Effect on Strength Properties of Concrete by Using Mechanical Sand as Fine Aggregate

Deep Narayan Gautam[1], Prof. Dr. Dk Jain[2]

[1]MTech Scholar, Civil Engineering Department, Rewa Engineering College, Rewa, Madhya Pradesh 486001
[2]Professor, Civil Engineering Department, Rewa Engineering College, Rewa, Madhya Pradesh 486001

Abstract
This study investigates the viability of using mechanical sand (M-Sand) as an environmentally friendly alternative to river sand in concrete production. Given the growing environmental concerns and the depletion of natural sand sources, M-Sand, produced by crushing granite, presents a sustainable option. Concrete mixes were created by replacing river sand with M-Sand at proportions of 25%, 50%, 75%, and 100%, and their compressive and flexural strengths were tested at 7 and 28 days. The results show that replacing up to 50% of river sand with M-Sand leads to an increase in compressive strength, reaching its maximum at 28 days with a 50% replacement. The flexural strength showed minimal variation across different M-Sand replacement levels, with a slight decrease at higher percentages of M-Sand. These findings suggest that M-Sand is a viable substitute for river sand in concrete, offering a sustainable solution for construction practices.

Keywords: Manufactured Sand, Concrete Mix Design, Replacement of Fine Aggregates, Sustainable Construction, Durability of Concrete**.**

I. INTRODUCTION

The performance of concrete is significantly influenced by the materials used, and with the increasing cost of river sand due to high transportation charges from natural sources, the demand for eco-friendly alternatives has grown substantially [1, 2, 3, 4, 5]. Mechanical sand (M-Sand) is emerging as a widely adopted replacement for river sand. It is produced by crushing hard rocks into fine grains, offering uniform quality and precise grading. Using M-Sand not only supports sustainable construction practices by reducing the environmental footprint of natural resource extraction but also promotes the utilization of locally available materials Mechanical sand (M-sand) has gained significant traction as an alternative to river sand, driven by concerns over environmental impacts and the depletion of natural sand reserves. In 2011, Prakash Nanthagopalan et al. [6] investigated the potential of using M-sand in self-compacting concrete (SCC), a material known for its excellent properties in both fresh and hardened states. Their study concluded that M-sand could effectively produce low to medium-strength SCC (ranging from 25 to 60 MPa). However, achieving the desired flow properties required a higher volume of paste. The research emphasized M-sand's role as a sustainable and eco-friendly substitute for river sand in SCC production, helping reduce dependence on natural resources.

In 2012, T. Shanmugapriya and RN Uma [7] explored the optimization of M-sand and silica fume as substitutes for natural sand and cement in high-performance concrete (HPC). Their findings revealed that replacing 50% of natural sand with M-sand led to significant improvements in compressive and flexural strength, with increases of approximately 20% and 15%, respectively. The addition of silica fume further enhanced the strength properties of the concrete, highlighting the potential of M-sand as a sustainable and effective material for producing HPC while minimizing environmental impact.

In 2013, M. Adams Joe et al. [8] examined the use of M-sand as a replacement for river sand in structural concrete, with a focus on the material's quality and performance. Their findings indicated that M-sand, known for its consistent quality and absence of impurities like silt and clay, contributed to the production of high-strength concrete. Moreover, M-sand helped reduce defects commonly observed in concrete made with river sand, such as honeycombing, segregation, and void formation. The study underscored the advantages of using M-sand to enhance the durability and overall performance of concrete structures.

Tao Ji et al. [9] investigated the role of microfine in manufactured sand concrete (MSC) using the minimum paste theory for mix design. Their research revealed that incorporating moderate levels of microfines improved the workability of MSC and boosted its compressive, axial compressive, and splitting tensile strengths. However, excessive microfines were found to negatively affect the mechanical properties. The study highlighted that microfines could reduce cement consumption, lower concrete costs, and promote sustainability in the concrete industry by cutting down on carbon emissions.

In 2015, V. Umamaheswaran et al. [10] conducted a study on the use of high-strength concrete (M100 grade) incorporating M-sand and mineral admixtures for urban infrastructure development. Their research revealed that the combination of Alccofine (a type of mineral admixture) and M-sand enhanced the compressive strength by 21% at 56 days compared to conventional concrete. Additionally, the study highlighted improvements in durability characteristics, such as chloride permeability and water absorption, with M-sand-based concrete slightly outperforming river sand-based concrete. This study emphasized M-sand's potential to improve both strength and durability in high-strength concrete applications.

In 2016, Xinxin Ding et al. [11] explored the impact of stone powder content on the long-term compressive strength of manufactured sand concrete (MSC). Their findings showed that when the stone powder content was maintained below 13%, it had a beneficial effect on the long-term compressive strength of MSC. They also proposed a forecasting model that accounted for factors like curing age, water-to-cement ratio, and the compressive strength and density of cement. The study highlighted the importance of optimizing stone powder content to achieve better strength and durability for MSC.

In 2017, Shunbo Zhao et al. [12] investigated the development of tensile strength in concrete made with M-sand. They found that including up to 13% stone powder content positively impacted the long-term tensile strength of MSC. The study also introduced forecasting models to predict long-term tensile strength, aiding in the optimization of MSC for various construction applications. The research demonstrated that MSC not only performed well in compressive strength but also exhibited favorable tensile strength, making it suitable for a wide range of structural applications.

Ayinampudi Kavya and A. Venkateshwara Rao [13] assessed the use of M-sand and offshore sand as complete substitutes for river sand in cement-sand mortar. Their study revealed that replacing river sand with offshore sand enhanced both the wet and dry bulk densities and improved the workability of the mortar, especially at 25%–50 % replacement levels. At these levels, the mortar showed increased compressive and flexural strength, as well as better water retention. The research identified a 25% blend of M-sand and offshore sand as the most efficient and cost-effective alternative to river sand in mortar production.

In 2021, Branavan Arulmoly et al. [14] also explored the use of M-sand and offshore sand as substitutes for river sand in cement-sand mortar. Similar to Kavya and Venkateshwara Rao's findings, their study demonstrated that replacing river sand with offshore sand improved the wet and dry bulk densities and workability of the mortar at 25%–50 % replacement levels. At these levels, the mortar exhibited enhanced compressive and flexural strength, along with improved water retention. Their research also identified a 25% blend of M-sand and offshore sand as the most cost-effective and efficient substitute for river sand in mortar production.

K.M. Mane et al. [15] investigated the use of E-waste-derived sand (E-sand) as a partial replacement for M-sand in concrete. Their study showed that replacing 20% of M-sand with E-sand resulted in improved strength, better chloride permeability, and enhanced microstructure, offering a sustainable solution to reduce both E-waste and dependence on natural aggregates.

S. Pranavan and G. Srinivasan [16], in 2021, studied the potential of untreated sea sand as a fine aggregate in concrete due to the government restrictions on river sand mining. Their findings indicated that concrete made with sea sand had higher strength compared to concrete made with M-sand, suggesting that untreated sea sand could be a viable and cost-effective alternative for fine aggregates in concrete production.

In 2022, Zhiming Ma et al. [17] introduced recycled manufactured sand as an alternative to river sand. Their research found that recycled manufactured sand, primarily composed of natural stone particles with minimal old mortar content, exhibited higher density and lower water absorption than traditional recycled fine aggregates. They concluded that replacing river sand with recycled manufactured sand not only improved the mechanical properties of concrete but also reduced drying shrinkage, making it a suitable material for sustainable concrete production.

Finally, in 2024, Hua Yang et al. [18] investigated the impact of several factors, including water-cement ratio, M-Sand replacement rate, and stone powder content, on the mechanical and fracture characteristics of MSC. Their study revealed that increasing the M-Sand replacement rate positively influenced both compressive strength and flexural toughness. Additionally, the optimal stone powder content further improved the concrete's mechanical properties. This research provided valuable insights into the factors that influence MSC performance, contributing to the development of more durable and efficient concrete alternatives.

II. MATERIALS AND METHODOLOGY

In this study, Ordinary Portland Cement (OPC) of grade 43 was used for preparing the concrete mixes. Mechanical sand (M-Sand), produced by crushing hard granite stones, was employed as a partial or complete substitute for river sand. The M-Sand was sourced locally and was free from impurities like clay and silt. Natural river sand was used in the control mix as the baseline material for comparison with the M-Sand-based concrete. Crushed granite aggregates, with a maximum particle size of 20 mm, were selected as the coarse aggregate. Potable water, meeting the standards specified in IS 456:2000, was used for mixing and curing.

The properties of the constituent materials were tested for uniformity and quality. The fineness of the cement was determined using the Blaine air permeability method as per IS 4031 (Part 2): 1999, and the specific gravity was measured by the Le Chatelier flask method according to IS 4031 (Part 11): 1988. For the fine aggregates, sieve analysis was performed according to IS 2386 (Part 1): 1963, and the specific gravity was determined using the pycnometer method as per IS 2386 (Part 3): 1963. Additionally, the water absorption of the fine aggregates was tested in accordance with IS 2386 (Part 3): 1963. The coarse aggregates were tested for sieve analysis, specific gravity, and water absorption as per IS 2386 (Part 1) and IS 2386 (Part 3): 1963.

The concrete mix design adhered to the guidelines of IS 10262:2019. The control mix ratio was 1:1.5:3 (Cement: Fine Aggregate: Coarse Aggregate), using river sand. Experimental mixes were designed by replacing river sand with M-Sand at 25%, 50%, 75%, and 100% replacement levels, maintaining a constant water-cement ratio of 0.45 for all mixes.

Concrete was mixed by first dry combining the coarse aggregates, fine aggregates, and cement for 2-3 minutes. Water and superplasticizer were then added, and the mixture was mixed for another 4-5 minutes to achieve uniform consistency. Concrete samples were cast into 150mm x 150mm x 150mm cubes for compressive strength testing and 100mm x 100mm x 500mm beams for flexural strength testing.

After casting, the samples were kept in molds for 24 hours at room temperature, demolded, and cured in water for 28 days. Compressive strength tests were conducted on the cubes at 7 and 28 days using a compression testing machine. The flexural strength of the beams was tested using a three-point bending test, as specified in IS 516:1959. The results from these tests were analyzed and compared across different M-Sand replacement levels. The performance of M-Sand-based concrete was evaluated in terms of strength development and workability. The data were statistically analyzed to assess the viability of M-Sand as an alternative to river sand in concrete production.

III. RESULTS AND DISCUSSION

Compressive and flexural strength tests were performed to assess the performance of concrete samples with different levels of M-sand substitution. These tests were carried out at both 7 and 28 days, and the findings are summarized as follows:

Compressive Strength:

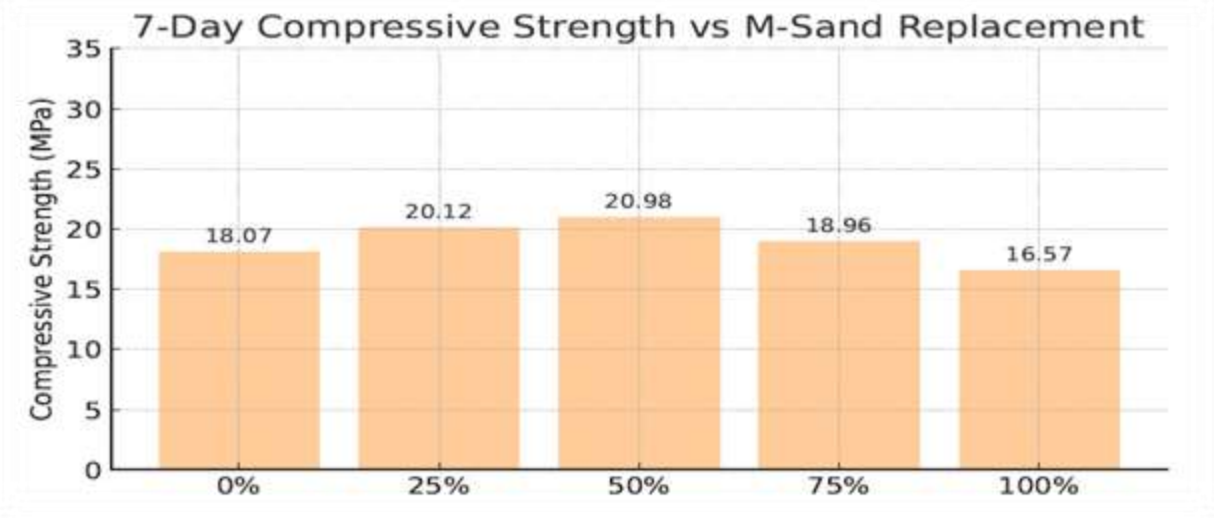
In this investigation, the compressive strength of concrete was determined using 150 mm cube specimens tested on a Universal Testing Machine (UTM). The control mix (0% M-sand) achieved an average compressive strength of 18.07 MPa at 7 days, increasing to 28.33 MPa at 28 days. When 25% of the river sand was replaced with M-sand, the strength values rose to 20.12 MPa at 7 days and 29.11 MPa at 28 days. A further increase was observed in the 50% M-sand mix, which reached 20.98 MPa at 7 days and 30.16 MPa at 28 days. However, at 75% M-sand replacement, the 7-day strength slightly decreased to 18.96 MPa, while the 28-day strength was recorded at 28.60 MPa. The compressive strength for the mix with 100% M-sand dropped to 16.57 MPa at 7 days and 27.13 MPa at 28 days. These findings are summarized in Table 1, and a graphical comparison is illustrated in Figure 1.

Table 1: Compressive Strength Results

M-sand %	0%	25%	50%	75%	100%
7-Day Compressive Strength (MPa)	18.07	20.12	20.98	18.96	16.57
28-Day Compressive Strength (MPa)	28.33	29.11	30.16	28.60	27.13

International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Figure 1: 7-Day Compressive Strength vs. M-Sand Replacement



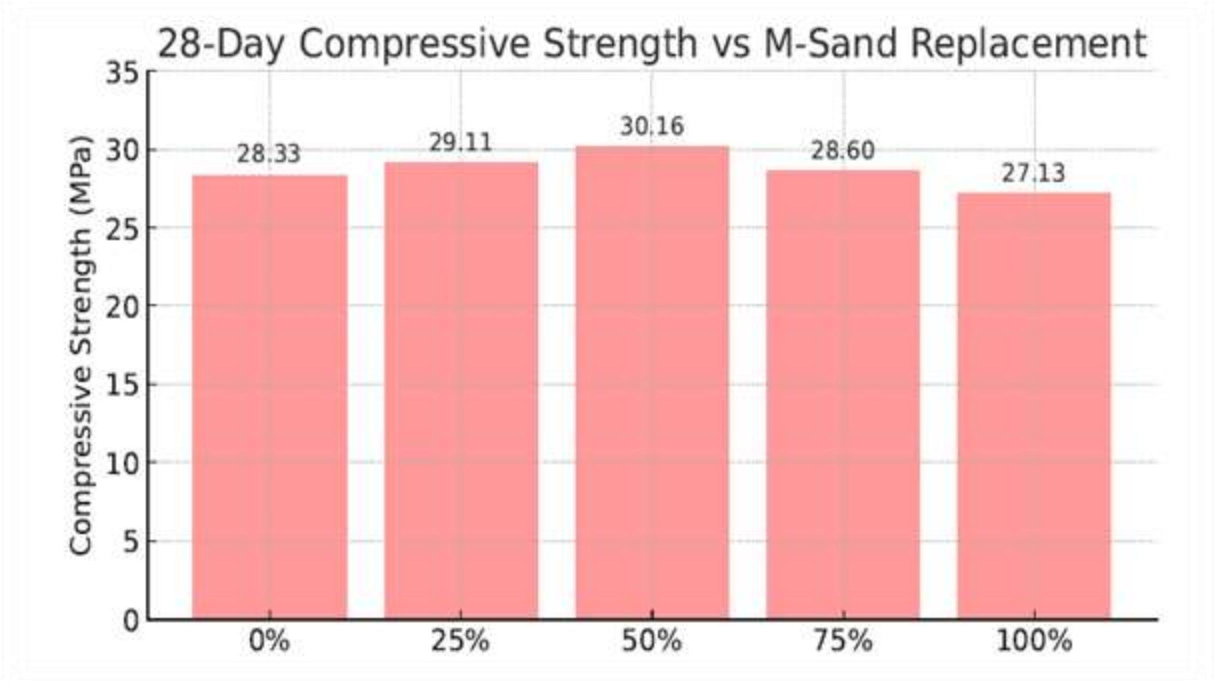


Figure 2: 28-Day Compressive Strength vs. M-Sand Replacement

Flexural Strength:

Flexural strength was evaluated using concrete prisms measuring 500 mm × 100 mm × 100 mm through a three-point bending test. The average flexural strength for the control mix containing 0% M-sand was 3.86 MPa at 7 days, increasing to 5.54 MPa at 28 days. When 25% of natural sand was substituted with M-sand, the flexural strength reached 3.44 MPa at 7 days and 4.85 MPa at 28 days. With a 50% replacement, the strength was recorded at 3.13 MPa 1after 7 days, decreasing slightly to 4.37 MPa at 28 days. In the case of 75% M-sand, the 7-day flexural strength averaged 3.47 MPa, while the 28-day result was 3.65 MPa. Finally, for the mix with 100% M-sand, the flexural strength was 2.81 MPa at 7 days, increasing to 3.32 MPa at 28 days. The detailed results are presented in Table 2, while Figure 2 offers a visual comparison of the data.

M-sand %	**0%**	**25%**	**50%**	**75%**	**100%**
7-Day Flexural Strength(MPa)	3.86	3.44	3.13	2.81	2.19
28-Day Flexural Strength(MPa)	5.54	4.85	4.37	3.65	3.32

Table 2: Flexural Strength Results

Figure 3: 7-Day Flexural Strength vs. M-Sand Replacement

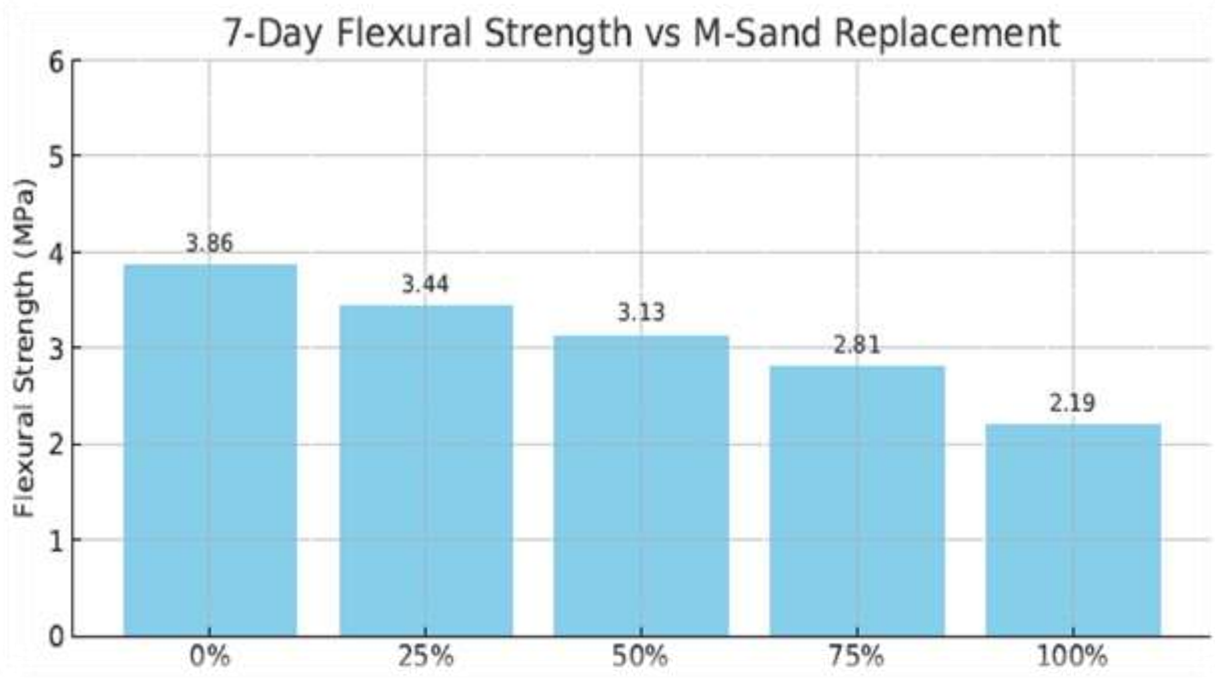
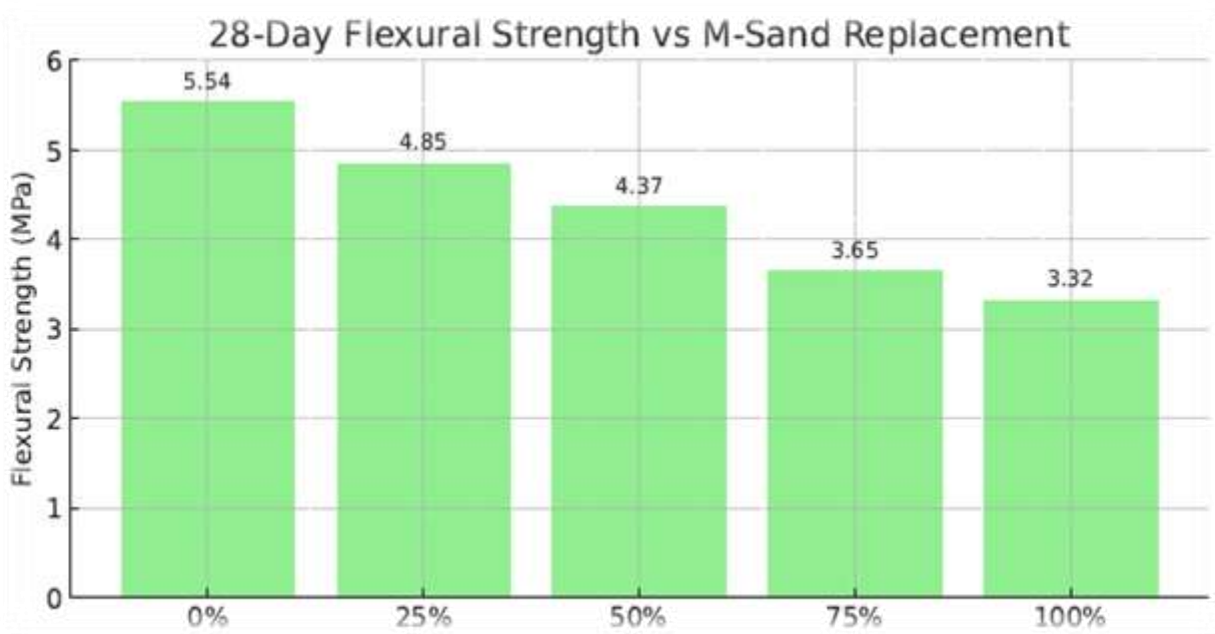


Figure 4: 28-Day Flexural Strength vs. M-Sand Replacement



Summary of Strength Results:

The compressive and flexural strength test results indicated that concrete strength improved with increasing M-Sand content up to a 50% replacement level, beyond which a decline was observed at 75% and 100% replacement. At 7 days, the compressive strength values ranged from a minimum of 16.57 MPa for 100% M-Sand to a peak of 20.98 MPa at 50% replacement. Similarly, the 28-day compressive strength varied between 27.13 MPa (100% M-Sand) and 30.16 MPa (50% M-Sand). For flexural strength, the 7-day results showed a range from 2.19 MPa at 100% M-Sand to 3.86 MPa in the control mix (0% M-Sand), while the 28-day flexural strength extended from 3.32 MPa (100% M-Sand) to a maximum of 5.54 MPa

(0% M-Sand). Thus, the optimal mechanical performance, considering both compressive and flexural strength, was achieved at a 50% M-Sand replacement level.

CONCLUSION

This study evaluates the performance of M-sand as a partial replacement for fine aggregates in concrete, focusing on compressive and flexural strength. The results suggest that M-sand can be effectively incorporated into concrete without significantly compromising its strength properties.

Compressive Strength Findings:

- At 7 days, concrete with 0% M-sand exhibited compressive strengths between 16.57 MPa and 18.07 MPa.
- Concrete with 50% M-sand replacement showed the highest compressive strength of 20.98 MPa.
- By 28 days, concrete with 50% M-sand exhibited the maximum strength (30.16 MPa), while 100% M-sand showed the lowest strength (27.13 MPa), still within a comparable range.

Flexural Strength Findings:

- At 7 days, specimens with 0% M-sand exhibited flexural strengths between 2.19 MPa and 3.86 MPa.
- 50% M-sand specimens showed a slightly higher strength (3.13 MPa).
- At 28 days, the 0% M-sand specimens achieved the highest flexural strength (5.54 MPa), with 50% M-sand closely following at 4.37 MPa.

Key Inferences:

1. **Optimum M-Sand Replacement:** A 50% M-sand replacement exhibited the highest compressive strength at 28 days, while flexural strength was relatively unaffected at all M-sand replacement levels. This suggests that 50% replacement provides a balanced performance.
2. **Comparable Performance Across Variations:** Concrete with up to 100% M-sand showed strength values comparable to those with natural river sand, confirming the feasibility of M-sand as an

alternative fine aggregate.

3. **Sustainability Potential:** The use of M-sand in concrete reduces reliance on natural sand, offering a more sustainable and environmentally friendly alternative for concrete production.

Recommendations for Future Work:

1. Investigate the long-term durability and performance characteristics of M-sand concrete, including its resistance to weathering, shrinkage, and cracking.
2. Study the workability, flowability, and bonding characteristics of M-sand concrete for enhanced mix design optimization.
3. Explore the compatibility of M-sand with different cement types, additives, and superplasticizers to develop more efficient and versatile mix design

REFERENCES

1. Venkatesan, K., & Natarajan, V. (2018). *Effect of Manufactured Sand on Mechanical Properties of Concrete*. Materials Today: Proceedings, 5(1), 2733–2737.
2. Mahendra, R., & Aruna, M. (2016). *Strength Characteristics of Concrete Using M-Sand as Fine Aggregate*. International Journal of Engineering Research and Applications (IJERA**)**, 6(7), 55–59.
3. Safiuddin, M., Raman, S. N., & Zain, M. F. M. (2007). *Utilization of Manufactured Sand as Fine Aggregate in Concrete*. Journal of Civil Engineering and Management, 13(2), 85–92.
4. Ilangovana, R., Mahendran, N., & Nagamani, K. (2008). *Strength and Durability Properties of Concrete Containing Quarry Rock Dust as Fine Aggregate*. ARPN Journal of Engineering and Applied Sciences, 3(5), 20–26.
5. Saravanan, S. S., & Jagadeesh, P. (2016). *Effect of Manufactured Sand on the Durability Characteristics of Concrete*. Carbon – Science and Technology, 8(4), 70–81
6. Raut, H. R., & Ugale, A. B. (2024). *A Review on Use of Manufactured Sand in Concrete*. International Journal of Progressive Research in Engineering Management and Science, 4(2), 32717
7. Reddy, Y. M., Swetha, D. V., & Dhani, S. K. (2015). *Study on Properties of Concrete with Manufactured Sand as Replacement to Natural Sand*. International Journal of Civil Engineering and Technology, 6(8), 29–42.
8. Abdi, A. M., Mwero, J., & Ochieng, A. S. (2022). *Experimental Study on the Influence of Mogadishu Manufactured Sand on the Engineering Properties of Concrete*.
9. MuraliKrishnan, S., Kala, T. F., Asha, P., & Elavenil, S. (2018). *Properties of Concrete using Manufactured Sand as Fine Aggregate*. Research Journal of Engineering and Technology, 11(3), 94–100
10. Yajurved Reddy, M., Swetha, D. V., & Dhani, S. K. (2024). *Study on Properties of Concrete with Manufactured Sand as Replacement to Natural Sand*. International Journal of Engineering Research and Applications (IJERA), 14(2), 45–52
11. Krishnan, P., & Kumar, R. (2024). *Influence of Manufactured Sand on Fresh Properties, Strength, and Microstructure of Self-Compacting Concrete*. Buildings, 14(8), 2281
12. X. Ding, C. Li, Y. Xu , F. Li and S. Zhao, "Experimental study on long-term compressive strength of concrete with manufactured sand," Construction and Building Materials, vol. 108, pp. 67-73, 2016
13. V. Umamaheswaran, C. Sudha, P. Ravichandran and P. R. Kannan Rajkumar, "Use of M Sand in High Strength and High Performance Concrete," Indian Journal of Science and Technology, vol. 8, no. 28, 2015.

14. M. Joe, R. A. Maria , P. Brightson and M. Anand, "Experimental Investigation on The Effect Of M-Sand In High Performance Concrete," American Journal of Engineering Research (AJER), vol. 03, no. 12, pp. 46-51, 2013.
15. T. Ji, C.-Y. Chen, Y.-Z. Zhuang and J.-F. Chen, "A mix proportion design method of manufactured sand concrete based on minimum paste theory," Construction and Building Materials, vol. 44, pp. 422-426, 2013
16. T. S. a. R. Uma, "Optimization of partial replacement of m-sand by natural sand in high performance concrete with silica fume. (2012). International Journal of Engineering Sciences & Emerging Technologies, 2(2), 73–80
17. Arulmoly, B., Konthesingha, C., & Nanayakkara, A. (2021). Performance evaluation of cement mortar produced with manufactured sand and offshore sand as alternatives for river sand. Construction and Building Materials, 297, 123784.
18. "Yang, H., Jiao, Y., Xing, J., & Liu, Z. (2024). Statistical model and fracture behavior of manufactured sand concrete with varying replacement rates and stone powder contents. Journal of Building Engineering, 95, 110102