Experimental Investigation into the Impact of Substituting Natural Sand with Manufactured Sand in Landfill Construction

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Abstract. There is a lower requirement for river sand in construction because of a number of logistical and environmental problems. In response to these issues, alternative materials are being increasingly recognized by the construction field progressively M. Sand, derived from the mining and processing of rocks that is a low-particle-size substitute to natural sand which demonstrates potential. Amongst its numerous applications are surface polishing, prefabricated cement components, hollow block development, and lightweight component production. Practitioners and researchers both have been giving special attention on the usage of M. sand in the last few years. This has led to further study into its suitability for replacing river sand in concrete production. The formulation of concrete blends using M. Sand has been made possible through various mix designs developed according to relevant design codes such as IS codes. An assessment of the mechanical properties and structural performance -of concrete containing M. Sand has been conducted using cubes, cylinders, and beams compared to traditional natural sand concrete. As a result of these tests, the compressive, flexural, and tensile strength properties of M. Sand and M. Sand can be compared, suggesting M. Sand has similar properties. Concrete construction applications can utilize sand as an environmentally sustainable and viable alternative to natural-river sand, thereby addressing sustainability concerns and resource scarcity concerns.

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1 Introduction

In order to meet the needs of a world that is rapidly globalizing, there may be a concentrated effort made in India to create vital infrastructure, such as power initiatives, express highways, and industrial structures. The strength and economic feasibility of concrete structures have significantly improved as a result of significant advancements in concrete technology in recent years. However, a significant portion of the natural sand used in the traditional construction of concrete comes from riverbeds; this resource is not only becoming more and more expensive, but it is also becoming scarcer. The rapid depletion of river sand stocks is a result of the increased demand for concrete across a range of construction projects, which has also led to a commensurate increase in the consumption of natural sand. Because of such an alarming depletion of natural sand resources has prompted an important need to explore alternative solutions. Manufactured sand can be produced from crushed natural stones of specific sizes and grades, which is one of the most promising options. Despite the growing demand for sand from natural sources from a wide range of sectors and concerns over its conventional nature, this technology offers a feasible and affordable replacement for manufacturing. As the manufacturing of synthetic sand through stone crushing operations is proving to be a viable and sustainable response to India's construction industry's ongoing growth and sustainability, which will lessen the country's reliance over river sand for concrete manufacturing. Sand founded near river areas has become a very significant raw material for the production of concrete in recent years, particularly in the infrastructure, building and construction sectors. In order to avoid resource depletion and compromise the needs of generations to come, sustainable construction practices are important. River weathering affects the shape and size of natural sand, which is derived from weathered rock particles. In spite of the fact that natural sand with the desired properties may be easier to obtain regionally, securing it with the desired properties from remote locations has proved to be difficult, resulting in higher construction costs. In addition, as river sand resources deplete, the problem of sand shortages becomes even more acute. Therefore, alternative substances that possess comparable properties to natural river sand may be urgently needed in order to substitute it partially or completely. Produced from crushed hard granite, manufactured sand, or M-sand, has become an effective replacement. M-sand has been graded and structured like the shape of a cube with grounded edges, often with sizes of particles from 150 microns and 4.75 mm. It is used in construction. Its higher percentage of finer particles reduces voids, thereby reducing the required cement amount and making construction more economical. The increasing demand for M-sand arises from the lack of ability of river sand to satisfy the escalating construction sector demands. Natural river sand formation is a slow process, resulting in limited supply and high costs, making M-sand essential. additionally, M-sand exhibits lower silt content and natural material in comparison to river sand, improving the durability and lifespan of concrete structures'-sand, derived from the crushing of granite stones, is obtained in controlled grading appropriate for construction purposes, serving as a feasible alternative to river sand. Its production involves processing quarry fines of specific rock types through screening and further processing to fulfill preferred specifications. The properties of M-sand must involve a more smooth texture, more powerful crushing power, and a lack of natural pollutants. Previous studies used M-sand to substitute the sand from rivers in laboratory investigations, finding that a 50% substitution enhanced power and sturdiness. Natural river sand can be replaced with quarry fines that are abundant inside Tamil Nadu's quarries for stone. Making use of heaps of quarry fines produced by crushers could increase the amount of M-sand that is available for building. The parent rock affects M-sand's composition, texture, chemical makeup, and mineral qualities, all of which affect how suitable it is for building. This paper presents experimental results on the properties of M-sand generated from various sources to ease mix design for various concrete grades using M-sand as a natural sand substitute. Additionally, by analyzing the characteristics of clean, hardened concrete created using the suggested mix proportions, the study sheds light on the use of M-sand in the construction industry.

2 Methodology

The availability and use of river sand for construction are progressively less favoured due to various environmental and logistical limitations. The principal objective of this experimental investigation is to elucidate the ramifications of substituting natural sand with manufactured sand across various proportions (25%, 50%, 75%, and 100%) in M30 grade concrete. This comprehensive study encompasses the entire experimental process, including the casting, meticulous curing, and subsequent rigorous testing of specimens. We meticulously execute four separate trials for every water-cement ratio and mortar mix proportion, developing a systematic progression from a reference mix that replaces natural sand by 25% with manufactured sand to a scenario where manufactured sand is completely replaced. By using such a methodical approach, it will be possible to assess the performance of concrete in a variety of replacement scenarios to determine whether manufactured sand is an effective alternative for concrete. This will provide valuable insights into the effectiveness of manufactured sand. In order to ensure uniformity and accuracy of results, all experimental procedures are cautiously conducted under controlled ambient conditions to ensure they are conducted under controlled conditions. In order to ensure homogeneity and consistency of the mortar mixture, each of the mortar components, namely cement and fine combination, is meticulously blended in a dry nation prior to use. Manufactured sand is carefully supplied to partially replace natural sand, and then the exact amount of water needed to produce the appropriate workability and flow characteristics is added. To achieve the intended results, the different components are then completely mixed to guarantee a uniform dispersion and complete integration. The concrete's mechanical properties have been assessed with a 150 x 150 x 150 mm cube. Following an extensive 28-day period of curing in water, these specimens undergo by an in-depth evaluation procedure using standard equipment in order to ensure the most effective feasible development of strength. Through methodical experimentation and assessment, this research aims to provide an in-depth knowledge of the distinct advantages of manufactured compared to naturally occurring sand in cement applications, explaining any possible implications.

2.1 Investigation of Materials and Their Properties

The experiment, that was important to the research, made utilization of a variety of resources, including water from the tap, naturally occurring sand from rivers, coarse crumbled dioxide of silicon stone particles, and regular Portland cement. Conventional Portland cement was used to formulate the concrete mixtures in accordance with IS: 279-2015 standards as shown in Table 1. The Zone II rating of a concrete mix depends upon an array of variables, such as the makeup of the smaller particles. For added strength and volume, coarse aggregate—crushed silicon dioxide stones no larger than 10 mm—was used into the cement mixtures.

Table 1. A description of the properties of OPC (ordinary Portland cement)

Attribute	Description	Attribute
Grade of Cement grade	43	Grade of Cement grade
Specific Gravity	3.15	Specific Gravity
Normal Consistency	25-30%	Normal Consistency
Initial Setting time	30 minutes	Initial Setting time
Final Setting time	600 minutes	Final Setting time
3 days compressive strength	22 N/mm²	3 days compressive strength
7 days compressive strength	33 N/mm²	7 days compressive strength
28 days compressive strength	43 N/mm²	28 days compressive strength

Grade 43 cement is commonly used in construction projects, as shown in the table below. Compressive strength is an important feature of Grade 43, which is essential to the structural integrity of the material. Its specific gravity is 3.15, which indicates its density in relationship to water, and its consistency is typically 25-30%, making it a very workable cement. Application and curing can be completed during the initial 30 minute setting period and the final 600 minute setting period. During 3 days (22 N/mm2), 7 days (33 N/mm2), and 28 days (43 N/mm2), the compressive strength values show a progressive increase, which is vital to ensuring that concrete structures remain stable and durable.

Table 2: Natural and manufactured sand have different properties

S. No	Characteristic	Natural-Sand	Manufactured-Sand
1	Density (Specific Gravity)	2.59	2.67
2	Absorption of Water	6.5%	5.6%
3	Modulus of Fineness	2.88	2.82

The Present Table 2 compares the characteristics of artificial and natural sand. The specific gravity of manufactured sand is 2.67, somewhat higher than that of natural sand, which is 2.59. The percentage with which artificially created sand absorbs water is 5.6%, in comparison to 6.5% for natural sand. Moreover, an average modulus of fineness of produced sand is 2.82, compared to 2.88 for natural sand. Using these values, construction material selection and performance evaluation can be improved by gaining insight into how natural sands differ from manufactured sands in terms of their physical characteristics.

Table 3: Coarse Aggregate's characteristics

S. No	Property	Value
1	Particular Gravity	2.85
3	Absorption of Water	0.90%
4	Index of Flakiness	20%
5	Index of Elongation	20%
6	Fineness Crushing	21.33%
7	Impact Value	15.40%
8	Value The modulus	6.65

The Table 3 outlines several key properties of a specific material, likely an aggregate used in construction. Firstly, the specific gravity is noted at 2.85, indicating its density relative to water. Additionally, its water absorption rate stands at 0.90%, highlighting its propensity to absorb water when submerged. Moreover, both the flakiness index and elongation index are recorded at 20%, illustrating the percentage of particles in the material that are flat or elongated. The crushing value of 21.33% indicates the fines produced upon crushing, while the impact value of 15.40% reflects the material's resistance to impact loads. Lastly, the fineness modulus of 6.65 suggests the overall fineness or coarseness of the aggregate particles. These properties collectively influence the material's suitability and performance in various construction applications.

3 Results and Discussion

The primary focus of this experimental study is to investigate the impact of substituting natural sand with manufactured sand at different percentages (25%, 50%, 75%, and 100%) on the hardened properties of concrete, particularly the compressive strength. The experimental procedure encompasses the casting, curing, and subsequent testing of concrete specimens. These specimens are subjected to various proportions of manufactured sand in M30 grade concrete mixes, namely M30 with 25% M-sand, M30 with 50% M-sand, M30 with 75% M-sand, and M30 with 100% M-sand. By using extensive testing, like the evaluation of split tensile, flexibility, and compressible strengths, the comparative research aims to find any significant variations in the outcomes of concrete mixes including various amounts of manufactured sand. We analyze and present the results of these tests in order to shed light on the effect that manufactured sand has on concrete's mechanical properties.

Table 4: M30 Grade after 14, 28 and 60 days in compression strength (N/mm^2)

S. No.	**Ratio of Manufactured Sand to Natural Sand**	**Compressive Strength (N/mm^2)**
S1	25% Manufactured, 75% Natural Sand	34
S2	50% Manufactured, 50% Natural Sand	36
S3	75% Manufactured, 25% Natural Sand	38

The percentage of manufactured sand that are substituted for natural sand, along with the associated compressive strengths expressed in N/mm², are shown in Table 4. After starting with a 25% substitution rate for synthetic sand and a 75% substitution rate for natural sand, 34 N/mm² was the resultant compressive strength. The compressive strength improved to 36 N/mm² when the amount of manufactured sand was increased to 50% and the percentage of natural sand was decreased to the same extent. The compressive strength then rose to 38 N/mm² at a substitution rate of 75% for synthetic sand and 25% for natural sand. The greatest compressive strength of 40 N/mm² was finally achieved by completely replacing natural sand with manufactured sand, or 100% manufactured sand and 0% natural sand.

Table 5: M30 grade split tensile strength versus 14 and 28 day tests

S. No.	Ratio of Manufactured Sand to Natural Sand	**Spilt Tensile Strength (N/mm^2)**
S1	25% Manufactured, 75% Natural Sand	3.25
S2	50% Manufactured, 50% Natural Sand	3.5
S3	75% Manufactured, 25% Natural Sand	3.6
S4	0% Natural Sand,	3.7

Table 5 shown in Based on their split tensile strengths measured in N/mm2, the table below shows what percentage of natural sand is replaced by manufactured sand. After substituting 25% of the natural sand for manufactured sand, the resulting split tensile strength measured 3.25 N/mm2. A split tensile strength of 3.5 N/mm2 was achieved by increasing the proportion of manufactured sand to 50% and reducing the natural sand to 25%. In addition, the split tensile strength increased further to 3.6 N/mm2 when manufactured sand was substituted for 75% of natural sand. Finally, when natural sand was totally substituted with manufactured sand, a formulation containing 100% synthetic sand and 0% natural sand produced a split tensile strength of 3.7 N/mm2.

Table 6: M30 grade flexural tensile strength versus 14 and 28 day tests

S. No.	Ratio of Manufactured Sand to Natural Sand	Flexural Strength (N/mm2)
S1	25% Manufactured, 75% Natural Sand	3.6
S2	50% Manufactured, 50% Natural Sand	3.8
S3	75% Manufactured, 25% Natural Sand	3.9
S4	0% Natural Sand	4.2

Natural sand replacement percentages are provided in the Table 6, along with the flexural strengths of products corresponding to those replacement percentages, measured in N/mm2. The flexural strength was recorded at 3.6 N/mm2 when manufactured sand was substituted at a rate of 25% and natural sand at a rate of 75%. A flexural strength of 3.8 N/mm2 was reached when the proportion of manufactured sand increased to 50% while the proportion of natural sand decreased. Subsequently, at a substitution rate of 75% for manufactured sand and 25% for natural sand, the flexural strength further increased to 3.9 N/mm². Finally, complete replacement of natural sand with manufactured sand, constituting 100% manufactured sand and 0% natural sand, yielded the highest flexural strength of 4.2 N/mm².

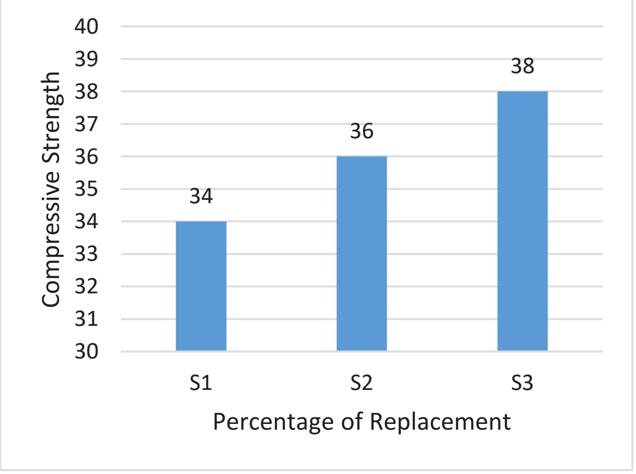

Fig. 1: Comparatively results of compressive strength for M30 grade of concrete

The compressive strengths of concrete samples that were exposed to different ratios of manufactured sand to natural sand replacement are compared in this Fig. 1. This diagram illustrates the impact of replacing all natural sand in concrete mixes with manufactured sand. Interestingly, at 40 N/mm², this substitution produced the most compressive strength yet measured. These results highlight the possible advantages of using synthetic sand in place of natural sand for producing concrete, implying improved strength characteristics in the

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finished concrete samples. This comparative approach helps with concrete mixture optimization for better performance and sustainability in construction processes.

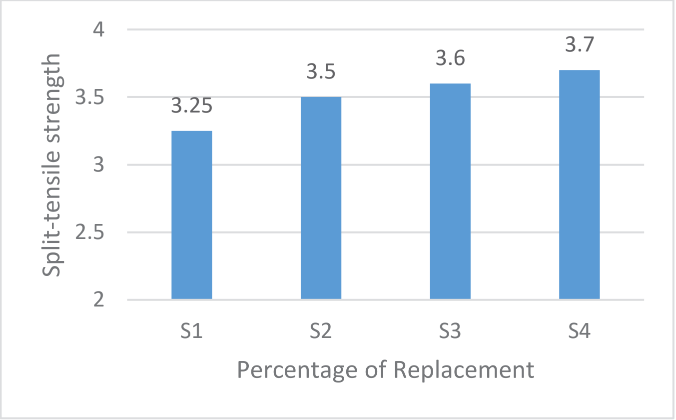

Fig. 2: Comparatively results of spilt tensile strength for M30 grade of concrete

Data on the split tensile strength of concrete samples exposed to various percentages of artificial sand substituted for natural sand are shown in Fig. 2. Higher percentages of produced sand are invariably linked with better spilt tensile strength. There is no doubt that specimens of concrete with 100% manufactured sand (0% natural sand) exhibited the highest spilt tensile strength, measured at 3.7 N/mm2. Comparing manufactured sand to other replacement ratios, this outcome suggests that manufactured sand improves tensile strength in concrete.

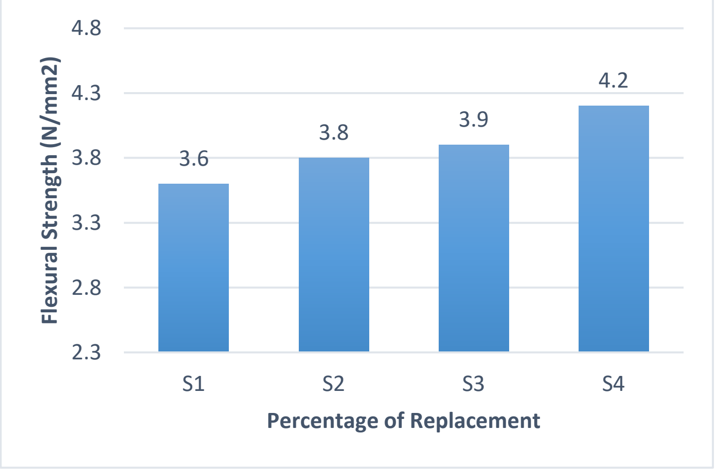

Fig. 3: Comparatively results of flexural strength for M30 grade of concrete

In the Fig. 3, different replacement percentages of natural sand by manufactured sand are shown as a comparative analysis of the flexural strength of concrete samples. With increasing proportions of manufactured sand, flexural strength shows a consistent improvement. As a result, concrete specimens with 100% manufactured sand (0% natural sand) acquired the greatest flexural strength, measuring 4.2 N/mm2, demonstrating manufactured sand's favourable influence on concrete's flexural strength. Combining these results, we can say that artificial sand can increase concrete compositions' flexural strength without lowering the strength of natural sand.

6 Conclusion

These samples are made from M30 grade concrete mixes that have different amounts of synthetic sand in them. There are four different amounts of M-sand in these mixes: 25%, 50%, 75%, and 100%. This study uses extensive testing methodologies, such as flexural strength, split tensile strength, and compressive strength, to assess the effectiveness of substituting manufactured sand for natural sand in concrete compositions. The research work revealed a lot about the behavior of concrete when different percentages of manufactured sand were used as a substitution for natural sand.

- In an academic work of concrete samples with varying parts of manufactured sand and natural sand replacement ratios, 40 N/mm2 was the highest compressive strength measured when natural sand was completely replaced with manufactured sand in a complete replacement process, where the manufactured sand completely got replaced by natural sand in a replacement procedure.
- With the rise in manufactured sand percentage, and in combination of tensile, strength of concrete split increased consistently. It was found that concrete specimens containing 100% manufactured sand exhibited the strongest strength with 3.7 N/mm2 as their maximum strength in this process.
- This analysis exhibits the flexural strength of concrete specimens increased as the proportion manufactured sand was increased. Manufactured sand has a greater flexural strength exhibiting its maximum strength.
- It has been seen that sand substituted with manufactured sand enhanced the strength properties of concrete specimens, this will lead in future concrete production.

The conclusion drawn from this study have demonstrated that manufactured sand is a highly effective alternative to natural sand as an increase in the flexural strength of the concrete composition in building and infrastructure sectors.This contributes to ongoing endeavors aimed at optimizing concrete mixtures for improved performance and sustainability.

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