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Replacement of Sand with Various Material for Higher Grade of Concrete

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ABSTRACT
This study investigates the partial replacement of natural sand with industrial and construction waste materials such as quarry dust, foundry sand, and concrete debris. These alternative materials not only help reduce the environmental footprint of concrete production but also offer the potential to enhance specific concrete properties such as compressive strength, durability, and workability. A range of mix designs with varying replacement levels are analyzed to evaluate their effects on the mechanical and physical performance of high-grade concrete.
The research findings indicate that an optimal combination of these waste materials can result in concrete that meets or exceeds standard performance benchmarks for high-strength applications. This promotes sustainable construction practices, encourages waste reutilization, and contributes to the conservation of natural resources, paving the way for environmentally responsible and economically viable concrete technology.
In the quest for sustainable development and eco-friendly construction practices, the replacement of natural sand in concrete with alternative materials has become a crucial area of research, especially for higher-grade concrete like M40 and M50. Natural sand, a non-renewable resource, is extensively used in concrete production, causing environmental degradation and resource scarcity. This study focuses on the partial replacement of natural sand with a combination of quarry dust, foundry sand, and concrete debris to evaluate their suitability in producing high-strength concrete.
A series of mix combinations were developed for M40 and M50 grades by partially replacing 50% of the natural sand using varying proportions of the selected waste materials. Compressive strength tests were conducted at 7 and 28 days to assess the mechanical performance of the mixes. The results indicated a noticeable improvement in strength for several combinations. For instance in M40 concrete a mix with 20% quarry dust 10% foundry sand, and 20% concrete debris achieved a 28-day compressive strength of 51.62 N/mm² surpassing the control mix. Similarly in M50 concrete optimal combinations exhibited strength values exceeding the targeted grade requirements.
The study concludes that the partial replacement of sand with these industrial by-products not only maintains or enhances concrete performance but also contributes to sustainable construction by reducing the demand for natural resources and promoting the reuse of industrial waste. This research supports the practical application of eco-friendly concrete in high-strength structural works, making it a viable alternative for future infrastructure projects.

I. INTRODUCTION

1.1 GENERAL:

Concrete is a fundamental construction material widely employed in the construction industry, known for its exceptional strength and versatility. The compressive strength and workability of concrete are two vital properties that determine its overall performance and suitability for different applications. In this comparative analysis, we delve into the impact of varying sand replacements on these key characteristics across different concrete grades. Hence the demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. The developing country like India facing shortage of good quality natural sand and particularly in India, natural sand deposits are being used up and causing serious threat to environment as well as the society. Rapid extraction of sand from river bed causing so many problems like losing water retaining soil strata, deepening the river beds and causing bank slides, loss of vegetation on the bank of rivers, disturbs the aquatic life as well as disturbs agriculture due to lowering the water table in the well etc. are some of the examples.

Now a day there is a scarcity of sand and it has become very difficult to get sand easily in economical way. Overcoming of this problem is very essential to research the alternative materials. In order to fulfil the requirement of the fine

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aggregates, some alternative material must be found. Hence, in this project it is planned to carry an experimental work by preparing concrete blocks with partial replacement of sand.

The proportion of fine aggregate sand in concrete mixtures plays a significant role in the material's performance. By replacing a portion of the sand with alternative materials and combination of material, such as concrete debris, quarry dust, foundry sand for higher grade of concrete. We aim to assess how these substitutions affect both the compressive strength and workability of the concrete. Understanding these effects is crucial for optimizing concrete mixes for specific construction projects, considering factors like cost-effectiveness, sustainability, and structural integrity.

- **REPLACEMENT OF SAND BY VARIOUS MATERIAL**:

Replacement of sand byvarious material are quarrydust foundry sand and concrete debris.

Quarry dust:Quarry dust is fine rock particles. When boulders are broken into small pieces quarry dust is formed. It is grey in colour and it is like fine aggregate. In concrete production it could be used as a partial or full replacement of natural sand. Besides, the utilization of quarry waste, which itself is a waste material, will reduce the cost of concrete production.

Origin of quarry dust the quarry dust is the by-product which is formed in the processing of the granite stones which broken downs into the coarse aggregates of different sizes.

foundry sand:In construction, foundry sand particularly waste foundry sand can be used as a partial replacement for natural sand, especially in concrete mixtures, due to its similar granular structure and silica content, offering a more environmentally friendly option by reusing industrial waste; however, careful consideration is needed regarding the replacement percentage as too much foundry sand can negatively impact the concrete's strength and workability. The replacement of natural sand with used foundry sand up to 30 Percentage is desirable. As it is cost effective, reduce the amount of fine sand. Use ofwaste foundry sand in concrete reduces the production of waste through metal industries; it is an eco-friendly building material.

Concrete debris:replace natural sand with concrete debris in construction, the most common alternative is recycled concrete aggregate which is crushed concrete from demolished structures, often used as a partial replacement for natural sand in concrete mixtures depending on its particle size and quality. Using recycled concrete helps reduce waste disposal needs and minimizes the demand for virgin materials. Ensure the RCA is properly graded to achieve the desired particle size distribution for your concrete mix.

- **EFFECT OF REPLACEMENT OF SAND ON GRADE OF CONCRETE**:

Replacing sand in concrete with alternative materials can significantly affect the grade of concrete, often impacting its compressive strength, workability, and overall quality, with the specific effect depending on the type of replacement material used and the percentage of substitution; generally, replacing a portion of sand with well-graded crushed aggregate or certain industrial byproducts can sometimes improve concrete strength, while using poorly graded materials may weaken it.

- **REPLACEMENT OF ROLE OF SAND IN HIGHER GRADE OF CONCRETE:**

Quarry dust:-In higher grade concrete, quarry dust can be used as a partial replacement for sand, often leading to improved compressive strength and better overall concrete performance due to its finer particle size and increased surface area for cement bonding, making it a more efficient filler material compared to regular sand; however, careful consideration is needed regarding the percentage of replacement as too much quarry dust can negatively impact workability and may require adjustments to the water-cement ratio to maintain desired consistency.

Foundry Sand:-In higher grade concrete, foundry sand can be used as a partial replacement for regular fine aggregate sand potentially enhancing the concrete's compressive strength and durability when used in moderate quantities typically up to 30Percentage although it may slightly decrease workability and require adjustments to the mix design to maintain desired properties; essentially acting as a more robust aggregate, improving the concrete's overall performance when used appropriately.

1.2 SCOPE OF PROJECT:

A project utilizing quarry dust, concrete debris, and fine sand could focus on developing sustainable construction materials, primarily concrete mixes, where these recycled sand partially or fully replace natural sand like river sand, aiming to reduce environmental impact by reusing waste materials while maintaining acceptable structural strength and performance for applications like

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building foundations, walls, pavements, or precast concrete elements, with a primary focus on optimizing the mix ratios of these recycled materials to achieve desired properties while considering cost-effectiveness and environmental benefits.

1.3 AIM AND OBJECTIVE OF THE PROJECT:

To achieve the compressive strength of high grade concrete by partial replacement of sand by different material.

- **PROPOSED WORK:**

1) Carryout partial replacement of sand by various material such as quarry dust, foundrysand, concrete debris etc. for higher grade of concrete.
2) Proposed to observe effect on various parameters of high grade concrete due to replacement of sand by said materials.
3) Compare the results obtained by different material replaced to the sand.
4) To develop dimensionless chart for the results obtained by various combinations.

1.4 LAYOUT OF DESERTATION:

- **Introduction**

Concrete plays a vital role in the modern construction industry due to its strength, durability, and adaptability. As infrastructure development accelerates in developing countries, especially with high-rise buildings, bridges, and highways, the demand for higher-grade concrete such as M40, M50, and above has significantly increased. The compressive strength and workability of such concrete are critical for achieving desired structural performance. Traditionally, natural river sand has been the primary fine aggregate used in concrete; however, due to excessive mining, riverbeds are depleting, and environmental regulations are becoming more stringent.

This growing scarcity of natural sand, coupled with rising costs, has led researchers and engineers to explore alternative materials that can replace sand in concrete without compromising quality. Materials such as quarry dust, foundry sand, and recycled concrete debris offer promising potential due to their similar granular properties. The primary goal of this study is to investigate the influence of these materials, either individually or in combination, on the strength and workability characteristics of high-grade concrete mixes, and determine their viability in sustainable construction.

- **Literature Review**

Over the last two decades, many studies have focused on the partial or complete replacement of sand in concrete with industrial or construction waste materials. Quarry dust, a by-product of stone crushing, has been found to improve the packing density of concrete and enhance its compressive strength when used in controlled proportions. Similarly, foundry sand, a waste product from metal casting industries, has been tested as a fine aggregate due to its fine texture and silica content. Research findings show that replacing 20Percentage to 30Percentage of sand with quarry dust or foundry sand can yield comparable or even superior results in certain grades of concrete.

Recycled concrete debris is another promising material, particularly in demolition waste management and sustainable construction practices. When crushed and screened, it can serve as a partial sand replacement while reducing the environmental footprint of concrete production. Despite numerous studies, research gaps still exist in understanding the combined effect of these materials in high-strength concrete. This study aims to bridge that gap by evaluating combinations of quarry dust, foundry sand, and debris in M40 and M50 grade concretes to determine their impact on strength and durability.

- **Materials and Mix Design**

This research utilizes OPC 53-grade cement, known for its high early strength, as the primary binding material. The coarse aggregates are angular crushed stones with appropriate gradation. Natural river sand serves as the control material for comparison. The alternatives considered are quarry dust (from stone crushers), foundry sand (from metal casting industries), and concrete debris (from demolished structures). Each material is tested for physical properties such as particle size distribution, specific gravity, and moisture content to ensure suitability.

The concrete mixes are designed as per IS 10262:2019 standards for M40 and M50 grades. Various combinations are prepared by replacing sand partially (e.g., 20Percentage, 30Percentage, and 40Percentage) using a mix of the selected alternatives. Each combination maintains a constant water-cement ratio, and superplasticizers are used where necessary to retain workability. A total of nine trial mixes are formulated, and concrete cubes are cast for testing compressive strength at 7 and 28 days, ensuring a systematic and reliable assessment of performance.

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- **CONCRETE MIX PROPORTION**

Target mean strength for mix design

Target mean strength is a strength of 28 days of concrete considering standard deviation ,characteristic strength (ft = fck + ks).

↓

Selection of Water/Cement ratio

The W/c ratio can be found from table-5 page no. 20 of IS 456-2000 according to exposure condition.

↓

Selection of water content

It can be selected from table 2 of IS 10262-2009 according to size of aggregate and workability need.

↓

Calculation of Cement content

It is checked for minimum cement content according to Exposure condition from Table no-5 IS 456-2000.

↓

Proportion of volume of coarse aggregate and fine aggregate

From table no-3 of IS 10262-2009, according to zone of sand and size of coarse aggregate select volume of coarse aggregate.

↓

Mix Calculations

Considering 1m3 volume concrete in that cement, Fine aggregate ,coarse aggregate water quantity is calculated

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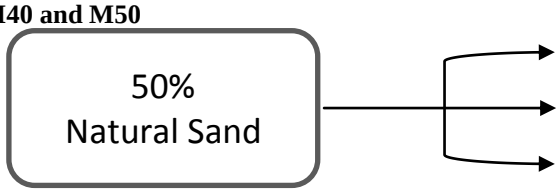
II. METHODOLOGY

The experimental process begins with the collection and testing of raw materials. After confirming that all materials meet IS standards, the mix design is prepared for M40 and M50 grades. For each mix, batching is done by weight to ensure precision. The concrete is mixed thoroughly, poured into standardized molds, and compacted using a vibrating table. Curing is done by immersing the specimens in water for 7 and 28 days.

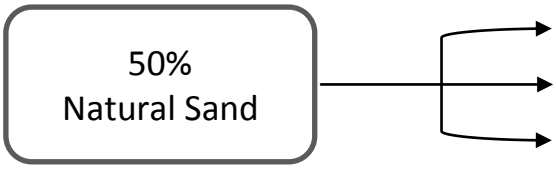
The methodology includes conducting standard laboratory tests such as the slump test for workability and compressive strength tests on cube specimens. Density and visual inspection are also conducted to assess surface finish and uniformity. A flowchart is included to illustrate the step-by-step process, starting from material procurement to final analysis. This systematic approach ensures reliable and replicable results.

For M40 and M50



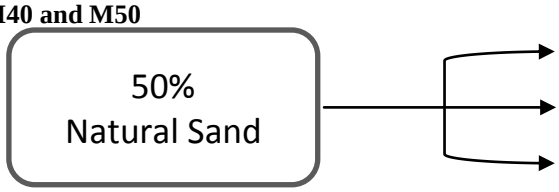
Quarry Dust	Foundry Sand	Concrete Debris
20%	20%	10%
20%	15%	15%
20%	10%	20%

For M40 and M50



Quarry Dust	Foundry Sand	Concrete Debris
15%	25%	10%
15%	20%	15%
15%	15%	20%

For M40 and M50



Quarry Dust	Foundry Sand	Concrete Debris
10%	25%	15%
10%	20%	20%
10%	15%	25%

III. RESULTS AND DISCUSSION

The results indicate that the partial replacement of sand with alternative materials affects both compressive strength and workability. Combinations with 20Percentage quarry dust and 10–20Percentage foundry sand showed improved compressive strength in both M40 and M50 grades compared to the control mix. However, as the percentage of concrete debris increased, a slight reduction in strength was observed, though still within acceptable limits. Workability generally decreased with increasing replacement levels, requiring the addition of admixtures to maintain slump values.

A detailed comparison of all combinations is presented using tables and bar charts. The optimal mix was found to be a combination with 20Percentage quarry dust, 15Percentage foundry sand, and 15Percentage debris, which balanced both strength and workability. The results confirm that alternative materials can successfully replace natural sand in high-grade concrete without significant performance loss. The discussion also highlights the microstructural reasons for strength improvement and points out any anomalies or unexpected outcomes observed during testing.

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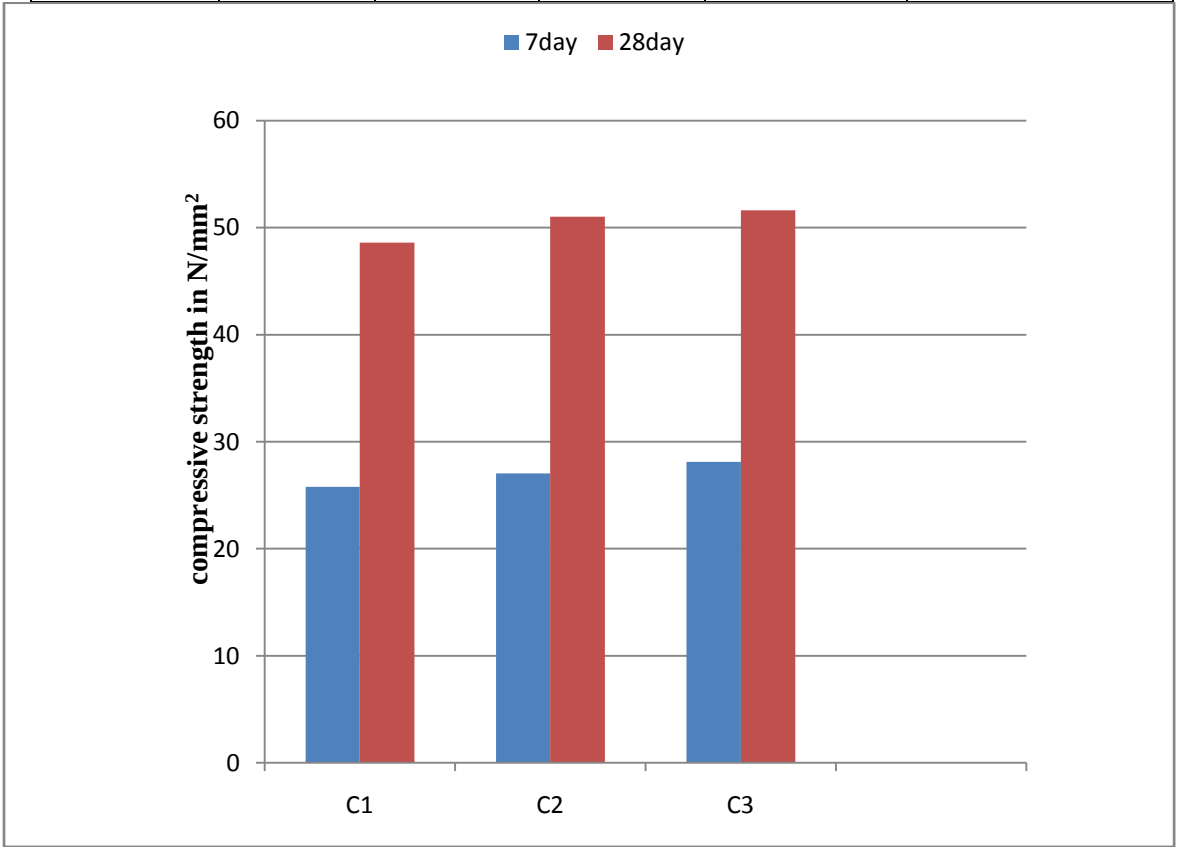
Table No.1.1: compressive strength for M40 grade concrete with sand replacement

Combination				Compressive strength 7day in N/mm^2	Compressive strength 28 day in N/mm^2
Designation	**Quarry dust Percentage**	**Foundry sand Percentage**	**Concrete debris Percentage**		
C1	**20**	20	10	25.79	48.61
C2	**20**	15	15	27.05	51.03
C3	**20**	10	20	28.11	51.62



Graph No. 1.1: Compressive strength for M40 grade concrete with sand replacement

Table No. 1.2: Compressive strength for M50 grade concrete with sand replacement

Combination				Compressive strength 7day in N/mm^2	Compressive strength 28 day in N/mm^2
Designation	**Quarry dust Percentage**	**Foundry sand Percentage**	**Concrete debris Percentage**		
C4	**20**	20	10	34.47	54.04
C5	**20**	15	15	32.71	47.2
C6	**20**	10	20	30.65	55.89

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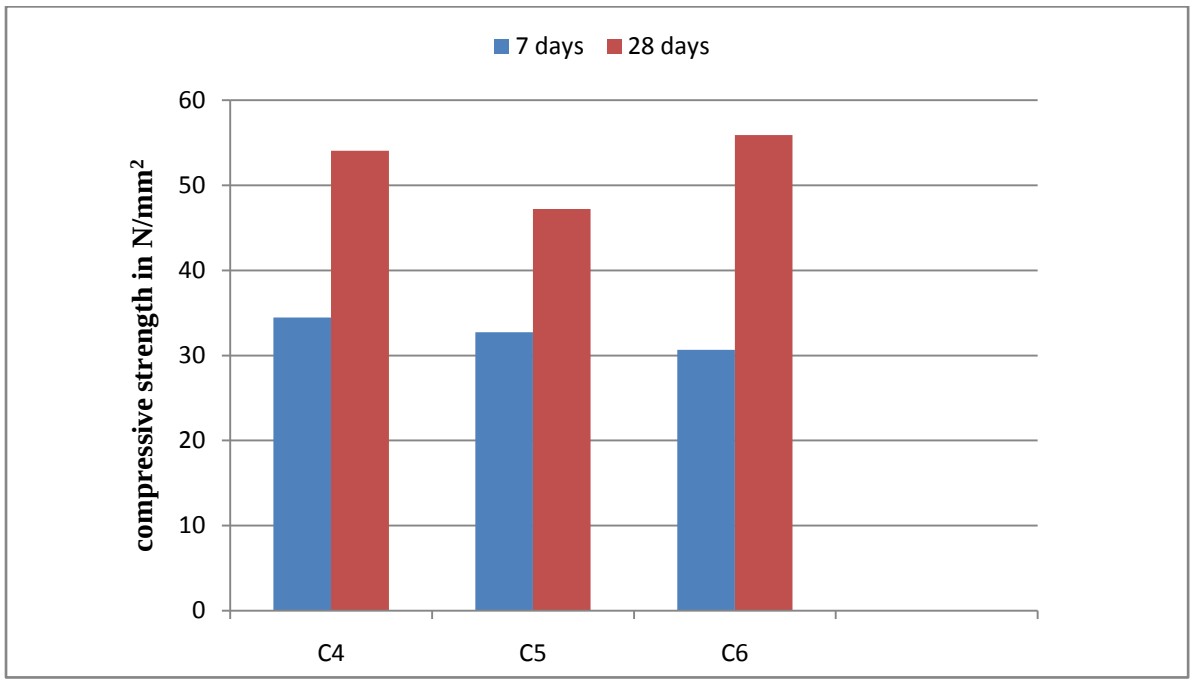

Graph No. 1.2: Compressive strength for M50 grade concrete with sand replacement

IV. CONCLUSION AND FUTURE SCOPE

The study concludes that partial replacement of sand with quarry dust, foundry sand, and concrete debris is a viable and sustainable solution for high-grade concrete production. Among the mixes tested, those containing up to 50Percentage replacement showed comparable or superior strength, particularly when using 20Percentage quarry dust with foundry sand and debris in varying proportions. Workability was manageable with minor adjustments, and no major defects were observed in the hardened concrete.

Future research can focus on higher-grade concretes such as M60, M70, and M80 to expand the scope of application in mega structures and high-rise buildings. Additional investigations into durability parameters such as sulfate resistance, water permeability, and freeze-thaw cycles can help evaluate long-term performance. Furthermore, life cycle cost analysis and carbon footprint assessments can provide deeper insight into the environmental and economic impact of large-scale implementation.

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