# Comparative Analysis of Concrete Properties using Natural Sand and Manufactured Sand: An Experimental Study

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**Abstract** - Sand is a natural material composed of tiny particles of decomposed rocks, shells, or corals. Its properties make it an essential component of construction materials like asphalt and concrete, as well as a decorative element in landscaping. However, river sand, which is commonly used as fine aggregate in concrete production, is becoming scarce and expensive due to transportation costs and environmental issues. This has led to the need for an alternative material that can replace river sand in the construction industry. Manufactured Sand (M. Sand) is a residue or waste material that is produced after the extraction and processing of rocks, with a particle size less than 4.75 mm. It is used extensively in building construction, highways, and for manufacturing of concrete prefabricated elements. This paper presents the feasibility of using M. Sand as a substitute for natural sand in concrete, by reporting various tests conducted on cubes to compare the strength of M. Sand and natural sand concrete. The results showed that the compressive strength of M. Sand concrete was comparable to conventional concrete made with natural sand.

**Index Terms** – Manufactured Sand (M. Sand), compressive strength, sieve analysis, natural sand .

## I. INTRODUCTION

### 1.1 General

Sand has been used for thousands of years for grinding, polishing, and construction. In the United States, sand was first used to produce glass in the 1600s, and the production of sand for construction grew significantly during World War I and the 1920s. Today, sand processing is a multi-billion dollar industry, with operations ranging from small plants to large, highly automated facilities. In India, traditional concrete is made using natural sand obtained from riverbeds, which is a costly and scarce ingredient. Due to the growing demand for concrete in construction projects, excessive quarrying of sand from riverbeds is taking place, leading to the depletion of sand resources. To address this issue, there is a need for a suitable substitute for natural sand. One such substitute is to crush natural stones to obtain artificial sand of desired size and grade. The non-renewable nature of natural sand and the increasing demand of the construction industry has made finding an alternative to river sand a necessity. The cheapest and easiest alternative to natural sand is to manufacture sand by crushing rocks/stones in a suitable method to obtain sand of the desired size and grade, which is known as manufactured/crusher/artificial sand. Compared to other conventional materials, the cost of crushed stone sand is relatively low. M-sand costs around Rs. 500 per ton, whereas natural sand costs Rs. 900 per ton. Additionally, crushed stone sand requires less water and has excellent load bearing capabilities and durability. Instead of being wasted, it can be used in various construction processes. To determine its suitability as an alternative to natural sand, various tests will be performed to analyze its properties. The goal of this work is to study the feasibility of replacing river sand by incorporating manufactured sand in various construction processes.

For the analysis, the M30 mix was used as the base. Crushed stone sand was used to partially or fully replace the aggregates. The test results show that crushed stone sand can effectively replace the natural sand.

### 1.2 Need for Replacing Natural Sand with Manufactured Sand for Construction purposes

There are several factors that have led to the replacement of natural sand with manufactured sand. These include:

a. the depletion of natural sand resources due to excessive mining and the resulting ecological imbalance.
b. the low quality of natural sand due to its high percentage of silt and clay which reduces the strength of concrete and holds dampness.
c. the presence of impurities such as mica, coal, fossils and other organic matter above certain percentage which makes the sand useless for concrete work.
d. manufactured sand can be produced to meet specific requirements for particle size, shape and texture, which can improve the quality and durability of concrete.

e. the use of manufactured sand helps to reduce the environmental impact of sand mining on river systems and other sensitive ecosystems.
f. cost effectiveness of manufactured sand over natural sand.

## II. LITERATURE SURVEY

### 2.1 Investigations on flexural behavior of high strength manufactured sand concrete: Opportunities and Solutions in Structural Engineering and Construction © 2010 Taylor & Francis Group, London, ISBN 978-0-415-56809- 8.

**V. Bhikshma, R. Kishore & C.V. Raghu Pathi** discussed the need to find a suitable substitute for natural sand, which is a key component of concrete construction. The authors experimented with manufactured sand as an alternative fine aggregate and studied its properties in M50 grade concrete. The strength properties, including compressive strength and flexural strength, load carrying capacity, and behavior of strains in compression and tension fibers were analyzed for 15 cube specimens of size 150 x 150 x 150 mm and 10 beam specimens of size 1500 x 150 x 230 mm. The results were compared to those of specimens made with natural fine aggregate.

### 2.2 The Use of Manufactured Sand in Concrete Production: Test Results and Cost Comparison: Addis Ababa University School of Graduate Studies.

**Shewaferaw Dinku Belay** conducted research on the use of manufactured sand in concrete production, which is a term for aggregate materials that are less than 4.75mm and processed from crushed rock or gravel. Due to the depletion of natural sand resources and its increasing cost, the study aimed to investigate the effect of manufactured sand on the compressive strength of concrete, compare the cost of different mix compositions, and assess the potential of using manufactured sand as a replacement for natural sand in Ethiopia. The results showed that using a proportion of both natural and manufactured sand in concrete achieved higher compressive strength than using 100% natural sand or 100% manufactured sand. The combination of natural and manufactured sand in a 50% proportion resulted in a mean compressive strength of about C-75 concrete, which was 93MPa. However, when 100% natural sand or 100% manufactured sand was used in the same proportion, the mean compressive strength was 88MPa, indicating that the appropriate mixture of natural and manufactured sand can improve compressive strength. The irregular shape and fine particles in manufactured sand contributed to the improved strength of the concrete. The research also revealed that there was no significant cost variation observed for mixes with fully or partial replacement of manufactured sand with natural sand. The use of manufactured sand in construction can prevent unnecessary damage to the environment and optimize resource exploitation.

### 2.3 Strength Studies on Self Compacting Concrete with Manufactured Sand as Partial Replacement of Natural Sand: International Journal of Scientific & Engineering Research Volume 3, Issue 9, September-2012 1 ISSN 2229-5518

The study conducted by **L. Kothai and R. Malathy** focused on the use of manufactured sand as a partial replacement for natural sand in self-compacting concrete. The goal was to determine the optimal proportion of manufactured sand to natural sand to achieve the highest mechanical strength properties, including compressive strength, split tensile strength, and flexural strength. The study found that using manufactured sand with a 30% replacement to sand, in the presence of fly ash, resulted in the highest strength of concrete. The study also establishes a relationship between compressive strength, split tensile strength, and flexural strength based on the test results. The study recommends the use of quarry fines as a cheap and environmentally friendly partial replacement material for natural aggregates in concrete to reduce costs and promote waste reduction and resource conservation. According to the study, the substitution of manufactured sand beyond the optimum value of replacement positively affects the compressive, tensile, and flexural strength of concrete.

### 2.4 Replacement of Natural sand with Manufactured sand

In order to overcome the limitations posed by environmental, transportation, and other factors that make natural sand less appealing for concrete production, **N. Vivek** conducted an experiment on the replacement of natural sand with manufactured sand. Manufactured sand has been available for quite some time, but people tend to focus on mimicking natural sand rather than taking advantage of the unique properties that good quality manufactured sand can offer to improve concrete performance. Nowadays, manufactured sand is being widely used across the globe, and it is increasingly important to understand the differences between manufactured and natural sand. Acceptance of high percentages of minus 75 micron (200 meshes) materials in manufactured sand, along with advancements in processing technology, have helped increase the popularity of manufactured sand.

**2.5 Specification and Use of Manufactured Sand in Concrete: Cement Concrete & Aggregates Australia 2008, ISBN 978-1-877023-25- 5.**

The primary goal of crushing and sizing rock in a quarry is to produce coarse aggregates and road construction materials that meet specific criteria. However, this process often results in a surplus of fine particles with variable properties that are smaller than 5 mm. The pre-mixed concrete industry has been trying to find ways to utilize this material as a controlled replacement for natural sand. In this study, it has been recognized that by appropriately processing and selecting suitable materials, this excess fines can be turned into a sand replacement that meets the highest quality concrete specifications. Manufactured sand is a crushed fine aggregate that is made specifically from a suitable source material. Typically, it involves crushing, screening, and washing.

## III. MATERIAL USED

This study utilized crushed stone as the replacement for natural sand in the concrete mix. The concrete mix used in the research was of M30 grade, which is commonly used in RCC work due to its high strength. Physical properties of the stone dust, such as sieve analysis and specific gravity, were determined through lab tests. The mix proportioning for M30 grade concrete was carried out following IS 10262-2009 after testing the aggregates, cement, and crushed stone. The raw materials used in the preparation of the M30 grade concrete are mentioned below.

**3.1 Cement :** This study used Ordinary Portland cement of 53 grade that is available in the local market. Cement is a material with adhesive and cohesive properties and is used to bind the particles into whole compact.

**3.2 Coarse Aggregate :** Coarse aggregate with an average size of 20mm is used. The coarse aggregate must be clean and free from impurities like dust, clay particles, organic matter, etc. Different properties of the coarse aggregate have been tested and the results are presented in a table. The particle size distribution of the coarse aggregate is nearly uniform with an average size of 20mm.

**3.3 Natural Sand (River Sand) :** River sand is the natural material used as fine aggregate in construction, and it is the most commonly used material for this purpose. However, due to recent social factors, there has been a shortage of river sand, causing problems in the construction industry. In this study, river sand from zone II was used as the fine aggregate in all the references.

**3.4 Manufactured Sand :** The study utilized manufactured sand (M-Sand) that meets the specifications for zone II as per IS:383-1970. The M-Sand was tested according to Indian Standard Specification and was obtained from a local supplier.

**3.5 Water :** The water used for mixing and curing of concrete must be clean and free from substances such as oils, acids, alkalis, salts, organic materials, and other harmful materials that could be detrimental to the concrete. Potable water is used for mixing and curing of concrete, as per the recommendations specified in the IS:456-2000 standard.

## IV. TESTS CONDUCTED AND RESULTS

### 4.1 Sieve Analysis

The particle size distribution of manufactured sand and natural sand was determined through a process called sieve analysis, which involved taking a 1000-gram sample of the material and sieving it for 10 minutes. The results of the test were recorded in a tabular form**.**

**Table 4.1 Sieve Analysis of Manufactured Sand**

| IS Sieve No. | Wt. retained on each sieve in (gm) | Cumulative Wt. retained | Cumulative Wt. retained % (A) | % Passing | Limits as per IS 383 (Zone II) |
|---|---|---|---|---|---|
| 4.75 mm | 0 | 0 | 0 | 100 | 90-100 |
| 2.36 mm | 4 | 4 | 0.4 | 99.6 | 75-100 |
| 1.18 mm | 333 | 337 | 33.7 | 66.3 | 55-90 |
| 600 micron | 278 | 615 | 61.5 | 38.5 | 35-59 |
| 300 micron | 199 | 814 | 81.4 | 18.6 | 8-30 |
| 150 micron | 125 | 939 | 93.9 | 6.1 | 0-20 |
| 75 micron | 50 | 989 | 98.9 | 1.1 | 0-10 |
| Pan | 11 | | | | |

Fineness Modulus of Manufactured Sand = (Sum of Cumulative wt. retained %)/100 = 2.7

**Table 4.2 Sieve Analysis of Natural Sand**

| IS Sieve No. | Wt. retained on each sieve in (gm) | Cumulative Wt. retained | Cumulative Wt. retained % (A) | % Passing | Limits as per IS 383 (Zone II) |
|---|---|---|---|---|---|
| 4.75 mm | 0 | 0 | 0 | 100 | 90-100 |
| 2.36 mm | 3 | 3 | 0.3 | 99.7 | 75-100 |
| 1.18 mm | 107 | 110 | 11 | 89 | 55-90 |
| 600 micron | 300 | 410 | 41 | 59 | 35-59 |
| 300 micron | 413 | 823 | 82.3 | 17.7 | 8-30 |
| 150 micron | 146 | 969 | 96.9 | 3.1 | 0-20 |
| 75 micron | 21 | 990 | 99 | 1 | 0-10 |
| Pan | 10 | | | | |

Fineness Modulus of Manufactured Sand = (Sum of Cumulative wt. retained %)/100 = 2.3
The Fineness Modulus lies in the range of 2.2 – 3.5, hence the samples of manufactured sand and the natural sand are in the limits of Zone II as per IS 383.

### 4.2 Specific Gravity

The specific gravity of crushed stone sand and natural sand was determined by the pycnometer method. The specific gravity of crushed stone sand was found to be 2.81 while the specific gravity of natural sand was found to be 2.40. This indicates that crushed stone sand has a higher specific gravity than natural sand, which leads to higher density. Due to the higher density, crushed stone sand can achieve a higher degree of compaction compared to natural sand.

### 4.3 Concrete Slump Test

The workability of concrete was tested using three different methods: slump cone, compaction factor, and vee-bee time tests. These tests are considered suitable for low workable mixes. During casting, the workability of the mix was measured, and if it did not meet the required slump of 40-80mm, then plasticizer was added to the mix.
The tests were conducted on M30 grade concrete, and the percentage of admixture required for low workable mixes to reach a slump of 40-80mm was determined. The results showed that as the percentage of replacement of natural sand by manufactured sand increased, the slump and compaction factor decreased, and the vee-bee time increased. The percentage of admixture required to reach a slump of 40-80mm also increased as the percentage of replacement of natural sand by manufactured sand increased.
Table showing the workability properties of different proportions of natural sand replaced by manufactured sand was provided, indicating the changes in slump, compaction factor, vee-bee time, and the percentage of admixture required for different mixes.

**Table 4.3 Workability Characteristics of M30 Grade Concrete**

| Mix | Slump (mm) | Compaction factor | Vee-Bee Time(Sec) | % of Admixture Required for Slump(40-80mm) |
|---|---|---|---|---|
| **M30 with 0% of M-Sand** | 50 | 0.91 | 9.2 | 0 |
| **M30 with 20% of M-Sand** | 37 | 0.89 | 13.1 | 0.1 |
| **M30 with 40% of M-Sand** | 20 | 0.87 | 19.9 | 0.2 |
| **M30 with 60% of M-Sand** | 8 | 0.84 | 27.5 | 0.3 |
| **M30 with 100% of M-Sand** | 0 | 0.81 | 36.1 | 0.5 |

### 4.4 Compressive Strength

Initially, after 7 days of curing, concrete made of manufactured sand exhibits lower strength compared to concrete made of natural sand. However, as the curing period extends, the compressive strength of concrete cubes made of M-Sand becomes nearly equivalent to that of natural sand. Since compressive strength is a critical property of concrete considered in design, it is feasible to completely substitute natural sand with manufactured sand in concrete production. The table shows the compressive strength results for a 28-day study period, considering partial replacement by M-sand.

**Table 4.4 Compressive Strength of concrete mix at different levels of replacement**

| Cube designation | Average compressive strength ($N/mm^2$) | | % replacement of Natural sand |
|---|---|---|---|
| | 07 days | 28 days | |
| **CS-1** | 24.80 | 34.20 | 0 |
| **CS-2** | 26.10 | 32.60 | 30 |
| **CS-3** | 25.70 | 34.80 | 40 |
| **CS-4** | 21.80 | 31.60 | 50 |
| **CS-5** | 21.50 | 30.90 | 60 |
| **CS-6** | 19.80 | 30.00 | 70 |

## V. CONCLUSIONS

Based on the results and analysis, the following conclusions have been reached:

- The use of M-sand as a partial replacement for natural sand in concrete is possible due to their similar particle gradation. However, the workability of the concrete increases only up to 40% replacement of natural sand with stone dust, and it decreases beyond this percentage.
- The compressive strength remains unaffected up to 40% replacement level of fine aggregate with manufacturing sand, regardless of the duration of curing.
- This research showed that the use of manufacturing sand in the concrete mix can minimize the mining of natural sand from the river bed which will help to maintain the ecosystem of our environment.
- Replacing the fine aggregate with M-Sand is a more cost-effective option.
- A complete replacement of natural sand with M-Sand is a reasonable option in situations where low workability is acceptable. However, in cases where high workability is required, a partial replacement of natural sand with M-Sand can be considered, taking into account both the strength and cost-effectiveness.

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