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Sustainable Concrete Solutions: Assessing the Effects of Marble Dust Substitution on Concrete Properties

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Abstract: This study investigates the impact of partial replacement of cement with marble dust on the strength and durability properties of concrete. With the rise in environmental awareness, utilizing industrial by-products like marble dust for sustainable construction practices has gained attention. Concrete specimens were prepared with various percentages of marble dust replacing cement, and were tested for compressive strength, tensile strength, and durability. The results indicate that marble dust can improve certain concrete properties while contributing to environmental sustainability.

Keywords: Concrete, Marble Dust, Cement Replacement, Strength Properties, Durability, Sustainable Construction

1. Introduction

1.1 Background

Concrete is one of the most widely used construction materials globally. The production of cement, a primary component of concrete, is associated with high carbon emissions and energy consumption. Marble dust, a by-product of marble cutting and processing, offers a potential solution for reducing environmental impact by partially replacing cement in concrete. This study aims to evaluate the effect of marble dust on concrete's mechanical and durability properties.

1.2 Objective

The primary objective of this study is to assess how replacing cement with marble dust affects the strength and durability of concrete. Specifically, the study aims to determine the optimal percentage of marble dust that enhances concrete performance while maintaining cost-effectiveness and sustainability.

1.3 Scope

The scope of this research includes preparing concrete mixes with varying proportions of marble dust, testing these mixes for compressive and tensile strength, and evaluating their durability under different conditions.

2. Literature Review

2.1 Properties of Marble Dust

Marble dust is a fine powder resulting from marble cutting and polishing. It is composed mainly of calcium carbonate ($CaCO_3$). Its physical properties, such as fineness and chemical composition, make it a potential partial replacement for cement in concrete. Studies have shown that marble dust can influence concrete's workability and strength characteristics.

2.2 Previous Studies

Various studies have explored the use of marble dust in concrete. For instance, Ahmed et al. (2021) found that incorporating marble dust can enhance the mechanical properties of concrete up to certain limits. Similarly, Babu et al. (2019) reviewed the benefits of marble dust in improving the durability of concrete. However, research on long-term durability and environmental impacts remains limited.

2.3 Gaps in Research

While existing studies provide insights into the short-term effects of marble dust on concrete, there is a need for more comprehensive research on its long-term durability and environmental benefits. This study addresses these gaps by focusing on extended performance metrics and sustainability.

3. Methodology

3.1 Materials

- **Cement:** Ordinary Portland Cement (OPC), conforming to IS: 269-2015

- **Marble Dust:** Obtained from local marble processing units in Bargarh, Odisha
- **Aggregates:** Coarse aggregates (20 mm) and fine aggregates (sand), conforming to IS: 383-2016
- **Water:** Clean, potable water used for mixing

3.2 **Concrete Mix Design**

Concrete mixes were designed based on the standard mix ratio for M25 grade concrete. The marble dust replaced cement at various percentages: 0%, 5%, 10%, 15%, and 20% by weight of cement. The mix proportions for each concrete batch are summarized in Table 1.

Table 1: Mix Proportions for Concrete

Mix Type	Cement (kg/m³)	Marble Dust (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Water (L)
Control	400	0	750	1150	180
MD5	380	20	750	1150	180
MD10	360	40	750	1150	180
MD15	340	60	750	1150	180
MD20	320	80	750	1150	180

3.3 **Testing Procedures**

Concrete specimens were cast in standard moulds and cured for 7 and 28 days. The following tests were conducted:

- **Compressive Strength:** Cubes (150 mm x 150 mm x 150 mm) were tested according to IS: 516-1959.
- **Tensile Strength:** Cylinders (150 mm x 300 mm) were tested using the split-cylinder method, as per IS: 5816-1999.
- **Durability Tests:** Water absorption (IS 1199:1959), acid resistance (5% sulfuric acid solution) ASTM C267, and sulphate resistance (5% sodium sulphate solution) ASTM C1012 were assessed according to standard procedures.

4. Results

4.1 **Compressive Strength**

The compressive strength results are shown in Table 2 and Figure 1. Concrete samples with up to 10% marble dust replacement exhibited a slight decrease in compressive strength, while samples with higher percentages showed more pronounced reductions.

Table 2: Compressive Strength of Concrete with Marble Dust

Marble Dust (%)	Compressive Strength (MPa) at 7 Days	Compressive Strength (MPa) at 28 Days
0	25.0	35.0
5	24.5	34.0
10	23.0	32.5
15	22.0	31.0
20	20.5	29.0

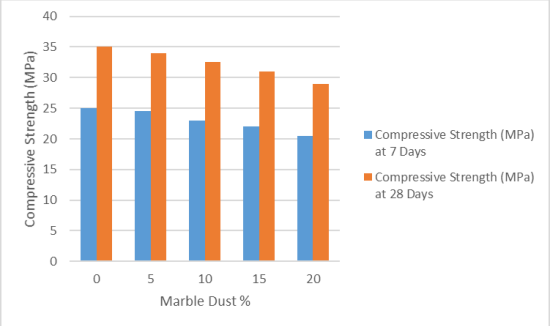

Figure 1: Compressive Strength vs. Marble Dust Percentage

The compressive strength decreases with increasing marble dust content. The control mix showed the highest strength, while the 20% replacement mix had the lowest strength, suggesting a diminishing effect of marble dust on compressive strength.

4.2 **Tensile Strength**

Tensile strength data is presented in Table 3 and Figure 2. The results indicate a similar trend as the compressive strength, with a gradual decrease in tensile strength as the marble dust content increases.

Table 3: Tensile Strength of Concrete with Marble Dust

Marble Dust (%)	Tensile Strength (MPa)
0	3.5
5	3.4
10	3.2
15	3.1

Marble Dust (%)	Tensile Strength (MPa)
20	3.0

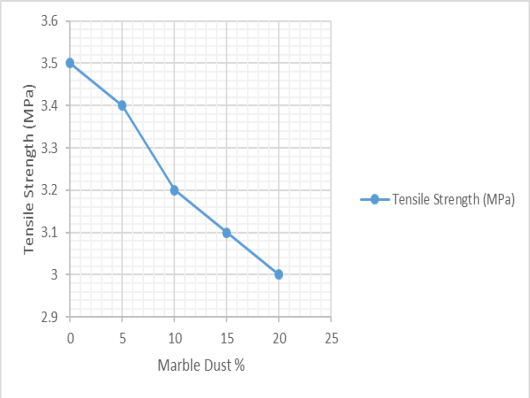

Figure 2: Tensile Strength vs. Marble Dust Percentage

The tensile strength results follow a similar pattern, with a noticeable reduction as the percentage of marble dust increases.

4.3 **Durability Tests**

Durability test results are summarized in Table 4 and Figure 3. Concrete samples with marble dust exhibited increased water absorption and decreased resistance to acid and sulphate attacks, indicating reduced durability with higher marble dust content.

Table 4: Durability Properties of Concrete with Marble Dust

Marble Dust (%)	Water Absorption (%)	Acid Resistance (%)	Sulphate Resistance (%)
0	5.0	92.0	85.0
5	5.2	90.0	83.0
10	5.5	88.0	80.0
15	5.8	85.0	78.0
20	6.0	82.0	75.0

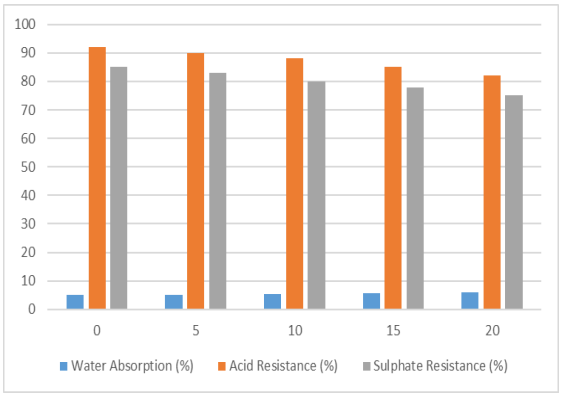

Figure 3: Durability Properties vs. Marble Dust Percentage

The increased water absorption and decreased resistance to chemical attacks with higher marble dust content suggest that while marble dust can be used as a partial replacement for cement, it may impact the long-term durability of concrete.

4.4 **Discussion**

The study demonstrates that marble dust can be used to partially replace cement in concrete. While it can enhance sustainability by utilizing a waste material, its impact on concrete strength and durability should be carefully considered. Up to 10% marble dust replacement shows acceptable performance, but higher percentages result in reduced strength and durability.

5. Conclusion

The study shows that partial replacement of cement with marble dust affects the strength and durability of concrete. Concrete with up to 10% marble dust maintains reasonable strength and durability. However, higher replacement results in decreased compressive and tensile strength and reduced durability. Marble dust can be effectively used as a partial replacement of cement up to 10% without significantly compromising concrete properties. Further research is recommended to explore the long-term performance and environmental benefits of using marble dust. Future studies should focus on optimizing the percentage of marble dust for various concrete grades, exploring alternative combinations with supplementary cementitious materials, and assessing the environmental impact over the lifecycle of concrete.

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