overall concrete quality. The results provide valuable insights into the feasibility of using artificial sand as a sustainable alternative to natural river sand in concrete production. The findings are discussed in terms of practical applicability, cost efficiency, environmental impact, and long-term performance, contributing to sustainable construction practices.



Fig. 4.1 casting Mould



Fig. 4.2 Pouring concrete in beam and cube

4.1 QUANTITIES AND ESTIMATION

- CUBE SPECIMENS (150 × 150 × 150 mm)

Material	Quantity per cube (kg)	No. of cubes	Total (kg)
Cement	1.450	12	17.40
Natural sand	2.650	12	31.80
Coarse aggregate	3.380	12	40.56
Water	0.640	12	7.68

Table No. 5: Concrete Mix with 100% Natural Sand

- Concrete Mix with 50% Natural Sand + 50% Artificial Sand

Material	Quantity per cube (kg)	No. of cubes	Total (kg)
Cement	1.450	12	17.40
Natural sand	1.325	12	15.90
Artificial sand	1.325	12	15.90
Coarse aggregate	3.380	12	40.56
Water	0.640	12	7.68

Table. 6. Concrete Mix with 50% Natural Sand + 50% Artificial Sand

- Concrete Mix with 100% Artificial Sand

Material	Quantity per cube (kg)	No. of cubes	Total (kg)
Cement	1.450	12	17.40
Artificial sand	2.650	12	31.80
Coarse aggregate	3.380	12	40.56
Water	0.640	12	7.68

BEAM SPECIMENS (150 × 150 × 700 mm)

Table No. 8: 100% Natural Sand Concrete

Material	Quantity per beam (kg)	No. of beams	Total (kg)
Cement	6.83	3	20.49
Natural sand	12.55	3	37.65
Coarse aggregate	15.65	3	46.95

Water	2.93	3	8.79
-------	------	---	------

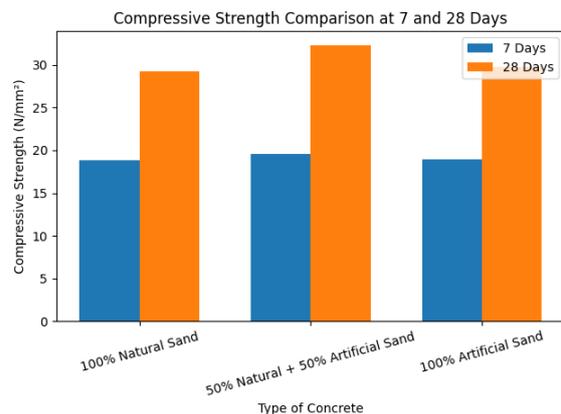
Table No. 9: 50% Natural Sand + 50% Artificial Sand Concrete

Material	Quantity per beam (kg)	No. of beams	Total (kg)
Cement	6.83	3	20.49
Natural sand	6.275	3	18.825
Artificial sand	6.275	3	18.825
Coarse aggregate	15.65	3	46.95
Water	2.93	3	8.79

Table No. 10: 100% Artificial Sand Concrete

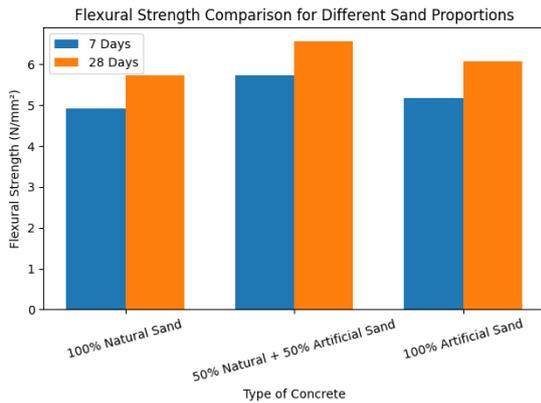
Material	Quantity per beam (kg)	No. of beams	Total (kg)
Cement	6.83	3	20.49
Artificial sand	12.55	3	37.65
Coarse aggregate	15.65	3	46.95
Water	2.93	3	8.79

4.2 COMPRESSIVE STRENGTH TEST



- Concrete with 50% natural sand + 50% artificial sand shows the highest compressive strength at both curing ages.
- Strength gain from 7 days to 28 days is significant for all mixes.
- Concrete with 100% artificial sand performs slightly better than 100% natural sand, indicating its suitability as an alternative fine aggregate.

4.3 FLEXURAL TEST



4.4 TENSILE STRENGTH TEST

Tensile strength is an important mechanical property of concrete that indicates its resistance to cracking under tensile forces. Since concrete is weak in direct tension, the tensile strength test is commonly conducted using the indirect splitting method. This test helps in assessing the cracking behavior and durability of concrete under service loads.

In the present study, tensile strength tests were carried out on concrete specimens prepared with natural sand, artificial sand, and a combination of both. The specimens were tested after 7 days and 28 days of curing using a compression testing machine. Load was applied gradually until failure occurred, and the corresponding tensile strength was calculated.

The tensile strength of concrete was determined using the following expression:

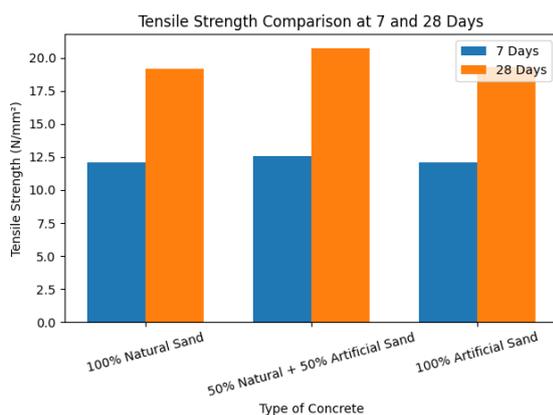
$$\text{"Tensile Strength"} = (0.642 \times P) / S^2$$

where:

P= Load at failure (N)

S= Size of the cube specimen (mm)

The results indicate that concrete containing 50% natural sand and 50% artificial sand



- The 50% natural sand + 50% artificial sand mix

shows the highest tensile strength at both curing periods.

- Tensile strength increases significantly from 7 days to 28 days for all mixes.
- Concrete with 100% artificial sand exhibits tensile strength comparable to conventional natural sand concrete, confirming its suitability as a replacement material.

V. CONCLUSION

This experimental investigation evaluated the performance of M30 grade concrete using natural sand, artificial sand, and a combination of both as fine aggregates. Concrete specimens were prepared and tested for compressive strength, flexural strength, and tensile strength at 7 days and 28 days of curing to assess the mechanical behavior of each mix.

The compressive strength results showed that concrete containing 50% natural sand and 50% artificial sand achieved the highest strength at both curing ages, with values of 19.61 N/mm² at 7 days and 32.30 N/mm² at 28 days, compared to 100% natural sand concrete (18.79 N/mm² at 7 days and 29.22 N/mm² at 28 days) and 100% artificial sand concrete (18.89 N/mm² at 7 days and 29.72 N/mm² at 28 days).

Similarly, the flexural strength test results indicated superior performance for the 50% natural sand + 50% artificial sand mix, recording 5.74 N/mm² at 7 days and 6.57 N/mm² at 28 days. Concrete made with 100% artificial sand exhibited flexural strength values (5.18 N/mm² at 7 days and 6.08 N/mm² at 28 days) that were higher than those of conventional natural sand concrete (4.91 N/mm² at 7 days and 5.74 N/mm² at 28 days).

The tensile strength test further confirmed this trend. The 50% natural sand and 50% artificial sand mix achieved the highest tensile strength, with 12.59 N/mm² at 7 days and 20.73 N/mm² at 28 days. Concrete with 100% artificial sand showed tensile strength values (12.12 N/mm² at 7 days and 19.31 N/mm² at 28 days) comparable to those of 100% natural sand concrete (12.06 N/mm² at 7 days and 19.19 N/mm² at 28 days).

Based on the experimental results, it can be concluded that partial replacement of natural sand with artificial sand at 50% provides optimum performance in terms of strength characteristics. Additionally, concrete

produced with 100% artificial sand demonstrates mechanical properties comparable to conventional concrete, making it a viable and sustainable alternative to natural sand. The study supports the use of artificial sand in concrete construction to reduce dependency on natural river sand and promote environmentally sustainable construction practices.

REFERENCES

- [1] IS 456:2000, Plain and Reinforced Concrete – Code of Practice, Bureau of Indian Standards, New Delhi, India, 2000.
- [2] IS 10262:2019, Concrete Mix Proportioning – Guidelines, Bureau of Indian Standards, New Delhi, India, 2019.
- [3] IS 383:2016, Coarse and Fine Aggregate for Concrete – Specification, Bureau of Indian Standards, New Delhi, India, 2016.
- [4] IS 516:1959, Methods of Tests for Strength of Concrete, Bureau of Indian Standards, New Delhi, India, 1959.
- [5] A. M. Neville, *Properties of Concrete*, 5th ed., Pearson Education, London, U.K., 2011.
- [6] M. S. Shetty, *Concrete Technology: Theory and Practice*, 7th ed., S. Chand & Company Ltd., New Delhi, India, 2019.
- [7] S. A. Kandekar, S. S. Mehetre, and P. A. Murnal, “Effect of replacement of natural sand by manufactured sand on properties of concrete,” *Int. J. Civ. Struct. Eng.*, vol. 3, no. 3, pp. 551–558, 2013.
- [8] R. Ilangovana, N. Mahendrana, and K. Nagamanib, “Strength and durability properties of concrete containing quarry rock dust as fine aggregate,” *ARNP J. Eng. Appl. Sci.*, vol. 3, no. 5, pp. 20–26, 2008.
- [9] V. M. Sounthararajan and A. Sivakumar, “Effect of the manufactured sand on the mechanical properties of concrete,” *Int. J. Eng. Adv. Technol.*, vol. 2, no. 4, pp. 81–84, 2013.
- [10] S. Ramanathan, K. S. Satyanarayana, and P. N. Rao, “Performance evaluation of concrete using manufactured sand,” *Int. J. Civ. Eng. Technol.*, vol. 8, no. 4, pp. 160–168, 2017.
- [11] M. Singh and R. Siddique, “Effect of waste foundry sand as partial replacement of sand on the strength, ultrasonic pulse velocity, and permeability of concrete,” *Constr. Build. Mater.*, vol. 26, no. 1, pp. 416–422, 2012.
- [12] T. S. Raghavendra and R. R. Prakash, “An experimental investigation on strength of concrete with manufactured sand,” *Int. J. Innov. Res. Sci. Eng. Technol.*, vol. 4, no. 2, pp. 234–240, 2015.
- [13] P. S. Patil and J. R. Pitroda, “Performance of concrete with partial replacement of natural sand by manufactured sand,” *Int. J. Eng. Sci. Innov. Technol.*, vol. 2, no. 3, pp. 257–264, 2013.
- [14] K. K. Sangle, V. S. Patil, and S. S. Shinde, “Effect of manufactured sand on compressive and flexural strength of concrete,” *Int. J. Civ. Eng. Res.*, vol. 5, no. 3, pp. 291–296, 2014.
- [15] J. C. Walraven, “Fundamental analysis of aggregate interlock,” *J. Struct. Eng.*, vol. 107, no. 11, pp. 2245–2270, 1981.
- [16] A. Sivakumar and P. Santhanam, “Mechanical properties of high strength concrete reinforced with metallic and non-metallic fibres,” *Cem. Concr. Compos.*, vol. 29, no. 8, pp. 603–608, 2007.
- [17] K. H. Yang, H. S. Chung, and A. F. Ashour, “Influence of type and replacement level of fine aggregate on concrete properties,” *Cem. Concr. Res.*, vol. 38, no. 5, pp. 689–696, 2008.
- [18] S. Popovics, *Strength and Related Properties of Concrete*, Wiley, New York, NY, USA, 1998.
- [19] R. Siddique, “Properties of concrete incorporating high volumes of class F fly ash and natural sand replacement,” *Resour. Conserv. Recycl.*, vol. 42, no. 3, pp. 251–260, 2004.
- [20] A. K. Mullick, “Use of manufactured sand in concrete and construction,” *Indian Concrete Journal*, vol. 87, no. 8, pp. 7–16, 2013.