

Enhancing the Strength and Durability of Concrete with Integration of Manufactured Sand as a Fine Aggregate

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Abstract — The rapid growth of construction activities has increased the demand for natural river sand as a fine aggregate in concrete, resulting in resource depletion, environmental degradation, and increasing material costs. Manufactured sand (M-sand) are alternative fine aggregates that can reduce dependence on natural river sand while providing an opportunity for beneficial utilization of quarrying by-products. This review examines the influence of M-sand and rock quarry dust on the fresh, mechanical, and durability properties of concrete. The literature indicates that the angular shape, rough surface texture, particle-size distribution, and fines content of M-sand significantly influence workability, strength, and internal packing of concrete. Similarly, quarry dust can improve particle packing and mechanical strength at moderate replacement levels, although excessive fines may reduce workability and adversely affect some durability-related properties. Recent studies have reported improved compressive, tensile, and durability performance at optimized replacement levels, while excessive replacement can lead to higher water demand and reduced workability. The combined utilization of M-sand and quarry dust has potential to produce more resource-efficient concrete by improving aggregate packing and diverting quarry waste from disposal. However, the optimum proportion depends on aggregate mineralogy, grading, fines content, water-to-cement ratio, admixture dosage, and concrete grade. Further research is required on long-term durability, field performance, life-cycle assessment, and optimized hybrid proportions of M-sand and quarry dust.

Keywords: Manufactured Sand, Rock Quarry Dust, Fine Aggregate, Concrete, Compressive Strength, Durability, Sustainable Construction, River Sand Replacement

I. INTRODUCTION

Concrete is one of the most widely used construction materials because of its high strength, durability, versatility, and relatively economical production. Fine aggregate constitutes a significant proportion of concrete volume and traditionally consists of naturally occurring river sand. However, excessive extraction of river sand has created environmental concerns, including riverbed degradation, erosion, disturbance of aquatic ecosystems, and depletion of naturally available resources. Consequently, increasing attention is being given to alternative fine aggregates such as manufactured sand and quarry-derived materials.

Manufactured sand is produced by crushing and processing hard rocks into particles generally suitable for use as fine aggregate. Unlike naturally rounded river sand, M-sand commonly contains angular and rough-textured particles. These characteristics can increase interparticle friction and influence the workability and water demand of concrete. At the same time, appropriate grading and particle packing can improve the compactness of the concrete matrix

and contribute to mechanical performance. A 2024 review emphasized that particle shape, gradation, fines content, and parent-rock characteristics are important parameters controlling the performance of concrete containing machine-made sand.

Rock quarry dust is a fine by-product generated during crushing and processing of rocks and aggregates. Large quantities of this material may accumulate around quarrying and stone-crushing facilities. Uncontrolled disposal can create dust, land-use, and environmental problems. Using quarry dust as a partial replacement for natural sand provides a potential waste-valorization route and can reduce the consumption of natural fine aggregates.

Recent investigations have demonstrated that quarry dust can improve concrete strength at moderate replacement levels because its fine particles can fill voids between larger aggregate particles and improve packing. However, higher proportions may increase water demand and reduce workability. A 2025 investigation of M40 concrete found that quarry-dust replacement up to 20% produced favorable strength results, while higher replacement levels resulted in declining compressive and tensile strengths. A 2026 study similarly reported that moderate quarry-dust replacement improved compressive strength but found increasing water absorption at higher replacement levels, demonstrating the need to balance mechanical performance with durability.

II. LITERATURE SURVEY & BACKGROUND

Patel (2023) Patel investigated the flexural strength and structural performance of concrete using M-sand and quarry dust. The study involved casting beam specimens and testing them under flexural loads. The results showed that flexural strength improved due to better bonding and reduced crack propagation. The study also observed improved tensile strength, which is crucial for structural applications. Another important finding was the reduction in crack width, indicating better durability. However, workability was reduced, requiring the use of admixtures. In conclusion, Patel demonstrated that M-sand and quarry dust enhance structural performance and are suitable for load-bearing applications.

Mishra (2024) Mishra conducted a study on eco-friendly concrete using quarry dust, focusing on sustainability and performance. The study found that quarry dust reduces the need for natural sand and promotes sustainable construction practices. In terms of strength, the concrete showed improved compressive strength due to better particle packing. The study also observed reduced porosity, which enhances durability and resistance to environmental factors. Another key finding was the reduction in carbon footprint due to the use of industrial by-products. However, workability issues were noted and required mix adjustments. In conclusion, Mishra highlighted the environmental and technical benefits of quarry dust in concrete.

A. Umar et al. (2025)

Umar et al. investigated the combined use of quarry dust and bentonite clay in concrete. The study found that this combination improves both strength and durability. Bentonite clay enhances binding, while quarry dust fills voids, resulting in a dense matrix. The researchers observed improved compressive strength and reduced permeability. The study also highlighted improved resistance to chemical attack. However, excessive use of bentonite may affect workability. In conclusion, Umar et al. showed that combining materials can further enhance concrete performance

III. OBJECTIVE OF RESEARCH WORK

Evaluate the influence of M-sand and quarry dust on the workability, fresh density, and compaction characteristics of concrete using standard laboratory tests.

Investigate the effect of replacing natural river sand with M-sand and quarry dust on the compressive, split tensile, and flexural strength of concrete.

A. Result

Test on concrete with m-sand

The slump test was performed to assess the workability of M40 grade concrete containing different percentages of manufactured sand (M-sand) as a replacement for natural fine aggregate. Workability is a critical property of fresh concrete that affects its ease of mixing, transportation, placement, and compaction. The slump values obtained for various replacement levels of manufactured sand are presented in Table X.4.2.1 Slump Test

MIX	% Replacement	M30	M40
NC	0	95	90
M-10 & SF-10	10	88	84
M-20 & SF-10	20	85	80
M-30 & SF-10	30	81	78
M-40 & SF-10	40	74	71
M-50 & SF-10	50	71	68
M-60 & SF-10	60	66	63
M-70 & SF-10	70	61	58
M-80 & SF-10	80	55	52
M-90 & SF-10	90	50	45
M-100 & SF-10	100	47	42

Table 1: Slump Value of concrete with M-Sand

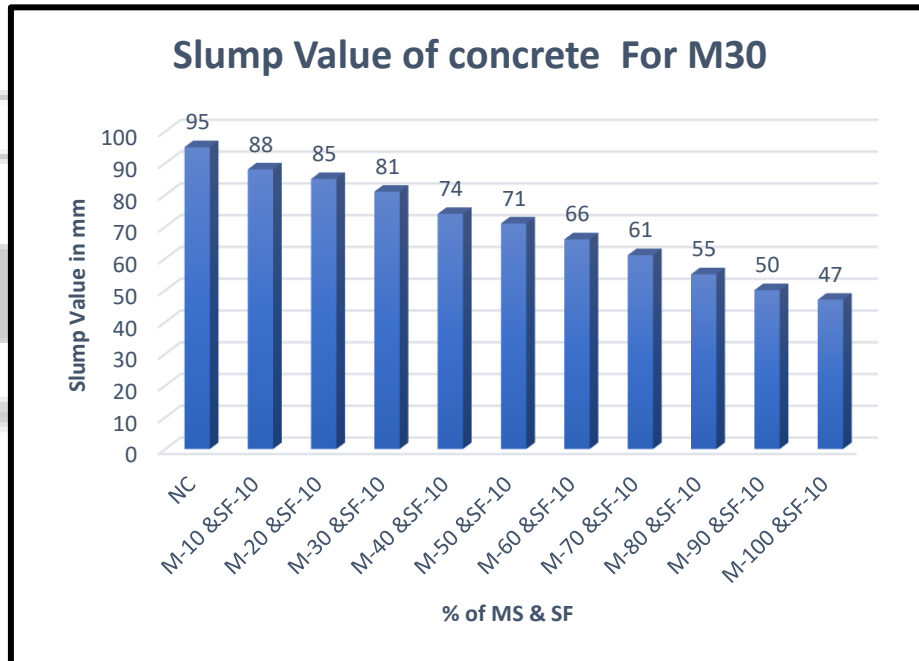


Fig. 1: Slump Value of concrete with M- Sand

The slump test results indicate a continuous decrease in workability with increasing replacement percentage. The control mix (0% replacement) exhibited the highest slump value of 95 mm, indicating good workability and ease of placement.

The reduction in slump values with increasing replacement content can be attributed to the finer particle size, higher specific surface area, and greater water absorption characteristics of the replacement material. These factors increase the water requirement of the mix and reduce its fluidity. Nevertheless, all mixes maintained measurable slump values, indicating acceptable workability for concrete production, although additional water-reducing admixtures may be required at higher replacement levels to achieve the desired consistency.

Overall, the results demonstrate that increasing the replacement percentage adversely affects the workability of fresh concrete. Therefore, an optimum replacement level should be selected to achieve a balance between fresh concrete properties and the desired mechanical and durability performance.

B. Compressive Strength

The compressive strength test was conducted on M30 grade concrete containing different percentages of manufactured sand (M-sand) as a replacement for natural fine aggregate. The test was performed at curing ages of 7, 28, and 56 days to evaluate the effect of manufactured sand on strength development. The results are presented in Table 2

MIX	% Replacement of manufacturing sand	Compressive Strength-M30		
		7 Day	28 Day	56 Days
NC	0	26	33	35
M-10 &SF-10	10	25.62	32.6	35.89
M-20 &SF-10	20	26.28	33.62	36.78
M-30 &SF-10	30	26.91	34.44	37.69
M-40 &SF-10	40	27.5	35.31	38.66
M-50 &SF-10	50	28.28	36.21	39.61
M-60 &SF-10	60	28.97	37.1	40.58
M-70 &SF-10	70	29.76	38.04	41.6
M-80 &SF-10	80	30.46	38.99	42.63
M-90 &SF-10	90	31.22	39.96	43.7
M-100 &SF-10	100	32	40.95	44.81

Table 2: Compressive Strength-M30 concrete with M-Sand

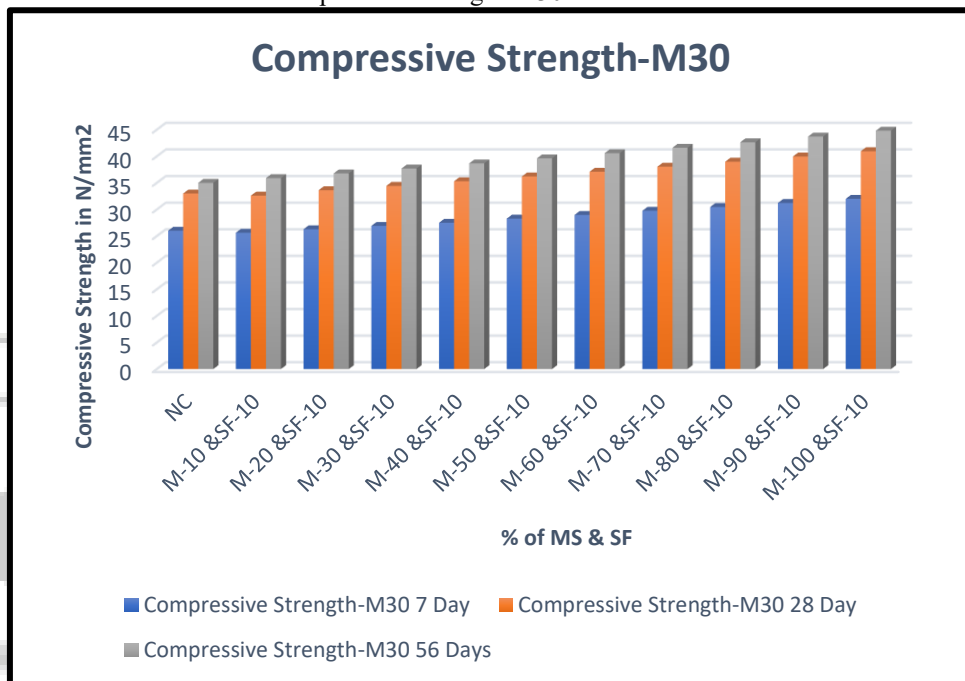


Fig. 2: Compressive Strength-M20 concrete with M-Sand

The compressive strength results indicate that the replacement of natural sand with manufactured sand significantly influences the strength characteristics of M30 concrete. The control mix containing 0% manufactured sand achieved compressive strengths of 26.00 MPa, 33.00 MPa, and 35.00 MPa at 7, 28, and 56 days, respectively.

The continuous increase in strength with increasing manufactured sand content can also be attributed to the presence of fine particles in manufactured sand, which fill micro-voids within the concrete matrix and contribute to a denser microstructure. The improved particle packing enhances the bond between aggregate and cement paste, leading to higher compressive strength and better overall concrete performance.

The strength gain observed between 28 and 56 days for all mixes indicates continued hydration and matrix densification. The higher rate of strength development in manufactured sand concrete suggests that the improved grading and filler effect contribute positively to long-term performance.

Overall, the results demonstrate that manufactured sand can effectively replace natural river sand in M30 concrete without compromising strength. In fact, increasing

manufactured sand content enhances compressive strength, making it a sustainable and technically viable alternative for concrete production

IV. CONCLUSION

Manufactured sand can contribute to improved particle packing and mechanical performance when its grading, particle shape, and fines content are properly controlled. Quarry dust can also enhance concrete strength at moderate replacement levels because its fine particles can fill voids and improve the compactness of the matrix. However, excessive quantities of quarry dust or manufactured-sand fines can increase water demand, reduce workability, and adversely affect certain durability properties. Recent studies confirm that an optimum replacement level is material- and mix-dependent rather than universal.

The combined use of M-sand and rock quarry dust presents an opportunity to develop a more sustainable fine-aggregate system. Appropriate proportioning can potentially improve particle packing, reduce voids, utilize quarry waste, and decrease consumption of natural river sand. Recent comparative research supports the broader feasibility of quarry-derived materials while also demonstrating that their

mechanical and durability behavior varies according to material type and dosage.

Therefore, future experimental investigations should focus on optimizing the combined percentage of manufactured sand and rock quarry dust, while simultaneously evaluating slump/workability, compressive strength, split tensile strength, flexural strength, water absorption, permeability, chloride resistance, sulfate resistance, carbonation, and microstructural characteristics. Life-cycle assessment and economic analysis should also be incorporated to establish the overall sustainability of the proposed concrete.

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