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Effect of Partial Replacement of Cement with Marble Dust and Coarse Aggregates with Marble Aggregates on Concrete

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Abstract - Environmental problems are caused due to waste produced by industries. A recently introduced composite material called Marble Dust Powder (MDP) will enable the concrete industry to maximize material consumption, provide economic advantages, and construct strong, durable, and environmentally friendly structures. MDP is a by-product of the parent marble rock, which that possesses a high calcium oxide content of about 50%, and is obtained during the quarrying process. Since the presence of lime boosts the reactivity efficiency, MDP may be an ideal alternative for cementitious binder technique. In this study, the characteristics of hardened concrete were investigated using waste MDP that passed through 90 microns. Additionally, the impact of varying MDP replacement percentages on compressive strength and splitting tensile strength has been noted. The impact of MDP in concrete on strength has been demonstrated in this experimental investigation. Four concrete mixtures have been developed, with 10% and 15% MDP replacing cement and 20% and 40% MA replacing coarse aggregate on a weight basis. All concrete mixtures had the same water/cement ratio (0.45). The concrete mixtures' compressive strength was measured at 7, 14, and 28 days, and its split tensile strength was measured at 7 days. The laboratory work's findings demonstrated that adding 15% MDP to the cement and 20% MA to the coarse aggregate increased the concrete's compressive and split tensile strengths.

***Key Words*:** Marble Dust Powder (MDP), Marble Aggregate (MA), Compressive Strength, Tensile Strength.

1. INTRODUCTION

Several million tons of MDP are estimated to be produced globally during quarrying. Marble powder has therefore emerged as a significant substitute material for concrete that may be used effectively for improving the concrete's hardening qualities. Pure limestone undergoes metamorphism to transform into marble, a type of rock. Marble's color and appearance are determined by its purity; if the limestone is made entirely of calcite (100% CaCO3), it will turn out white. Marble is used in both construction and decoration because it is strong, looks prestigious, and is therefore popular for. Marbles are crystalline rocks that are mostly made of minerals like calcite, dolomite, or serpentine. The other components of minerals differ depending on where they come from. Magnesia, phosphate, leads, zinc, alkalis, and sulfides are the primary contaminants in raw limestone (for cement) that might alter the characteristics of final cement. The cutting process produces a significant amount of MDP. As a result, the amount of marble waste—which accounts for 20% of all marble quarried—has increased to millions of tons. Direct release of these waste products into the environment may result in environmental issues. Additionally, the supply of natural aggregate and minerals needed to make cement is limited, and energy consumption and carbon dioxide emissions from construction processes must be decreased. MDP is being used as a partial substitute for Portland pozzolana cement in order to address these issues. In India, MDP settles through sedimentation before being disposed of, polluting the environment, creating dust in the summer, and endangering public health and agriculture. Environmental protection would therefore be aided by the use of the MDP in a variety of industrial sectors, particularly the construction, agricultural, glass, and paper industries. Waste can be recycled into new goods or utilized as admixtures to safeguard the environment from waste deposits and make better use of natural resources.

1.1. RESEARCH SIGNIFICANCE

MDP gathered from a local source was utilized in this study's investigation. Various replacement amounts of MDP and MA, together with fine and coarse aggregate, were used for making concrete mixtures.

1.2. OBJECTIVE OF INVESTIGATION

Our primary goal in this project is to investigate the effects of partially substituting MDP for cement and MA for coarse aggregates. Ordinary M25 grade concrete's compressive strength is determined. Similar results were achieved for the 10% and 15% weight replacement of cement with MDP and the 20% and 40% substitution of coarse aggregates with MA in terms of compressive strength and split tensile strength. The water-to-cement ratio (0.45) remained constant throughout the project's investigation.

- To investigate the compressive strength of concrete with partial replacement of cement with marble dust powder & coarse aggregates with marble aggregates.
- To evaluate the tensile strength of concrete incorporating various proportions of marble aggregates & marble dust powder.
- To compare the workability of concrete mixes with varying percentage of marble aggregates & marble dust powder.

2. LITERATURE REVIEW

The purpose of this study is to develop high-strength concrete by using combination of MDP and MA. MDP is a good material to utilize in concrete since it has good pozzolanic activity. These days, MDP is also widely used in a variety of

structural areas, such as reinforced cement concrete, which is becoming more and more well-liked due to its beneficial effects on concrete's many qualities. Even though there has been a lot of interest in MDP utilizing, research over the past few decades, the most recent findings are included below:

A. Corinaldesi V et al., (2010) Marble has been widely used as a building material, particularly for palaces and monuments. However, its application is restricted to usage as stone bricks for walls or arches or as lining slabs for walls, roofs, or floors; it is typically wasted in quarries or the sizing industry for use as a plasticizer or filler in mortar or concrete in the building industry itself. As a result, the mass—which accounts for 40% of all marble quarried—has increased to millions of tons. One of the major environmental issues facing the world today is the tremendous amount of unoccupied marble trash, which is made up of extremely small particles. [1]

B. V.M. Sounthararajan et.al (2013) The impact of the lime content in MDP on the production of high-strength concrete has been studied. They discovered that the properties of hardened concrete were examined when the MDP was up to 10% by weight of cement. Additionally, the impact of varying percentages of MDP replacement on the flexural, splitting tensile, and compressive strengths was assessed. It is evident that the ratios of cement to total aggregate and fine to coarse aggregate had a greater impact on the enhancement of strength characteristics. In addition to demonstrating better mechanical properties when compared to controlled concrete, a remarkable rise in compressive strength of 46.80 MPa at 7 days was seen with 10% replacement of MDP in cement content. [2]

C. Manju Pawar et.al (2014) Periodic Research has undertaken a study on the significance of using leftover marble powder in place of certain cement. They discovered that the relative compressive, tensile, and flexural strengths of concrete or mortar have been examined when marble powder is used as a fines component by partially lowering cement proportions. When different percentages of marble powder are used to partially replace cement, it is found that higher waste marble powder (WMP) ratios lead to stronger mortar and concrete. Direct disposal of waste items into the environment can lead to environmental issues. Therefore, adding waste marble powder to concrete up to 12.5% of the weight of cement increases its compressive strength; however, adding more WMP causes its compressive strength to diminish. Up to 12.5% of the weight of cement can be replaced with waste marble powder to boost the tensile strength of concrete; however, the tensile strength diminishes with each further addition of WMP. As a result, they discovered that the ideal amount of cement to replace MDP is around 12.5% for both compressive and tensile strength. [3]

3. MATERIALS USED IN THE INVESTIGATION

3.1. CONCRETE MIX CONSTITUENTS

Concrete is a composite material that is made through mixing cement, water, fine and coarse aggregates.

3.1.1. CEMENT

Portland Pozzolana Cement (53 Grade) was used in the entire experimental study.

3.1.2. AGGREGATE

MA was utilized as 20% and 40% by weight of the total aggregate obtained in this experiment, whereas CA and normal river sand that is locally accessible in the market and conforms to Zone II as per BIS (IS 383:1970) were used.

Table -3.1: Physical properties of Fine and Coarse aggregate

Properties	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.68	2.8

Fig -3.1: Fine Aggregate

Fig -3.2: Coarse Aggregates (20mm size)

Fig -3.3: Marble Aggregates (20mm size)

Fig -3.4: Marble Dust Powder

3.1.3. WATER

In this study, concrete was mixed and cured using potable water which is free from organic impurities.

3.2. MARBLE DUST POWDER (MDP)

MDP is one of the major wastes generated in the stone industry when marbles are cut, shaped, and polished. About 20–25% of the marble undergoes this process and becomes powder. Approximately 10% of the world's marble exports come from India, which releases millions of tons of waste marble from processing facilities annually. This project has been planned and preceded because of the significant amount of waste generated in the marble factory.

Table 3.2 provides information on MDP's physical characteristics.

Table -3.2: Physical Properties of MDP

Properties	Test Result
Colour	White
Form	Powder
Odour	Odourless
Sieve	90 µm

4. METHODOLOGY

In accordance with the Indian Standard (IS: 10262-2009), the design mix for M25 grade concrete was made by substituting two different weight percentages of MDP (10% and 15%) in certain amounts of the cement and two different weight percentages of MA (20% and 40%) for certain amount of the coarse aggregates. The ratios used throughout the study are shown in table 4.1.

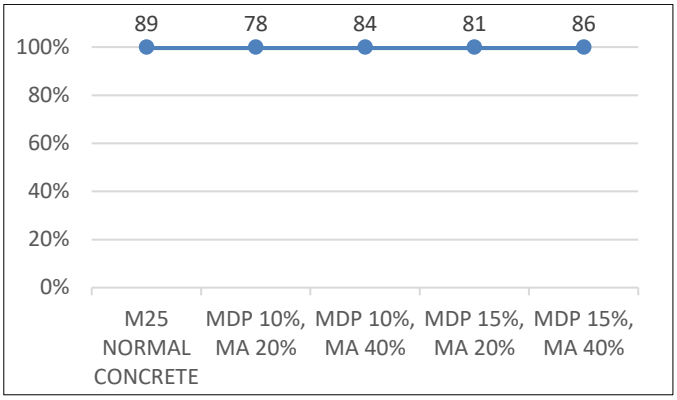
Table -4.1: Ratios used in the study

Marble Dust Powder (MDP)	Marble Aggregates (MA)
10%	20%
	40%
15%	20%
	40%

4.1. WORKABILITY

In graph 4.1, It is observed that degree of workability is medium as per BIS (IS: 456-2000) for the normal concrete and for all the ratios.

Graph -4.1: Slump Test Result



4.2. COMPRESSIVE STRENGTH TEST

In accordance with IS 516-1959, compressive strength tests are conducted. A 3000 KN compression testing machine is used for the test. Concrete's mechanical behavior has been studied for M25 grade cubes that were cast and allowed to cure for 7, 14, and 28 days. Concrete's compressive strength is measured on cubes at varying percentages of MDP and MA content. Concrete's strength was tested on cubes at 7, 14, and 28 days of curing; the findings are displayed in graph 4.2 and table 4.2. Concrete's compressive strength is tested using a compression testing machine.

4.3. SPLIT TENSILE STRENGTH

In accordance with IS 5816-99, split tensile strength is determined. The test is carried out using a 3000 KN capacity compression testing machine, and its results are displayed in graph 4.3 and recorded in table 4.3. The load is applied until the cylinder fails while it is horizontally positioned between the loading surfaces of the compression testing apparatus. In order to avoid accidental loads, plywood was utilized. During the test, the platens of the testing machine shall not be allowed to rotate in a plane perpendicular to the axis of the cylinder. The split tensile strength is computed using the following formula.

$$T = 2P/\pi LD$$

Where; T: Tensile strength in (N/mm^2)
P: Maximum load applied to the specimen in (N)
L: Length of the specimen in (mm)
D: C/S dimension of the specimen in (mm)

Fig -4.1: Compressive strength test experimental setup

Table -4.2: Analysis of test results of concrete (Compressive strength)

Mix		Compressive Strength (N/mm^2)		
		7 Days	14 Days	28 Days
M25 Normal Concrete		21.66666667	25.13333333	28.67
MDP 10%	MA 20%	22.62222222	24.2	28.93333333
	MA 40%	18.28888889	31.33333333	32.6
MDP 15%	MA 20%	19	27.95555556	33.68888889
	MA 40%	17.33333333	28.24444444	31.88148148

Table -4.3: Analysis of test results of concrete (Split tensile strength)

Mix		Split Tensile Strength (N/mm^2)
		7 Days
MDP 10%	MA 20%	2.315
	MA 40%	2.188
MDP 15%	MA 20%	2.462
	MA 40%	1.802

DESCRIPTION:

MDP: Marble Dust Powder. MA: Marble Aggregate.

M25 Normal Concrete: Standard M25 grade concrete.

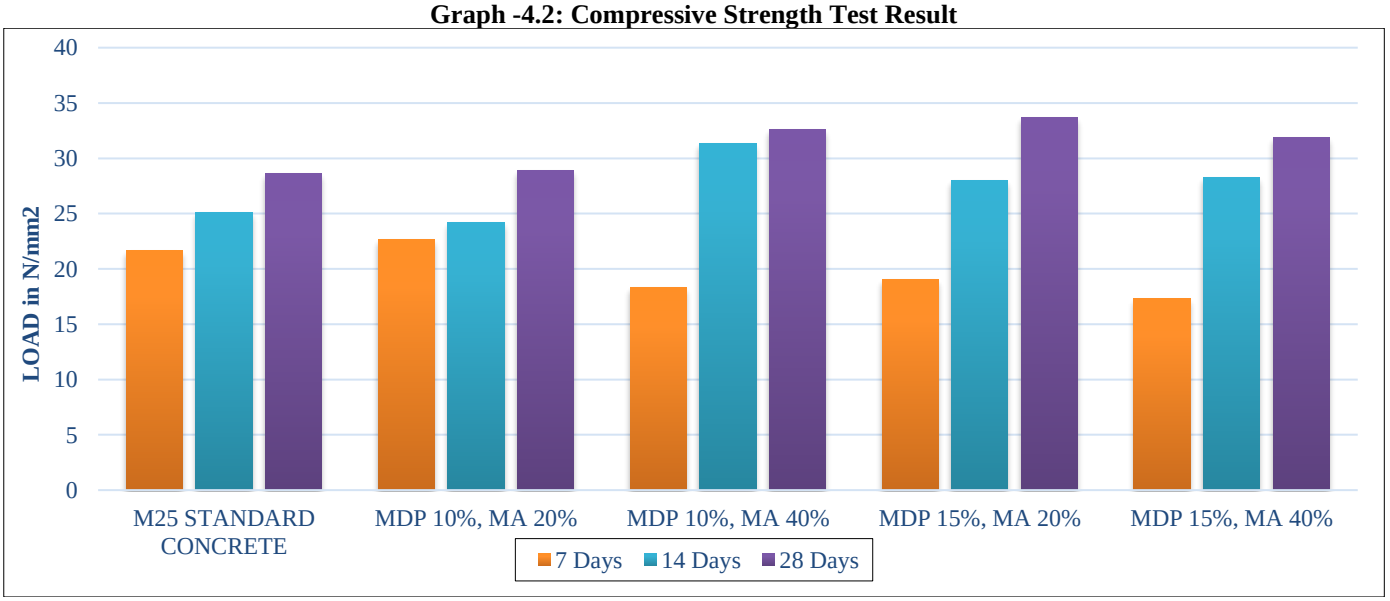
MDP 10% & MA 20%: 10% marble dust powder and 20% marble aggregate are substituted in the concrete mix.

MDP 10% & MA 40%: 10% marble dust powder and 40% marble aggregate are substituted in the concrete mix.

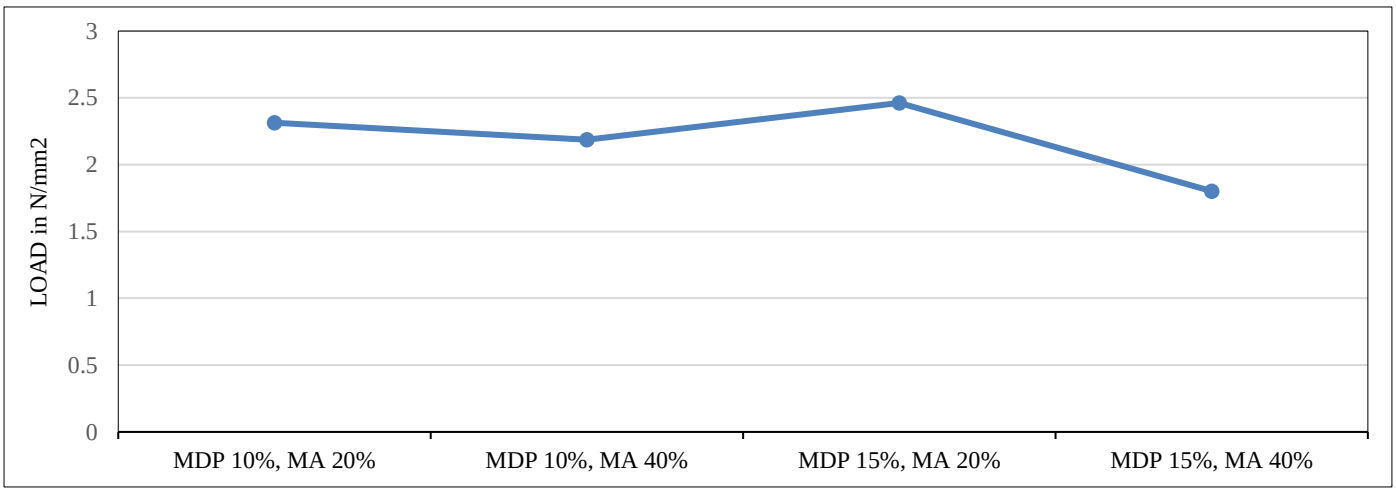
MDP 15% & MA 20%: 15% marble dust powder and 20% marble aggregate are substituted in the concrete mix.

MDP 15% & MA 20%: 15% marble dust powder and 40% marble aggregate are substituted in the concrete mix.

Graph -4.2: Compressive Strength Test Result



Graph -4.3: Split Tensile Strength Test Result



5. CONCLUSIONS

The following conclusions were based on the study on the test result:

1. The usage of MDP in concrete improved its quality in terms of strength.
2. When 15% of the cement is replaced with MDP and 20% of the coarse aggregates are replaced with marble aggregates, the concrete's compressive strength increases; however, when the percentage is increased further, the concrete's compressive strength decreases.
3. When 15% of the cement is replaced with MDP and 20% of the coarse aggregates are replaced with marble aggregates, the split tensile strength of the concrete increases; however, when the percentage is increased further, the split tensile strength of the concrete decreases.
4. According to the findings, MDP can be used in place of cement, and when compared to regular concrete, a 15% substitution of MDP for cement and a 20% substitution of marble aggregates for coarse aggregates yields good strength results.
5. Utilizing these waste materials promotes sustainable growth in the construction sector.

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LIST OF REFERENCE BUREAU OF INDIAN STANDARD CODES

1. IS: 456:2000 Code of practice for plain and reinforced concrete (fourth revision).
2. IS: 10262:2009, Indian Standard Concrete Mix Proportioning- guidelines (First Revision).
3. IS: 516:1959 Method of test for strength of concrete (sixth print January, 1976).
4. IS: 2386:1963(all parts) Methods of test for aggregate for concrete.
5. IS: 1727:1967 Methods of test for pozzolana materials (first revision, reprinted January, 1989).
6. IS: 1199:1959 Methods of sampling and analysis of concrete.
7. IS: 5816:1999 Method of test for splitting tensile strength of concrete cylinders.
8. IS: 7320:1974(reaffirmed1999) Specification for concrete slump test apparatus.
9. IS: 383:1970, Indian Standard specification for coarse and fine aggregates from natural sources for concrete (Second Revision).
10. IS: 1130:1969(reaffirmed 2003) Specification for marble (blocks, slabs and tiles).
11. IS: 10082-1982(reaffirmed 1999) Specification for moulds for use in tests of cement and concrete (Second Reprint DECEMBER 1995).