Effect of replacement of natural sand by manufactured sand on the self-compacting concrete

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Abstract. This paper investigates the experimental analysis of concrete mixtures with different percentages of manufactured sand replaced for natural sand, with a focus on M25 and M30 grades. The study analyses various repairing times, with a special focus on 3, 14, and 28-day periods. The main conclusions show a clear pattern, with the maximum compressive strength for M25 and M30 grades being found at 50% and 100% replacement levels, respectively. This positive connection indicates that the amount of manufactured sand incorporation affects the compressive strength and shows its effect over different curing times. It is noteworthy that self-compacting concrete (SCC) made using crushed sand has a higher compressive strength than SCC made with natural sand. The study's final findings, that emphasize the beneficial impacts of manufactured sand on SCC's overall compressive strength characteristics, provide crucial data for enhancing concrete mix design. For the purpose of developing M sand, rocks are crushed to a similar size and form as natural sand or N-sand. The possible use of M-sand in SCC has been addressed in this paper. In this study, an effort has been made to analyze the potential use of M-sand in SCC. Self-Compacting Concrete (SCC) is a revolutionary concrete that allows for compaction and placement without the requirement for vibration. It may flow under its own weight even in the centre of dense reinforcement, entirely covering formwork and achieving full compaction. An attempt has been made to compare the characteristics of M35 self-compacting concrete in each its fresh and hardened states, substituting manufactured sand for river sand.

Keyword*: Concrete grade of M25, M30, manufactured sand, natural sand, concrete mixtures, and compressive strength,

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1 Introduction

Self-compacting concrete (SCC), a significant advancement in concrete technology, is a highly flowable mixture that self-consolidates without the need for external vibration. This innovative material makes regular concrete installation difficult in hard-to-reach areas and quantities with dense reinforcement since it does not require conventional compaction techniques. Due to its outstanding characteristics, particularly its lack of bleeding and segregation, SCC is highly preferred for usage in concrete pavements [1-3]. Systems with complex reinforcing frameworks or confined access for the application of concrete are specifically appropriate for it. An efficient SCC design requires striking the right balance between resistance to segregation and flexibility—qualities that at first glance appear to be incompatible. This high-quality equilibrium is as a result of a considerable dosage of excellent plasticizer, a higher powder content material, a most reliable water-to-powder ratio, a larger quantity of fine aggregate than coarse aggregate, and so on [4-6]. When opposed to typical concrete, self-compacting concrete (SCC) offers several advantages in terms of placement and production. These advantages include improved workability, pumpability, flowability, and bonding with crowded reinforcing, as well as the removal of internal or external vibration for compaction. In addition, SCC placement takes less work and happens faster. When compared to conventional concrete, SCC can have significantly improved durability, mechanical performance, and appearance (surface finish). On the other hand, SCC depends on the manufacture, positioning, quality control, and finishing techniques. If relevant standards, rules, or practices are not adequately followed for manufacture and placement, constructability concerns may potentially occur for specifiers and contractors. Concrete that self-compacts is less resilient to sudden variations in the water content, chemical admixtures, and aggregate moisture content [7-9].

The qualities of SCC can be impacted by the kind of concrete mixer used, the duration of the transport, and the techniques used for placing and finishing the concrete. As a result, stringent quality control procedures need to be followed when producing and distributing SCC. Because SCC flows more easily than regular concrete, pumping is the most effective way to put it [10-13]. A larger flow rate, however, increases the likelihood of air entrainment and can cause segregation and bugholes. SCC typically has less surface defects than regular concrete, but if production and placement rules were not properly followed, it would be prone to cracking, honeycombing, and bugholes. SCC typically has an enormous powder content to ensure excellent cohesion and flow characteristics [14,15]. To generate profits, fly ash can replace a vast portion of this powder, particularly in regions like India where there are abundant quantities of low-calcium fly ash from several coal-based thermal power plants [16-20]. Presently increasing prospects for fly ash to be widely used in construction projects across the country since individuals become aware of its advantages in SCC. Self-Compacting Concrete (SCC) is a new type of concrete mixture that requires no external vibration to fully compact. Its exceptional flexibility allows for easy insertion in challenging circumstances and locations with intricate reinforcing [21-22]. SCC changed the use of concrete pavement by offering a solution to issues such as segregation and bleeding. This state-of-the-art method works extremely well for placing concrete in structures with complex reinforcing arrangements or restricted access [24].

![Fig. 1. Self compacting concrete [8]](image-url)
The concept of self-compacting concrete (SCC) emerged in 1988 as a means of producing durable concrete structures. The practical uses and extensive research of large construction enterprises have led to a gradual evolution in the knowledge and application of SCC in Japan [22]. This paper focuses on three different types of mixes with varying concentrations of fly ash (FA), silica fume (SF), and a mixture of SF and FA. Through the application of distinct cement percentages, SCC is experimentally investigated. This experiment evaluates the compressive strength of SCC under different curing settings by appropriately casting, curing, and evaluating the specimens as shown in Fig. 1. The mixes with 30% FA did not demonstrate the same compressive strength as the SCC utilizing 15% SF, according to the data; specimens that were water cured for 28 days had the highest energy values. The purpose of curing, casting, and assessing the specimens has been fulfilled for determining the SCC’s compressive strength under various curing conditions [23]. The study emphasises the necessity for substitute resources, especially given Tamil Nadu's dearth of naturally occurring river sand. Experiments examining the characteristics of M-sand from different sources provide information for mix designs for different classes of concrete, indicating that M-sand can be a good alternative [26]. The practical applicability of the developed mix proportions is validated by further assessments of the properties of both fresh and hardened concrete [27]. This multidisciplinary study advances our knowledge of SCC and M-sand and how to apply them in the field concrete technology. It is necessary to investigate several stresses induced in such coatings, especially residual stress. Self-Compacting Concrete (SCC) is a distinctive type of concrete that flows into and fully occupies the formwork under its own weight without needing mechanical vibration, thanks to its low viscosity and high workability. The key attribute of SCC lies in its unique fluidity combined with stability, which refers to its ability to resist material segregation, whether in motion (during transport) or at rest (after being placed). This innovative form of concrete aims to enhance certain practices within the construction industry.

Industry professionals consider SCC to be the most significant advancement in concrete technology over the past five decades. Unlike traditional concrete, SCC's mix design incorporates higher amounts of fines, filler aggregates, and specific admixtures such as plasticizers and viscosity-modifying agents (VMA), tailored to improve its properties. One of the primary challenges in producing SCC has been sourcing sufficient quantities of fine aggregates. In the context of asphalt concrete production mentioned earlier, excess electric arc furnace (EAF) slag filler, which accumulated in baghouse filters, was identified as a potential solution to this issue [28].

2 Methodology

The foremost goal of this experimental study's is to determine how the characteristics of self-compacting concrete (SCC) are affected when 50% and 100% of the natural sand is replaced with manufactured sand [29-31]. An orderly method is used within the studies, with concrete specimens being exactly cast, cured, and then examined in a controlled environment. With the intention to offer an in-depth evaluation, the experimental framework compares a complete of four concrete mixes, each of which is differentiated by means of a unique cement-to-water ratio and mortar composition. Mix 1, which makes use of a 50/50 combination of manufactured and natural sand, is the standard mix. However, mix 2 is distinguished via a complete alternative, using most effective manufactured sand and getting rid of natural sand. A thorough examination of the effect of different ranges of sand replenishment on the mechanical and physical properties of self-compacting concrete is made possible via the implementation of a step-by-step technique. Consequently, this offers concluding views at the feasibility and effect on performance of incorporating those replacements into construction techniques.
Table 1. Requirements material

<table>
<thead>
<tr>
<th>S.no</th>
<th>Required Material</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Concrete grade</td>
<td>M25, M30</td>
</tr>
<tr>
<td>2</td>
<td>Cement</td>
<td>OPC</td>
</tr>
<tr>
<td>3</td>
<td>Aggregate size</td>
<td>10mm</td>
</tr>
<tr>
<td>4</td>
<td>Workability</td>
<td>80mm (slump)</td>
</tr>
<tr>
<td>5</td>
<td>Degree of Quality Control</td>
<td>Good</td>
</tr>
<tr>
<td>6</td>
<td>Exposure type</td>
<td>Severe</td>
</tr>
<tr>
<td>7</td>
<td>Admixture of Chemical type</td>
<td>Hyper Plasticize</td>
</tr>
</tbody>
</table>

While figuring out the materials and matching high-quality necessities required for a building project, Table 1 can be referred as it describes the details of several materials [32]. It cautiously describes the properties and requirements of quality for every material component, making sure that every preference is consistent with the project's necessities for durability and structural integrity. The concrete grades M25 and M30, which are selected to meet the task's specific structural requirements based on their composition and compressive strength, are shown in the table 1. It allows a thorough approach to material choice that highlights the project's dedication to structural excellence and durability by way of providing specifications that guarantee the substances used within the construction comply to the structural requirement and quality.

3 Material Investigation

Three systematic steps contain the inquiry on the usage of manufactured sand in self-compacting concrete (SCC). The observation starts by comparing the raw elements which are used to make concrete, focusing precise on how properly-desirable and high-quality they may be for creating concrete mixes which are rated M25 and M30. Throughout this step, materials are carefully examined and the results are meticulously documented. Final findings are then used to create genuine blend designs which might be precise to positive improvement in concrete strength [33]. The subsequent step optimizes the combination for better fluidity and workability by way of adjusting the coarse and fine aggregate proportions to suit the stern specifications particular to Self-Compacting Concrete, which include the ones located in the course of slump flow and Vee tests. The investigation's last phase focuses on the experimental substitution of manufactured sand for natural sand within the SCC, examining the impacts of 50% and 100% substitution rates. This methodological approach aims to provide a thorough understanding of the possible advantages and limits of manufactured sand in self-compacting concrete applications by carefully examining how it affects the different characteristics of the material.

3.1 M Sand

Throughout the production process, the product identified as Manufactured Sand is intended to maintain its cubic shape. M-sand particles' unique form add to the concrete structures' increase strength and longer lifespan. M-sand provides a noticeable 10-15% boost in compressive strength for concrete and a significant 20-30% gain in strength for masonry projects when compared to normal sand [35-39]. Two grades of M-sand are available to suit different plastering and concreting needs. One benefit is that since M-sand is carefully treated to satisfy uniform quality requirements, there is no longer a need for sand filtering. M-sand is a product of crushing hard granite stone. It has a cubic shape and ground edges, making it suitable for a variety of construction uses. It is a finely graded aggregate made from crushed stone, gravel, or slag that can be used in building instead of river sand because it is more
environmentally friendly. Table 2 presents the fundamental characteristics of sand utilised in building, together with comprehensive details and measurements.

**Table 2. Properties of fine aggregate (for manufactured sand)**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grading of Sand Zone I as per IS 383</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Specific Gravity</td>
<td>2.59</td>
</tr>
<tr>
<td>3</td>
<td>Density (Compacted)</td>
<td>1732 kg/m³</td>
</tr>
<tr>
<td>4</td>
<td>Absorption of Water</td>
<td>2.18 %</td>
</tr>
<tr>
<td>5</td>
<td>Fineness Modulus</td>
<td>2.97</td>
</tr>
<tr>
<td>6</td>
<td>Fines</td>
<td>5 %</td>
</tr>
</tbody>
</table>

The information provided in Table 2 describes the properties of sand that, in accordance with IS 383 standards, falls into Zone I, making it easier to determine whether or not it is suitable for use in building applications. The specific gravity of 2.59 of the sand indicates its density in relation to water. When compressed, its density of 1732 kg/m³ gives information about how much mass it can fit into a certain volume. The sand's ability to hold water is demonstrated by its water absorption rate of 2.18%, which has an impact on mix consistency and curing. The coarseness or fineness of the sand is categorised by the fineness modulus of 2.97, which affects the workability and strength of the mortar or concrete. Finally, it has 5% fines, or particles smaller than 75 microns, which have an impact on the final mix's smoothness and the sand's ability to bond.

### 3.2 N sand

Typically falling between 0.075 and 4.75 millimetres (mm) in diameter, fine to medium-sized grains define natural river sand, which is a popular building material. River sand is often light in colour, with beige or light grey tones frequently being seen. Water's abrasive pressures over time have produced well-worn, rounded particle forms, giving it a smooth, rounded texture. Because of its desirable qualities and versatility, natural river sand is widely used in construction operations. It is essential for the manufacture of concrete and mortar, landscaping projects, and different civil engineering applications. Although the precise grading requirements are not stated, the table lists the many qualities of sand, which is classified as Zone II by IS 383 standards. The specific gravity of 2.59 of the sand indicates its density in relation to water. Its density of 1671 kg/m³ makes it easier to calculate how much sand there is in a given volume. The sand's ability to absorb water is shown by its 1.61% absorption water percentage, which impacts both its moisture content and workability in mixes. The sand's particle size distribution is gauged by the fineness modulus, which is 2.45 and indicates a medium coarseness. Finally, 2% of the sand's particles are finer than 75 microns, which affects how well the sand performs overall in mortar or concrete.

**Table 3. Properties of fine aggregate (for natural sand)**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grading of Sand Zone II as per IS 383</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
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</tr>
<tr>
<td>3</td>
<td>Density</td>
<td>1671 kg/m³</td>
</tr>
<tr>
<td>4</td>
<td>Absorption Water</td>
<td>1.61 %</td>
</tr>
<tr>
<td>5</td>
<td>Fineness Modulus</td>
<td>2.45</td>
</tr>
</tbody>
</table>
Every material that was used could be found locally in India and its surrounding areas. To prevent grading, manufactured sand is carried in a moist state. It is possible to conclude that the characteristics of coarse aggregate meet the requirements because Table 3 displays cement properties that are within permitted bounds. These findings suggest that while manufactured and natural sand confirm to the same zone, their fineness moduli differ; the manufactured sand has a higher modulus and may produce more strength. Because manufactured sand contains more tiny particles, it has a higher water absorption rate, which could result in a less workable mix[40-42]. Natural sand is spherical, whereas manufactured sand has an angular shape. Creating a concrete mix design is a challenging task mostly because of the wide range of characteristics among the component materials the site-specific parameters such as exposure variables, and the particular needs of the intended use. The complexity of creating a concrete mix requires a deep comprehension of the various characteristics displayed by the component parts used in the procedure.

### 4 Results and Discussion

Self-Compacting Concrete (SCC) is a type of concrete that allows for compaction and placement without the requirement for vibration. It may flow under its own weight even in the centre of dense reinforcement, entirely covering formwork and achieving full compaction. An attempt has been made to compare the characteristics of M35 self-compacting concrete in each of its fresh and hardened states, substituting manufactured sand for river sand. Main goal of this experiment is to find out how the hardened properties of concrete specifically, its compressive strength is affected when natural sand is replaced with manufactured sand at replacement levels of 50% and 100%. Specimens intended for self-compacting concrete are cast, cured, and then tested as part of the experimental process. The comparative analysis includes evaluating the compressive strength factors for various concrete classes, like M25 and M30, provided in Table 4 & 5 and includes altering produced sand amounts in the self-compacting concrete formulation.

**Table 4.** Results of compressive strength (N/mm²) for concrete of M25 grade at 3, 14 and 28 days

| Percentage Substitution of Naturally Occurring Sand with Manufactured Sand | M25 Grade |
|---|---|---|
| | 3 Days | 14 Days | 28 Days |
| 50% M-Sand (50% N-Sand) | 16 | 24 | 26 |
| 100% M-Sand (0% N-Sand) | 18 | 26 | 30 |

The compressible strength of concrete of grade M25 at 3, 14, and 28 days is compared in the Table 4 with varying ratios of manufactured sand (M-Sand) and naturally occurring sand (N-Sand). It displays two mixtures: one with 100% M-Sand and the other with 50% M-Sand and 50% N-Sand. In comparison to the mix including 50% M-Sand and 50% N-Sand, the strength data show that the concrete containing 100% M-Sand continually exhibits a greater compressive strength at all testing intervals. This shows that, in the course of time, it would be more advantageous to use produced sand exclusively for improving the strength of M25 grade concrete.

**Table 5.** Results of compressive strength (N/mm²) for concrete of M30 grade at 3, 14 and 28 days
Percentage replacement of natural sand by manufactured sand

<table>
<thead>
<tr>
<th></th>
<th>M30 Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 Days</td>
</tr>
<tr>
<td>50% M-Sand (50% N-Sand)</td>
<td>18</td>
</tr>
<tr>
<td>100% M-Sand (0% N-Sand)</td>
<td>20</td>
</tr>
</tbody>
</table>

Data on the compressive strength of M30 grade concrete at intervals of 3, 14, and 28 days, along with varying ratios of M-Sand to N-Sand, are shown in the Table 5. It contrasts two scenarios: one in which M-Sand is utilised to replace 50% of the N-Sand, and another in which N-Sand is completely replaced. The findings demonstrate that, in comparison to the mix containing 50% M-Sand and 50% N-Sand, the 100% M-Sand combination for the M30 grade concrete consistently results in greater compressive strengths at all evaluated ages. Given that manufactured sand can completely replace natural sand, more durable concrete could result, as evidenced by the higher values of strength at 3, 14, and 28 days.

![Graph showing compressive strength](image)

**Fig. 2.** The results of measuring the M25 grade concrete's compressive strength at 3, 14 and 28-days intervals are displayed in N/mm².

When it comes to the concrete's compressive strength after 28 days, Fig. 2 illustrates the benefits of having 100% manufactured sand (M-Sand) in the mix as opposed to mixes that only contain 50% M-Sand. When manufactured sand makes up the entire aggregate, as opposed to a blend that contains only half M-Sand and half naturally occurring sand or another material, the data clearly shows an increase in compressive strength. Based on actual research, the strength qualities of the concrete are greatly increased when manufactured sand replaces the entire aggregate after a 28-day curing period. The analysis supports the usage of manufactured sand aggregate above standard mixes that contain only 50% M-Sand by highlighting the possible performance gains in concrete that can be achieved. In essence, this research backs up the idea that replacing all of the natural sand in M25 grade concrete with manufactured sand provides a more durable way to improve the structural integrity of the material over time.
Fig. 3. The outcomes of measuring the compressive strength of M30 grade concrete at 3, 14, and 28-days intervals are displayed in N/mm².

Fig. 3 suggests how utilising 100% manufactured sand for concrete M30 at 28 days should potentially improve compressive strength when compared to 50% M sand. When compared to a mix that comprises 50% manufactured sand, the results show that using 100% manufactured sand at the 28-day curing point significantly improves the compressive strength of concrete of grade M30. This evaluation shows how the concrete's strength measurements are affected by the quantity of sand produced. The outcomes indicate that including more manufactured sand to the concrete aggregate has a massive positive impact on compressive strength. The aforementioned perception highlights the benefits and superior functionality linked to optimizing the use of generated sand in the composition of concrete, particularly during the precise 28-day curing time for M30 grade concrete.

5 Conclusion

This paper investigates the experimental analysis of concrete mixtures with different percentages of manufactured sand replaced for natural sand, with a focus on M25 and M30 grades. The study analyses various repairing times, with a special focus on 3, 14, and 28-day periods. The main conclusions show a clear pattern, with the maximum compressive strength for M25 and M30 grades being found at 50% and 100% replacement levels, respectively. This positive connection indicates that the amount of manufactured sand incorporation affects the compressive strength and shows its effect over different curing times. It is noteworthy that self-compacting concrete (SCC) made using crushed sand has a higher compressive strength than SCC made with natural sand. Overall paper is concluded in the following points:

a. The amount of manufactured sand incorporated affects the compressive strength and its effect over different curing times. SCC made with manufactured sand has higher compressive strength than SCC made with natural sand.

b. An effective comparison between compressive strength in the precise concrete grade and the percentage of manufactured sand as an alternative along with curing instances is provided. Furthermore, self-compacting concrete (SCC) containing manufactured sand has a better compressive strength than SCC which includes natural sand is found. Those persuasive results emphasize the advantages of using...
manufactured sand in the combination and offer helpful facts for optimizing concrete mix designs for SSC.

c. The results of the study suggest a fascinating pattern: the most compressive strength for grades M25 and M30 is obtained at 3, 14, and 28 days while manufactured sand replaces 50% and 100% of natural sand, respectively.

References


