

EXPERIMENTAL STUDY ON STRENGTH IMPROVEMENT OF CONCRETE USING MARBLE DUST AS PARTIAL CEMENT REPLACEMENT WITH LIME-SATURATED MIXING WATER

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Abstract – This paper explores the strength improvement of M25 concrete using marble dust as partial replacement of cement and lime-saturated mixing water (Prepared using hydrated lime). In this study five concrete mixes are considered, they are control mix, control mix using lime-saturated mixing water and for other mixes, the cement is partially replaced with marble dust at various percentages such as 5%, 10%, 15% with Lime-saturated mixing water. Concrete cube specimens were cast and cured for 7, 14, 21 & 28 days. The compressive strength test is carried out for all curing periods using Compression Testing Machine (CTM). The results showed increase in compressive strength of concrete with marble dust to an optimum replacement level of 5% when compared to conventional concrete. The use of lime-saturated mixing water enhanced the hydration process, leading to better strength development. The study concludes that the combined use of marble dust and lime-saturated mixing water can produce durable concrete.

Key Words: Marble dust (MD), Lime-saturated mixing water (LSM), Control mix (CM), Compressive strength test, Water absorption test, Workability.

1. INTRODUCTION

Concrete is one of the most widely used construction materials in the world, and its properties can be improved by incorporating alternative materials. In recent years, the use of industrial waste materials such as marble dust has gained attention due to environmental and economic benefits. Marble dust, a by-product of marble processing, can be used as a partial replacement of cement to enhance concrete properties and reduce waste disposal issues. In addition, the use of lime-saturated mixing water can improve the hydration process and bonding within the concrete matrix. This study focuses on evaluating the strength and durability characteristics of concrete by using marble dust along with lime-saturated mixing water, aiming to develop a more sustainable and efficient construction material.

1.1 MATERIALS USED

- Cement
- Fine aggregate
- Coarse aggregate
- Potable Water
- Marble Dust
- Hydrated Lime

1.1.1 CEMENT

Cement is a finely powdered binding material that plays a vital role in the production of concrete. When mixed with water, cement undergoes hydration and forms compounds that bind fine aggregate and coarse aggregate together, resulting in a hardened mass. In this study, Ordinary Portland Cement (OPC) 53 Grade was used due to its high early strength and suitability for structural concrete works. The cement used was tested in accordance with relevant Indian Standard (IS) codes to ensure its quality and conformity.

1.1.2 FINE AGGREGATE

Fine aggregate is an essential constituent of concrete that fills the voids between coarse aggregate particles and contributes to the strength and workability of concrete. It consists of natural sand or crushed stone sand passing through a 4.75 mm IS sieve. In this study, clean and well-graded natural river sand conforming to Zone II was used as fine aggregate. The fine aggregate was free from organic impurities, silt, and clay, and was tested as per relevant Indian Standard codes to ensure suitability for concrete production.

1.1.3 COARSE AGGREGATE

Coarse aggregate is a major constituent of concrete that provides bulk, strength, and dimensional stability to the mix. It consists of crushed stone or gravel retained on a 4.75 mm IS sieve. Coarse aggregate contributes significantly to

the compressive strength and durability of concrete. In the present study, well-graded crushed stone aggregates of suitable size were used and tested as per relevant IS codes.

1.1.4 PORTABLE WATER

Water is an essential component of concrete as it is required for the hydration of cement and to achieve adequate workability. During hydration, water reacts with cement compounds to form calcium silicate hydrate (C-S-H) gel, which provides strength and binding to concrete. The quantity of water used has a significant influence on concrete properties; insufficient water leads to incomplete hydration and reduced strength, while excess water increases porosity and decreases durability. The quality of water is also important, and it should be free from harmful impurities such as oils, acids, alkalis, organic matter, chlorides, and sulphates, as these may adversely affect setting time, strength, durability, and may cause corrosion of reinforcement. Generally, potable water is considered suitable for mixing and curing concrete, and proper curing ensures continuous hydration, minimizes shrinkage cracks, and improves the long-term performance of concrete. Properties of Water.

1.1.5 MARBLE DUST

Marble dust is a fine powder obtained as a by-product during the cutting, polishing, and processing of marble stones. It mainly consists of calcium carbonate (CaCO_3) and has very fine particle size, similar to cement. When used in concrete, marble dust acts as a filler material, improving particle packing and reducing voids. Partial replacement of cement or fine aggregate with marble dust can enhance workability and surface finish of concrete. Utilization of marble dust helps in reducing environmental pollution. Proper proportioning of marble dust can improve strength characteristics and durability of concrete.

1.1.6 HYDRATED LIME

Hydrated lime, chemically known as calcium hydroxide $\text{Ca}(\text{OH})_2$, is produced by adding a controlled amount of water to quicklime (calcium oxide). This process, known as slaking, converts quicklime into a fine, white powder called hydrated lime. It has been widely used in construction for centuries in mortar, plaster, soil stabilization, and as a supplementary material in concrete due to its excellent workability, binding, and durability-enhancing properties.

2. LITERATURE REVIEW

Prof. P. A. Shirule (2012): Investigated feasibility of marble dust powder as partial replacement of cement. Concrete cubes were tested at 7 and 28 days. Results showed improvement in compressive strength up to an optimum replacement level due to filler effect of marble dust.

Ghazi Abdullah (2013): Studied hydrated lime as partial cement replacement in roller compacted concrete. Results showed improvement in compressive strength and physical properties due to enhanced hydration and densification of concrete matrix.

Mariam Farouk Ghazy (2013): Studied cement pastes, mortars and concrete mixed with saturated lime water. Results showed improved consistency, delayed setting time and enhanced compressive strength due to increased calcium hydroxide availability and improved pozzolanic activity.

N. Gurumoorthy (2014): The main objective of this research is to investigate the performance of concretes contained marble dust as a cement replacement, mix was prepared with cement and sand blended with marble dust with replacement from 10%, 20%, 25% and 30%. The investigation indicates that replacement of cement by marble waste powder at different ranges, in concrete production, results in higher compressive strength, split tensile strength and flexural strength as of concrete specimens without marble dust.

Ranjan Kumar (2015): Studied marble dust powder as cement replacement at 0%, 5%, 10%. Observed increase in compressive strength up to 10% replacement, while further replacement caused strength reduction due to dilution of cement content.

Awodiji et al. (2018): studied the compressive strength of hydrated lime cement concrete with partial replacement of cement. The results showed optimum compressive strength of 30.83 N/mm^2 at 28 days with 18.75% hydrated lime replacement. Strength increased with curing age, and excessive replacement reduced strength. The study confirmed the feasibility of using hydrated lime in concrete for sustainable construction.

M. E. Mohammed (2020): Investigated two approaches: cement replacement with hydrated lime and use of lime-saturated mixing water (3 g/L). Lime-saturated water enhanced pozzolanic reaction and improved compressive and tensile strength up to 120 days.

Muhammad Jaffar (2021): Examined effect of marble powder on workability, compressive and flexural strength of M30 concrete. Found that 5–10% marble powder replacement improved strength and contributed to sustainable concrete production.

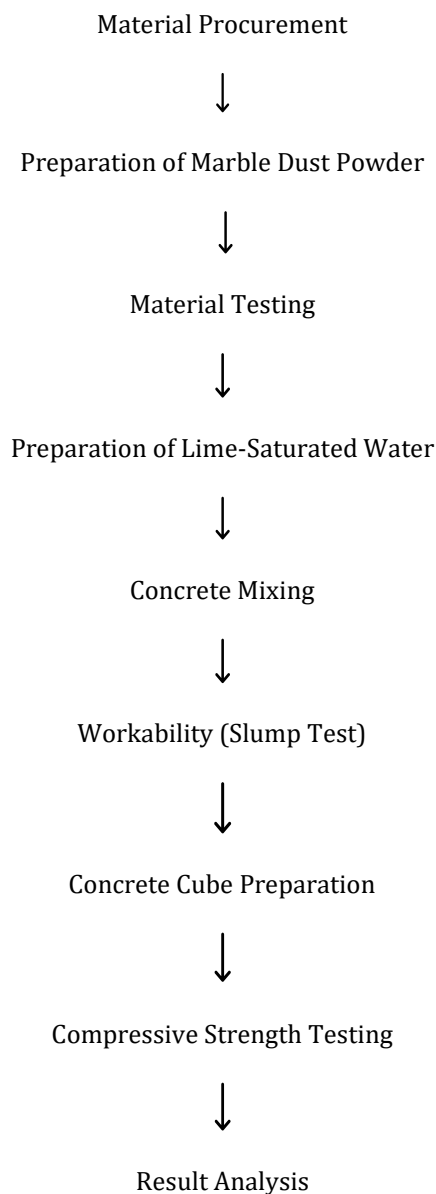
Majeed et al. (2021): Partial replacement of cement with waste marble powder at 10% enhances concrete compressive strength due to improved compactness of the mix, although workability decreases slightly due to higher fineness of marble powder. Non-destructive tests further confirm the densification of concrete at optimal replacement levels.

Shiren Osman Ahmed (2022): Studied the performance of concrete containing waste marble powder as partial replacement of cement. The study reported improved compressive, flexural, and tensile strength up to 10% replacement level. Workability decreased with increased marble waste content, while density increased and water

absorption reduced. The study concluded that marble waste can be effectively used in concrete for sustainable construction.

3. METHODOLOGY

The experimental methodology adopted in this study was planned systematically to evaluate the effect of marble dust and hydrated lime on the properties of concrete. The methodology includes material procurement, preparation, testing, concrete mixing, casting, curing, and strength evaluation.



3.1 MATERIAL PROCUREMENT

Material procurement for this experimental study was carried out by carefully selecting and collecting all the

required materials from reliable and locally available sources. Proper care was taken to ensure that the materials used were of good quality and conformed to the relevant Indian Standard specifications.

3.2 PREPARATION OF MARBLE DUST POWDER

3.2.1 Collection of Marble Waste

Waste marble pieces generated during marble cutting operations were collected from a local marble cutting and polishing shop. The collected marble pieces were small and free from visible impurities.

3.2.2 Transportation

The collected marble pieces were transported to the residence for further preparation and processing.

3.2.3 Initial Crushing

The marble pieces were manually crushed into smaller fragments using a traditional stone grinding tool available at home. This step helped in reducing the size of the marble pieces into small chips.

3.2.4 Secondary Grinding

The crushed marble fragments were further ground using a mortar and pestle to obtain finer particles.

3.2.5 Final Grinding

The partially ground marble material was then placed in a household mixer grinder and ground thoroughly to obtain a fine marble powder.

3.2.6 Storage

The prepared fine marble powder was collected and stored in a clean, dry, and airtight container to prevent moisture absorption and contamination until it was used for concrete mixing.

3.3 MATERIAL TESTING

Before using the materials for concrete preparation, all the constituent materials were tested to determine their physical properties and to ensure compliance with relevant Indian Standard (IS) specifications. The tests were conducted to assess the suitability and quality of materials used in the experimental investigation.

3.3.1 TESTS ON CEMENT

- Fineness test
- Standard consistency test
- Initial & Final tests

3.3.1.1 Fineness Test of Cement (IS Code: IS 4031 (Part 1): 1996)

This test is carried out to find the fineness (particle size) of cement.

3.3.1.2 Standard Consistency Test of Cement (IS Code: IS 4031 (Part 4): 1988)

This test is conducted to find water required to mix the cement.

3.3.1.3 Initial Setting Time of Cement (IS Code: IS 4031 (Part 5): 1988)

From this test the time taken to start setting is determined.

3.3.1.4 Final Setting Time of Cement (IS Code: IS 4031 (Part 5): 1988)

From this test the time taken to finish setting is determined.

3.3.2 TESTS ON FINE AGGREGATE

- Sieve analysis
- Specific gravity test
- Moisture content test

3.3.2.1 Sieve Analysis of Fine Aggregate (IS Code: IS 383:2016)

To determine the particle size distribution.

3.3.2.2 Specific Gravity of Fine Aggregate (IS Code: IS 2386 (Part 3): 1963)

Density of sand was determined.

3.3.2.3 Moisture Content of Fine Aggregate (IS Code: IS 2386 (Part 3): 1963)

To determine the moisture content present in sand.

3.3.3 TESTS ON COARSE AGGREGATE

- Sieve analysis
- Specific gravity test
- Aggregate impact value test

3.3.3.1 Sieve Analysis of Coarse Aggregate (IS Code: IS 383:2016)

Size distribution was determined.

3.3.3.2 Specific Gravity of Coarse Aggregate (IS Code: IS 2386 (Part 3): 1963)

The test is carried out to find density.

3.3.3.3 Aggregate Impact Value Test (IS Code: IS 2386 (Part 4): 1963)

This test is conducted to know the toughness and resistance to sudden loads.

3.4 PREPARATION OF LIME-SATURATED WATER

Potable water was taken in a clean container for the preparation of lime-saturated water. Hydrated lime was accurately measured at a dosage of 3 grams per liter of water. The measured hydrated lime was added gradually to the water. The mixture was stirred thoroughly to ensure uniform mixing of hydrated lime in water. The prepared lime-treated water was used directly for concrete mixing. Lime-saturated water was prepared fresh before mixing to maintain uniformity and consistency.

3.5 CONCRETE MIXING

In this study hand mixing is carried out for preparation of M25 Concrete. Mixing consists of two, they are as follows:

- Dry mixing
- Wet mixing

3.5.1 DRY MIXING

The process of mixing all dry components like cement, fine aggregate, coarse aggregate until a uniform mix is obtained.

3.5.2 WET MIXING

After dry mixing, the water is added and mixed thoroughly to obtain a workable concrete mix.

3.6 WORKABILITY (SLUMP TEST) IS Code: IS 1199: 1959)

Workability of concrete indicates the ease with which fresh concrete can be mixed, placed, and compacted. In this study, workability was determined using the slump test as per IS 1199.

The slump obtained represents the consistency of the concrete mix and was used to compare normal concrete with marble dust and hydrated lime mixed concrete.

3.6.1 4.7.1 Slump Cone Test (IS 7320: 1974)

This test is used to determine the workability of concrete, consistency of fresh concrete and also maintain proper mix proportion.

3.7 CONCRETE CUBE PREPARATION

3.7.1 CASTING

Concrete cubes of standard size **150 mm × 150 mm × 150 mm** were cast using the prepared concrete mix. The concrete was placed in moulds within 3 layers and compacted with tampering rod at each layer with 35 blows to remove air voids. After casting, the specimens were kept undisturbed for 24 hours at room temperature.

3.7.2 DEMOULDING

After 24 hours of casting, the concrete cubes were carefully removed from the moulds without causing any damage. The demoulded specimens were then marked and immediately placed in water for curing.

3.7.3 CURING

After 24 hours of casting, the concrete cubes were demoulded and cured in clean water. Curing was carried out for **7, 14, 21, and 28 days** to ensure proper hydration and strength development of concrete.

3.8 COMPRESSIVE STRENGTH TEST (IS 516: 1959)

Compressive strength of concrete cubes was determined using a **Compression Testing Machine (CTM)** as per IS 516. The load was applied gradually until failure, and the maximum load was recorded. The compressive strength was calculated by dividing the failure load by the cross-sectional area of the cube.

3.9 WATER ABSORPTION TEST OF CONCRETE CUBES

Water absorption of concrete indicates the amount of water absorbed by hardened concrete and helps evaluate its porosity and durability. In this study, concrete cubes were first oven-dried and their dry weight was recorded. The cubes were then immersed in water for 24 hours and weighed again. The percentage increase in weight represents the water absorption of the concrete. Lower water absorption indicates a denser concrete structure with better durability.

4.RESULTS & DISCUSSIONS

4.1 MATERIAL TESTING

1. TESTS ON CEMENT
2. TESTS ON FINE AGGREGATE
3. TESTS ON COARSE AGGREGATE

4.1.1 TESTS ON CEMENT

TESTS	VALUES
Fineness (%)	10
Standard consistency (%)	33
Initial setting time (min)	110
Final setting time (min)	215

4.1.2 TESTS ON FINE AGGREGATE

TESTS	VALUES
Sieve analysis	2.27
Specific gravity	2.62
Moisture content (%)	4.17

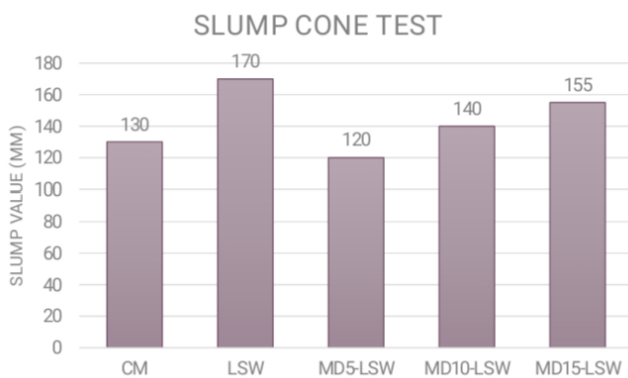
4.1.3 TESTS ON COARSE AGGREGATE

TESTS	VALUES
Sieve analysis	Well graded
Specific gravity	3.02
Aggregate impact value (%)	10.2

4.2 SLUMP CONE TEST

MIX	MIX DESCRIPTION	SLUMP VALUE (mm)
CM	Control mix	130
LSM	Control mix + lime water	170
MD5-LSM	5% marble dust+ lime water	120
MD10-LSM	10% marble dust+ lime water	140
MD15-LSM	15% marble dust+ lime water	155

Workability of Concrete: The workability of concrete was evaluated using the slump cone test for different mix proportions. Overall, the results indicate that workability decreases at optimum replacement level and increases with higher marble dust content.



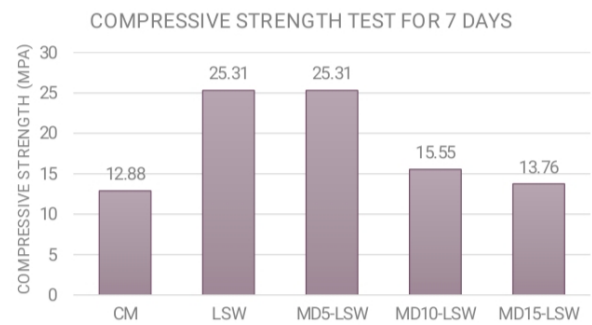
4.3 COMPRESSIVE STRENGTH ANALYSIS

4.3.1 7 Days

MIX	CM	LSM	MD5-LSM	MD10-LSM	MD15-LSM
7 Days	12.88	25.31	25.31	15.55	13.76

The compressive strength of concrete at 7 days shows that the control mix attained a strength of 12.88 MPa. The use of lime-saturated mixing water significantly increased

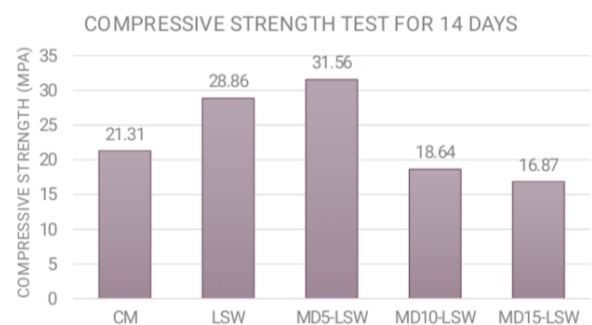
strength to 25.31 MPa due to improved hydration. The mix containing 5% marble dust also exhibited a strength of 25.31 MPa, indicating better early strength development due to improved particle packing. However, further increase in marble dust content resulted in a decrease in strength, with values of 15.55 MPa and 13.76 MPa for 10% and 15% replacements due to reduction in cement content.



4.3.2 14 Days

MIX	CM	LSM	MD5-LSM	MD10-LSM	MD15-LSM
14 Days	21.31	28.86	31.56	18.64	16.87

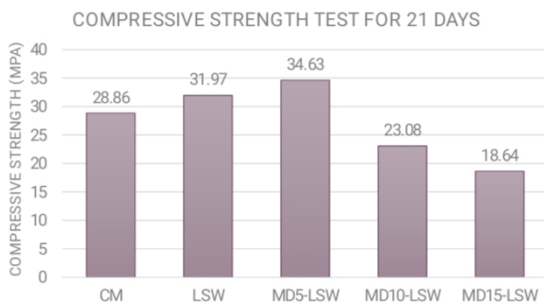
At 14 days, the compressive strength increased for all mixes compared to 7 days. The control mix achieved a strength of 21.31 MPa, while the lime mix showed improved strength of 28.86 MPa. The 5% marble mix exhibited the highest strength of 31.56 MPa, indicating optimum performance at this level. However, the strength decreased for higher replacements, with values of 18.64 MPa and 16.87 MPa for 10% and 15% respectively, due to dilution of cementitious material. This trend confirms that partial replacement of cement with marble dust is beneficial up to an optimum level of 5%.



4.3.3 21 Days

MIX	CM	LSM	MD5-LSM	MD10-LSM	MD15-LSM
21 Days	28.86	31.97	34.63	23.08	18.64

At 21 days, the compressive strength of all concrete mixes showed a significant increase compared to earlier curing periods. The control mix achieved a strength of 28.86 MPa, while the lime-saturated water mix improved to 31.97 MPa due to enhanced hydration. The mix containing 5% marble dust exhibited the highest strength of 34.63 MPa, indicating optimum performance at this level. However, with further increase in marble dust content, the strength decreased to 23.08 MPa and 18.64 MPa for 10% and 15% replacements. This reduction is due to the dilution of cement and reduced bonding properties.

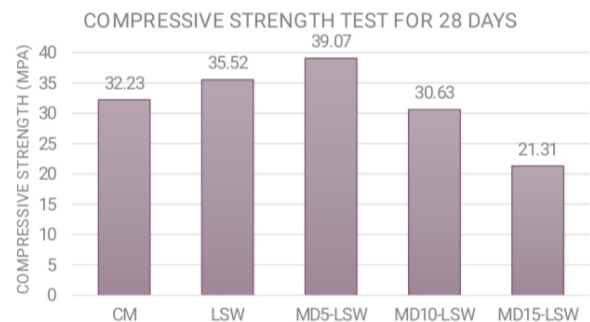


4.3.4 28 Days

MIX	CM	LSM	MD5-LSM	MD10-LSM	MD15-LSM
28 Days	32.23	35.52	39.07	30.63	21.31

The control mix attained a strength of 32.23 MPa, while the lime mix showed an increased strength of 35.52 MPa. The 5% marble dust mix exhibited the highest strength of 39.07 MPa, confirming it as the optimum replacement level. However, further increase in marble dust content led to a reduction in strength, with values of 30.63 MPa and 21.31 MPa for 10% and 15% respectively. This indicates that excessive replacement reduces the cementitious content, leading to lower strength. Overall, the results confirm that

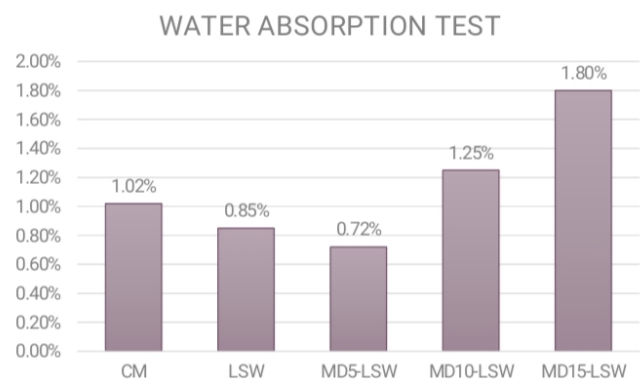
5% marble dust with lime-saturated water provides the best compressive strength.



4.4 WATER ABSORPTION TEST OF CONCRETE CUBES

4.4.1 28 Days

MIX	CM	LSM	MD5-LSM	MD10-LSM	MD15-LSM
VALUES (%)	1.02	0.85	0.72	1.25	1.80



The water absorption test was conducted to evaluate the porosity and durability of different concrete mixes. The control mix showed a water absorption of 1.02%, while the use of lime-saturated mixing water reduced it to 0.85%. At 5% marble dust replacement, the water absorption further decreased to 0.72%, indicating a denser and more compact concrete structure. However, with an increase in marble dust content to 10% and 15%, the water absorption increased to 1.25% and 1.80% respectively due to the reduction in cement content and increase in voids. The results indicate that the optimum mix (5%) exhibits the lowest water absorption and hence better durability.

5.CONCLUSION

Based on the experimental investigation carried out on concrete using marble dust and lime-saturated mixing water, the following conclusions were drawn:

- The experimental study shows that the addition of marble dust and lime-saturated water affects the properties of concrete.
- The workability of concrete, determined by the slump test, slightly changed with the addition of marble dust due to the finer particles present in the mix.
- The compressive strength of concrete increased up to an optimum percentage of marble dust replacement, after which the strength gradually decreased.
- The use of lime-saturated mixing water helped in improving the bonding and hydration process in the concrete mix.
- The experimental results indicate that marble dust can be effectively used as a partial replacement material in concrete, which helps in reducing cement consumption and utilizing industrial waste.
- Therefore, the use of marble dust and lime-saturated water in concrete can contribute to sustainable construction practices.

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