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A Study on the Partial Replacement of Cement using Sawdust and Micro-Silica

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ABSTRACT: This study investigates the partial replacement of cement with sawdust ash and micro-silica in concrete, focusing on workability, optimum micro-silica percentage, and durability under specific environmental conditions. The primary objectives include evaluating the workability of concrete with micro-silica replacements at 0%, 10%, and 15%, determining the optimal percentage of micro-silica for conventional concrete, and achieving the desired durability in given environmental conditions. The research found that incorporating sawdust ash in concrete is economical and cost-free, providing a sustainable alternative to traditional cement. The workability of concrete was assessed at various replacement levels, revealing that it maintained its workability at 0%, 10%, and 15% micro-silica replacements. The study also identified that the maximum compressive strength achieved was 34.21 N/mm² after a specific curing period, indicating the potential of micro-silica to enhance the mechanical properties of concrete. Furthermore, the research highlights the environmental benefits of using sawdust ash, which reduces waste and contributes to the sustainability of construction materials. The findings suggest that the optimal percentage of micro-silica in conventional concrete can significantly improve its durability and strength, making it a viable option for various construction applications. This study provides valuable insights into the practical applications of sawdust ash and micro-silica in concrete, promoting sustainable construction practices and offering a cost-effective solution for the industry.

KEYWORDS: Sawdust Ash, ordinary Portland cement (OPC), partial replacement. Silica fume, cement, physical properties, concrete properties.

I. INTRODUCTION

Developing countries like India are facing a shortage of good quality natural sand. In India, natural sand deposits are being used up and causing serious threats to the environment and society. Iron waste is an industrial by-product that is produced as a result of producing steel from the steel factory.

This waste material can be applied as a partial replacement of sand in concrete. This study aims to evaluate the suitability of using sawdust and micro silica as a partial replacement of fine aggregate and to observe that sawdust and micro silica lead to an increased compressive strength as used in certain proportions. Using sawdust and micro-silica instead of sand will reduce using sand in the construction industry, hence maintaining more of this natural resource. Cement concrete is commonly used in buildings and other important engineering works where strength and durability are prime importance.

Its huge popularity results from several advantages, such as general availability, wide applicability and high compressive strength. These advantages are also accompanied by a great environmental burden. Currently, the concrete construction business is unsustainable due to a multitude of factors. First of all, it uses up enormous amounts of virgin resources that are unavailable for future generations. Second, the main binder in concrete is Portland cement, whose manufacture contributes significantly to greenhouse gas emissions linked to climate change and global warming.

The billions of tons of raw materials mined and processed yearly leave a mark on the environment. The environmental load of concrete can be reduced by the partial replacement of Portland cement with other cement alternatives or additives. These Cement-replacing materials could be fillers or waste products. The materials utilized in our project encompass Cement, Water, Aggregate, Sand, Saw Dust, and Micro-Silica.

Objectives:

1. To determine how workable concrete is with partial replacements of micro silica at 0%, 10%, and 15%.
2. To determine the optimum percentage of micro-silica in conventional concrete.
3. To achieve the desired durability in the given environment conditions.

Scope of the Project Work:

The project's scope entails ensuring the project's success through collaboration with experts in environmental science, building engineering, and materials science, alongside engagement with local stakeholders. Funding from governmental bodies, academic establishments, or industry collaborators may also be necessary to facilitate the research.

II. LITERATURE REVIEW

The study by replacing cement with Sawdust Ash in concrete changes bulk density. Sawdust concrete specimens show irregular bulk density with increased SDA percentage. The workability of concrete increases with higher SDA replacement and longer curing duration (1). Using SDA in concrete reduces workability, suggesting its use in specific construction areas. By partially replacing cement with SDA, concrete gains durability, strength, crack prevention, and resistance to environmental factors (2). Replacing some cement with Saw Dust Ash in concrete can address environmental challenges. Sawdust ash cement outperforms Portland cement due to emission reduction during hydration. Saw Dust Ash concrete is lightweight, cost-effective, and suitable for various construction applications (3). The study suggests that the optimal replacement percentage of silica fume is approximately 10% for the specific concrete mix and silica fume utilized in the research (4). The study observed that incorporating silica fume up to 10% as a replacement for cement enhances compressive strength in concrete. Yet, once this maximum is reached, there is a decrease in compressive strength. Moreover, using silica fumes up to 10% replacement of cement results in increased split tensile strength, followed by a decline beyond this percentage. This rise in split tensile strength is mainly attributed to improved packing efficiency, where silica fume acts as a filler material. The study establishes that the optimum replacement percentage of cement with silica fume is 10% for M20-grade concrete (5). Nanotechnology is highlighted as a promising domain in the scientific field. Among these additives, silica fume is distinguished as a byproduct produced in significant quantities as industrial waste annually in the nation (6). To investigate the impact of incorporating sawdust in concrete as a low-cost alternative to traditional sand-based concrete blocks. The experimental investigation involved a mixture of coarse aggregate, fine aggregate, cement, water, and sawdust in producing these blocks. Discrepancies in weight between conventional concrete blocks and sawdust-based concrete blocks were assessed post-production. The study's findings indicate that sawdust concrete can be a feasible structural concrete option at suitable replacement percentages, influencing construction costs (7). The pursuit of increased strength has led to using alternative materials to achieve desired outcomes, emphasizing the significance of cementitious materials in enhancing concrete strength (8). Silica fume boosts concrete strength by more than 25%. It proves to be more cost-efficient than cement, making it a crucial aspect from an economic standpoint. This substance, which may contribute to air pollution, is a byproduct of specific industries. Incorporating micro-silica in concrete can aid in reducing air pollution levels. Moreover, silica fume assists in diminishing concrete voids, capillary absorption, and porosity by interacting fine silica fume particles with the lime present in cement (9). The most effective method identified was water curing, resulting in the highest levels of compressive strength, dynamic modulus of elasticity, and ultrasonic pulse velocity while displaying the lowest initial surface absorption. These results are attributed to the optimized pore structure and reduced porosity achieved through enhanced cement hydration and pozzolanic reaction without any moisture loss from the concrete specimens. In contrast, curing through wrapping led to increased compressive strength, ultrasonic pulse velocity, dynamic modulus of elasticity, and reduced initial surface absorption compared to dry-air curing. This difference is due to the limited moisture movement from the concrete specimens, encouraging a higher degree of cement hydration and pozzolanic reaction (10).

III. METHODOLOGY

The project's primary focus lies in examining the distinct aspects of investigating the diverse characteristics of sawdust and micro silica, alongside determining the optimal proportion of activated carbon utilized in concrete. Evaluation of the compressive strength of concrete cubes fabricated with sawdust and Microsilica. Conducting experimental analysis on the materials involved. Presenting experimental findings about various phases, namely 3, 7, and 28-day strength. Assessment of the cost implications associated with traditional concrete instead of concrete incorporating sawdust and Microsilica. Comparison of strength parameters between concrete compositions with and without the utilization of sawdust and Microsilica.

3.3 Mix Design:

Finding the ideal ratios of cement, sand, and aggregates in concrete to provide the desired strength in structures is the process of designing concrete mixes. Concrete Mix = Cement: Sand: Aggregates is the formula for the concrete mix design. To determine the proper mixing proportions, a number of procedures, computations, and laboratory testing are used in the design of the concrete mixture. This procedure is typically used for major building projects where a

significant amount of concrete is consumed, as well as structures that call for higher grades of concrete, such as M25 and above.

3.3.1 Mix Design for M25 (1:1:2)

Data required: [IS per IS 456:2000 Ct. 8-24-1]

- Specific gravity of cement - 2.88
- Maximum cement content: - 450 kg/m³
- Site condition: Exposure: Moderate
- Workability: 75mm

3.3.2 Casting Materials in constructions:

Concrete is an essential material that is key to building or structural quality. It is easy to make concrete, but it is not enough. A concrete mix must be correctly designed, batched, mixed and transported, but it is also important to place concrete correctly.

1. Aggregate
 - Coarse aggregate
 - Specific gravity @ (Saturated Surface Dry) = 2.75
 - Water absorption = 0.5%
 - Type of aggregate = Crushed
 - Maximum size of aggregate = 20 mm
2. Fine aggregate
 - Specific gravity = 2.65
 - Water absorption = 1%
 - Type of aggregate zone = 2

3.2.1.2 Steps of Mix Design: [IS 10262: 2019 Cl. NO 4:2]

STEP 1

Fine target means Strength (F'_{ck}).

$$F'_{ck} = F_{ck} + 1.65 \times S \text{ or } F'_{ck} = F_{ck} + X$$

$$S = 4$$

$$X = 5.5$$

$$F'_{ck} = 25 + 1.65 \times 4 = 31.6 \text{ N/mm}^2$$

..... [From Table 2 IS10262:2019]

..... [From Table 1 IS10262:2019]

STEP 2 [As per IS10262:2019 Cl no. 5.2 Table No. 3, page no 3]

Approximate air content: For 20mm Size aggregate

Approximate air content 1% of the volume of concrete

STEP 3 [As per IS10262:2019 Fig no.1, Page no.04]

Selection of w/c ratio

From Fig. 1, the free water-cement ratio required for the target strength of 31.6 N/mm² is 0.55 for the OPC 53 grade curve. Hence OK.

Compressive strength of cement.

Curve 1: for expected 28 days compressive strength of 33 and < 43 N/mm².

Curve 2: for expected 28 days' compressive strength of 43 and < 53 N/mm².

Curve 3: for expected 28 days compressive strength of 53 N/mm² and above

We use OPC 43 or 53 grade. The W/C Ratio = 0.55

STEP 4 Selection of Water content

[According to fig no. 1 of IS 10262:2019] [According to Table 5 of IS 456:2000]

[IS 10262:2019 from Table 4 clno5.3]

Table 4 shows water content = 186 kg (for 50 mm slump) for 20 mm aggregate.

Estimated water content for 75 mm slump

$$\text{Cement content} = 191.58 / 0.55 = 348.32 \text{ Kg/m}^3$$

STEP 5 Calculation of cementitious content

Cementitious content = Water content / WC Ratio

$$= 191.58 / 0.55 = 348.32 \text{ Kg/m}^3$$

STEP 6: Mix Design Calculation per unit Volume

a) Volume of Concrete = 1m^3

b) Volume of Cement = mass of cement/mass of density
 $= 348.327 / 3.15 \times 1000 = 0.1105$

c) Volume of water = mass of water/mass density.
 $191.58 / 1 \times 1000 = 0.1915\text{ m}^3$.

d) Volume of all in agg.
 (a) - $(0.1105 + 0.1915 + 0) = 0.698$

e) Volume of Course agg

[As per IS10262:2019 From Table 5, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 = 0.62 & pumpable concrete these values may be reduced by up to 10 percent. (Cl no. 5.5.2). Here, 10 % reduction is considered]

$= 0.62 \times 0.9 = 0.558$

f) Volume of fine aggregate = $1 - 0.558$
 $= 0.442$

g) Mass of Course agg, = Vol. of all agg. X Volume of Course agg. X Sp. Gravity X 1000
 $= 0.698 \times 0.558 \times 2.92 \times 1000$
 $= 1137.29 = 1138\text{ kg/m}^3$

h) Mass of fine agg. = Volume of all in agg x volume of fine agg X sp gr X 1000
 $= 0.698 \times 0.442 \times 2.92 \times 1000 = 900.86 = 901\text{ kg/m}^3$

Ratio: 1:2.58: 3:26:0.55

Total = 6.84 & Total Cube = 27

j) Cube Volume = $0.00375\text{ m}^3 \times 9 = 0.03375\text{ m}^3$

k) Wet Volume = 0.03375×1.5
 $= 0.0513\text{ m}^3$

l) Cement = $1 * 0.0513 / 6.84 = 0.0075\text{ m}^3$
 F.A = $(2.55 * 0.0513 / 6.84) = 0.0191\text{ m}^3$
 C.A = $(3.27 * 0.0513 / 6.84) = 0.0245\text{ m}^3$

STEP 9 SSD & DRY Condition Calculations

Adjustment on Water, Fine Aggregate and Coarse Aggregate (If the Coarse and Fine Aggregate is in Dry Condition)

a) Fine Aggregate (Dry)
 $= \text{Mass of fine aggregate in SSD condition} / (1 + \text{Water absorption}/100) - (\text{Moisture Content}/100)$
 $= 901 / (1 + (1/100)) - (0/100) = 892.077 = 892\text{ Kg/m}^3$

b) Coarse Aggregate (Dry)
 $= \text{Mass of fine aggregate in SSD condition} / (1 + \text{Water absorption}/100) - (\text{Moisture Content} / 100)$
 $= 1138 / (1 + (0.55/100)) - (0/100)$
 $= 1131.77 = 1132\text{ Kg/m}^3$

The extra water is to be added for absorption by the coarse and fine aggregate,

1) For coarse aggregate = Mass of coarse aggregate n SSD condition – Mass of coarse aggregate in dry condition = $1138 - 1132 = 6\text{ kg}$

2) For fine aggregate = Mass of fine aggregate in SSD condition – mass of fine aggregate in dry condition = $901 - 892 = 9\text{ kg}$

The estimated requirement for added water, therefore, becomes

$= 192 + 6 + 9$
 $= 207\text{ Kg/m}^3$

Table No. 1 Mix Design Calculations

Materials	SSD Conditions	Dry Conditions
Cement	348.32 = 350 Kg/m ³	350 Kg/m ³
10 mm Aggregate (35%)	35% x 1138 = 398.3 Kg/m ³	396.2 Kg/m ³
20mm Aggregate (65%)	65 % x 1138 = 739.7 Kg/m ³	735.8 Kg/m ³
Crush Sand	900.81 = 901 Kg/m ³	892 Kg/m ³
Water	191.58 = 192 Kg/m ³	207 Kg/m ³

STEP 10 Final Calculations for 9 Cube

for 9 Cube Volume Size = 0.03375 = 0.035 m³

Cement = 0.035 x 350 = 12.25 kg

10 mm Agg. = 0.035 X 396 = 13.86 kg

20 mm Agg. = 0.035 X 735 = 25.725 kg

Crush Sand = 0.035 X 892 = 31.22 kg

Water = 0.035 X 207 = 7.245 kg

Table No. 2 Mix Design Calculations

Sr. No.	Material	Actual Quantity by Manual Calculations
1	Cement	12.25 Kg
2	10 mm Aggregate (35%)	13.86 Kg
3	20mm Aggregate (65%)	25.725 Kg
4	Crush Sand	31.22 Kg
5	Water	7.245 Kg

The quantity of cubes tested included standard cubes and a combination of sawdust and micro-silica with 10% and 15% replacement. The testing was conducted at 3 days, 7 days, and 28 days intervals. A total of 27 cubes were tested in this study. Various quality tests on concrete, such as compressive strength tests, slump tests, permeability tests, etc., are used to ensure the concrete's quality for a given specification. This concrete quality testing provides an idea of concrete properties such as strength, durability, air content, permeability, etc



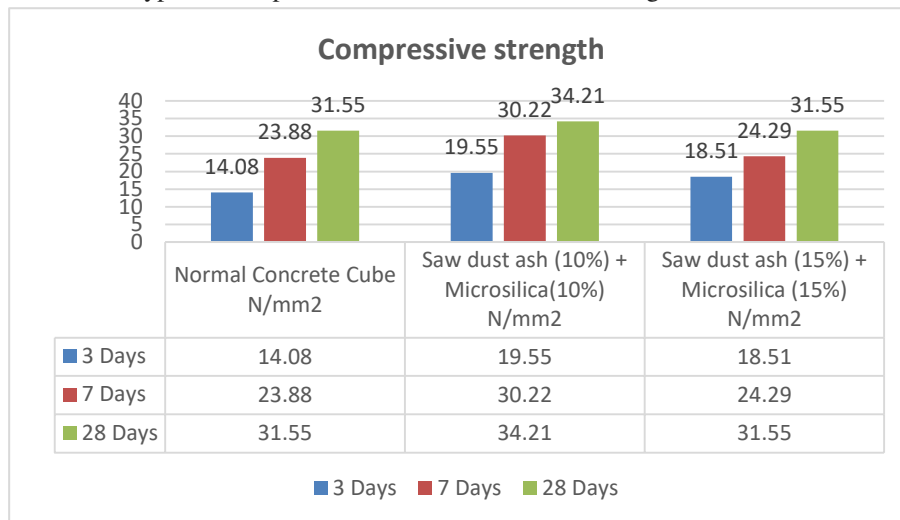
Fig. No. 1 Cube testing result on Compression Testing Machine

We conduct compressive strength tests on cubes after the curing periods of 3, 7, and 28 days. These assessments are executed utilizing a Compressive Testing Machine. The utilization of mix concrete is employed during the casting and curing processes. The results yielded from the compressive strength evaluations executed on the cubes at 3, 7, and 28 days are 19.55, 30.22 and 34.21 MPa, respectively. It should be noted that the compressive strength exhibited by these cubes is very low compared to others.

Days	Normal Concrete Cube N/mm ²	Saw dust ash (10%) + Microsilica (10%) N/mm ²	Saw dust ash (15%) + Microsilica (15%) N/mm ²
3	14.08	19.55	18.51
7	23.88	30.22	24.29
28	31.55	34.21	31.55

IV. RESULT AND DISCUSSIONS

The aim is to compare normal concrete and design mix concrete in concrete. For comparison, we cast concrete blocks in two batches: first batch of Normal Concrete Cubes and the second batch of Saw dust ash plus Micro-silica then, we took the test in 3 types to compare both normal concrete and design mix concrete results in 3, 7 and 28 days.



Graph 1. Compressive strength of Cube for 3, 7 & 28 days

As per the table the results of normal concrete are compared with Design mix concrete, Saw dust ash plus Micro-silica. When normal concrete is exposed to a blend of sawdust and micro-silica (10%) for 3 days, there is a marked increase in outcomes of around 38.84% that can be detected. In a similar vein, upon comparing normal concrete with a mixture of sawdust and micro-silica (15%), the findings indicate an augmentation of 31.46%. On the contrary, there is a reduction in results amounting to 7.38% when making a comparison between Sawdust in addition to Micro-silica (15%) and normal concrete. Likewise, in a scenario where normal concrete is evaluated against a blend of sawdust and micro-silica (10%) across a timeframe of 7 days, there is a conspicuous escalation in results reaching up to 26.54%. Similarly, when normal concrete is contrasted with a mixture of sawdust and micro-silica (15%), the data depicts an increase of 1.71%. Conversely, there is a downturn in results by 24.83% when scrutinizing the combination of Sawdust alongside Micro-silica (15%) in relation to normal concrete. In addition, when standard concrete is compared to a 10% mixture of sawdust and micro-silica over a 28-day period, there is a discernible increase in results of up to 8.43%. Additionally, when normal concrete is pitted against a fusion of sawdust and micro-silica (15%), the findings exhibit a rise of 0%. Conversely, there is a decline in results by 8.43% when evaluating the amalgamation of Sawdust with Micro-silica (15%) against normal concrete.

V. CONCLUSION

1. The utilization of saw dust ash in concrete was found to be economical and free of cost.
2. The workability of concrete was found to be at 0%, 10%, and 15% replacement levels.
3. The maximum compressive strength attained was 34.21 N/mm² after the curing period of 28 days when cement is replaced with 10%.
4. A decrease in strength was observed when the replacement percentage was increased to 15%. Hence, the optimum percentage of cement that can be replaced with saw dust ash is concluded to be 10%.
5. The desired durability in given environmental conditions was achieved with a 10% replacement level, indicating it is suitable for practical applications.

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IS CODE

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