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A Study on Partial Replacement of Cement by Marble Dust in Concrete

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ABSTRACT—

Improving the properties of concrete by addition of waste marble powder is becoming popular now a day because it helps in achieving the economy and is a superior alternative as concrete ingredient, which offers high strength. In this project we have investigated the mechanical characteristics of concrete cubes, beams & cylinders made by partially replacing cement with concrete. In this research we have conducted various tests on materials like cement, sand & aggregate. The optimum levels for replacement of cement by marble powder were determined for M30 grades of concrete. In this research marble dust was replaced with cement at 0%, 5%, 10%, 15% & 20% by weight of concrete. The subsequent modification in microstructure of cement composites may enhance the properties like compressive strength, flexural strength & split tensile strength.

Keywords: Marble Dust, cement, sand, Aggregate, compressive strength, Flexural Strength, Tensile Strength

1. INTRODUCTION

Concrete is the most extensively used and adaptable building material which is generally used to resist compressive forces. Since the use of cement and production of cement creates much more environmental issues and also it is long process. Hence Marble Dust can be used as a developing binding material that will allow the concrete industry to optimize materiel use, and construct structures that will be strong, durable and sensitive to the environment. The probable usage of Marble Dust can be an ideal choice if used as a substitute in a cementitious binder as its reacting efficiency increases due to the presence of lime. The surplus generated from the marble industries causes environmental problems. Hence the reuse of this waste material has to be emphasized. It has been estimated that several million tons of Marble dust are produced during quarrying worldwide. Hence consumption of marble powder has become a significant substitute materials towards the effective application in concrete for enhanced harden properties of concrete. A marble dust, obtained as a by-product of marble cutting, sawing, shaping was characterized from physical and chemical point of view for using it as binding material in production of concrete and mortar. Marble is a metamorphic rock resulting from the transformation of a pure limestone. Marble dust contains high calcium oxide content of more than 50%.

2. MATERIAL USED

2.1 Cement: Ordinary Portland cement, 53 grade conforming to IS 12269 was used.

2.2 Sand: Sand is available near Narmada River. This sand is used for the above research work.

2.3 Natural aggregate: 20 mm natural coarse aggregate is used having a specific gravity of 2.72.

2.4 Marble Dust*:* It has been calculated that huge tons of Marble Dust Powder are being produced in the process of quarrying worldwide. Disposal of this waste has become an environmental issue therefore it utilization of marble powder in concrete for improved harden properties. Marble is a metamorphic rock. It is composed of 100% CaCO3.Marble is used in construction and has a good durability and aesthetic appearance. Chemically, marbles are composed mostly of calcite, dolomite or serpentine minerals. Marble dust powder is produced during the marble cutting process, which is 20% of the total marble quarried. The limited availability of natural minerals in the production of cement pushes us to find alternatives for replacing cement, thereby reducing emission of carbon dioxide production which is harmful for the environment. Advantages of using marble powder are as follows: • It acts as a filler and reduces voids. • Increases the strength of concrete. • Low Cost. • Good binding.

3. MATERIAL TESTING:

The following tests were conducted on the material & their results are as follows:

3.1 Tests on cement

3.1.1 Normal consistency test: To determine the Normal consistency of a given cement sample.

Table 3.1 Results of normal consistency test

Trial No.	Percentage of water added	Penetration (mm)
1	28%	30mm
2	30%	16mm
3	32%	6mm

Results:

Normal consistency = 32%

Discussions:

The normal consistency of cement should be ranging from 28-32%. Hence O.K.

3.1.2 Setting time of cement:

To find the initial and final setting time of given cement sample.

- Weight of sample = 300gms.

Table 3.2 Results of setting time of cement

S.No.	Time in minute	Unpenetrated depth (mm) from bottom
1	0	0
2	15	0
3	30	1
5	65	2
6	135	5

- Normal consistency of cement = 32%

Amount of water added = = $\frac{0.85\times32\times300}{100}$ 81.6 ml

Results:

Initial Setting Time =135 min

Final Setting Time = 247 min

Discussions:

As per IS 269-1970 the initial setting time of cement should not be less than 30 min and final setting time should not be more than 600 min. As per IS specification the initial setting time and the final setting time is satisfactory.

3.1.3 Specific gravity of cement :

To determine the specific gravity of cement by density bottle.

Observation:

Specific gravity = $\frac{(W2-W1)}{((W2-W1)-(W3-W4)} \times \frac{1}{0.79}$

Table 3.3 Test results of specific gravity of cement

Description	Avg values
Weight of the specific gravity bottle (W1) gm	24
Weight of the specific gravity bottle + Cement (W2) gm	54
Weight of the specific gravity bottle + Cement +Kerosene (W3) gm	85
Weight of the specific gravity bottle + Kerosene (W4)	65

Results:

Specific Gravity, G = 3

Discussions:

The specific gravity value of OPC cement is generally around 2.9 – 3.2, our specific gravity value is 3, Hence OK.

3.2 Tests on coarse aggregate

3.2.1 Specific gravity of coarse aggregate:

To determine the specific gravity of given coarse aggregate

Specific gravity = $$\frac{W2-W1}{((W2-W1)-(W3-W4))}$$

Table 3.4 Test results of specific gravity of coarse aggregate

Description	Trail 1	Trail 2
Weight of the empty container W1 (gm)	3060	3060
Weight of the container + coarse aggregate W2 (gm)	7635	7630
Weight of the container + coarse aggregate + water W3(gm)	8900	8945
Weight of the container + water W4 (gm)	6080	6080

Results:

Specific Gravity, G = 2.68

Discussions:

The specific gravity of aggregates normally used in construction ranges from about 2.5 to 2.9. So obtained specific gravity is 2.68. Hence O.K.

3.2.2 Crushing value of coarse aggregate:

To determine the crushing value of the given sample of coarse aggregate. Observations:

Empty weight of cylinder (W1) = 240 gm

Weight of cylinder and sample (W2) = 2632 gm

Total weight of aggregate sample (W3) = (W2) - (W1)

= 2632-240 = 2392 gm

Weight of crushed material passing through 2.36 mm sieve (W4) = 580 gm

Aggregate crushing value = (580/2392) x 100

= 24.24 %

Discussions:

Indian road congress and ISI have specified that aggregate crushing value of the coarse aggregate should not exceed 30% for cement concrete pavement at surface. For aggregates used for concrete other than wearing surfaces, the crushing value should however be less than 45%. From the obtained crushing value of the given sample of aggregate, it can be used for cement concrete pavement.

3.2.3 Sieve analysis test on coarse aggregate

To determine the particle size distribution of given coarse aggregate.

Observation:

Weight of sample taken =5000 gm

Table 3.5 Observation of sieve analysis test on coarse aggregate

Sl.No.	Sieve size (mm)	Weight retained on each sieve (gm)	Cumulative weight retained	Cumulative % retained	Cumulative % finer
1	32.5	0	0	0	100
2	20	724	1724	34.48	65.52
3	16	1432	3156	63.12	36.28
4	12.5	1412	4568	91.36	8.64
5	10	362	4930	98.6	1.4
6	8	42	4972	99.4	0.6
7	6.3	28	5000	100	0

Discussions:

From the results the coarse aggregates are well graded and these are confirming to Grading Zone-II Table 2 of IS 383-1970.

3.3 Tests on fine aggregate

3.3.1 Sieve analysis test on fine aggregate

To determine the particle size distribution of given sand.

Observation:

Weight of sample taken =1000 gm

Table 3.6 Observation of sieve analysis test on fine aggregate

Sieve size (mm)	Weight retained on each sieve (gm)	Cumulative weight retained	Cumulative % retained	Cumulative % finer
4.75	0	0	0	100
2.36	5	5	0.5	99.5
1.18	104	109	10.9	89.1
0.60	306.5	415.5	41.55	58.45
0.30	468	883.5	88.35	11.65
0.15	107	990.5	99.05	0.95
0.075	4.5	995	99.5	0.5
Pan	5	1000	100	0.0

Fineness modulus = 2.40

Discussions:

The given sample confirming to grading zone 2 as per table 4 of IS 383.

4. EXPERIMENTAL WORK

4.1 Casting of cubes:

According to IS: 516-1959, test specimen for determining compressive strength of concrete of cubical shape should be 15 cm*15cm*15cm. If maximum size of aggregate is not more than 2 cm then a cubical shape of 10cm*10cm*10cm may be used as an alternative. In this research work i have used a cubical shaped specimen of size 15cm*15cm*15cm. During casting of cubes, mixing of materials and proportioning is done as per IS: 516-1959 as specified in clause in 2. Page no 4. A mix proportion of 1:1.75:2.75 of binder, fine aggregate and coarse aggregate respectively is adopted for this work.

4.2 Casting of beams:

As we talk about casting of beams for determining flexural strength of beams, according to IS: 516-1959, standard size of test specimen should be 15cm*15cm*70cm. If maximum size of aggregate does not exceed 19 mm, a beam of size 10cm*10cm*50cm may be used. In this research work I have used a beam of size 10cm*10cm*50cm for preparing specimen. During casting of beams IS standards were kept in mind and mixing of materials, proportioning and preparation of mould is done as per clause 7 on page no 15 in US: 516-1959. Same mix proportion is adopted for beam casting as adopted in casting in cubes, fine aggregates and coarse aggregates respectively.

4.3Casting of Cylinders:

As we talk about casting of cylinders for determining split tensile strength of concrete, according to IS 5816 - 1970, standard size of test specimen should be 15cm diameter and 30cm height. During casting of cylinders IS standards were kept in mind and mixing of materials, proportioning and preparation of mould is done IS 5816 - 1970. Same mix proportion is adopted for cylinder casting as adopted in casting of cubes & beams, fine aggregates and coarse aggregates respectively.

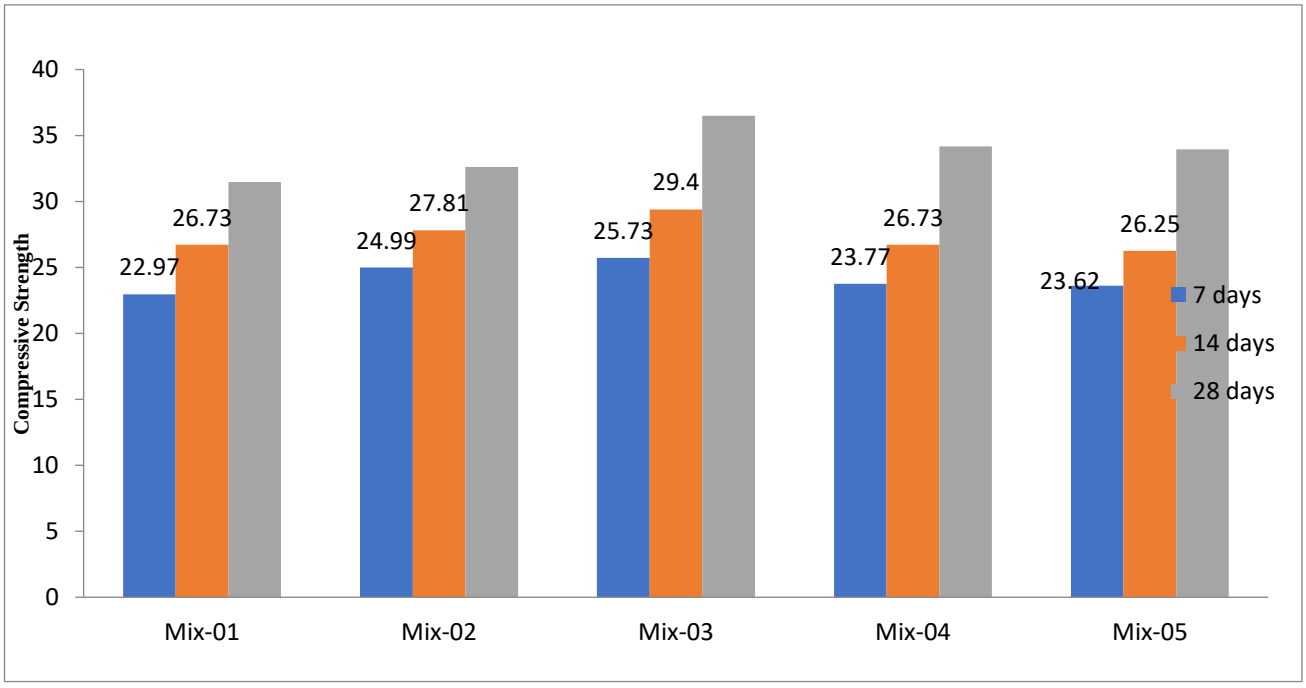
5. RESULT & DISCUSSION

5.1 Compressive Strength;

A minimum of three cubes are casted in each batch mix for determining compressive strength. Tests are performed at the age of 7 days, 14 days & 28 days of the specimens. Specimens are placed in the test machine as per IS: 516-1959 clause no 5.5.1 page no 11, also loading is applied on the specimen as per the same IS code. Calculation are made by dividing the maximum applied load by the cross sectional area of the specimen. As there are three specimens for each batch mix, the average of the three values is taken & calculates the compressive strength (for 7, 14 & 28 days) as shown in table below

Table 5.1 : Compressive Strength Result

% of MD	**0%**	**5%**	**10%**	**15%**	**20%**
7 Days	22.97 N/mm^2	24.99 N/mm^2	25.73 N/mm^2	23.77 N/mm^2	23.62 N/mm^2
14 Days	26.73 N/mm2	27.81 N/mm2	29.40 N/mm2	26.73 N/mm2	26.25 N/mm2
28 Days	31.47 N/mm^2	32.62 N/mm^2	36.51 N/mm^2	34.17 N/mm^2	33.95 N/mm^2



Graph: 1 Compressive Strength in N/mm^2 at Various age (days)

Discussion:

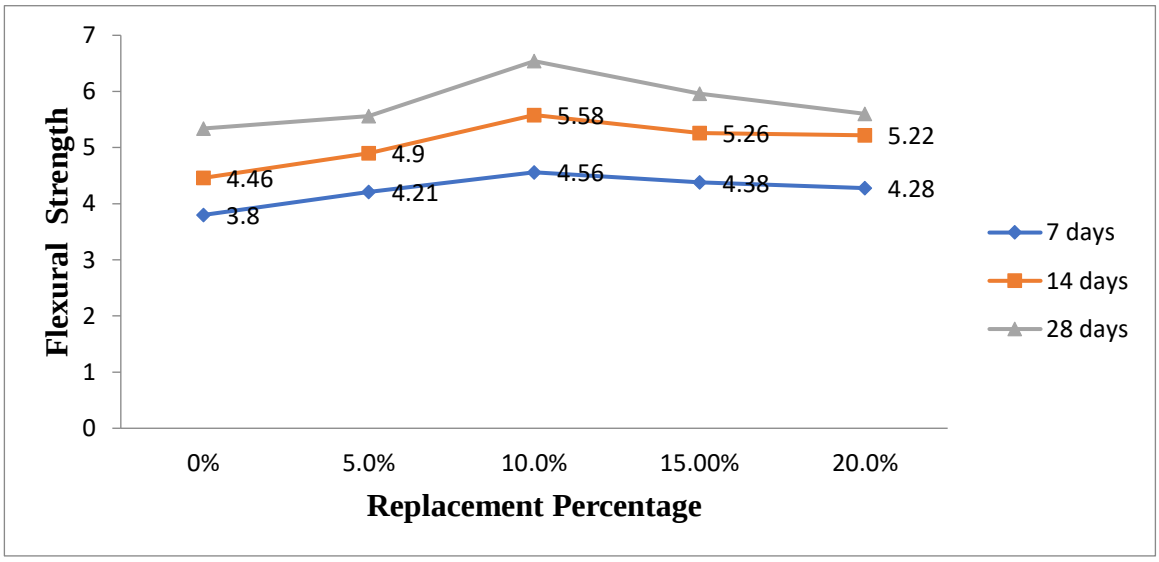
As shown in the graph: 1 (7 days strength), when cement is partially replaced 10% by MD, compressive strength is increased by 12.01%. Afterwards when addition of % of MD is replaced, strength starts decreasing, a minimum strength is achieved. As shown in the graph: 1 (14 days strength), when cement is partially replaced 10% by MD, compressive strength is increased by 9.98%. Afterwards when addition of % of MD is replaced, strength starts decreasing, a minimum strength is achieved. As shown in the graph: 1 28 days strength in graph:3 show an increment of 16.01% of strength of 10% replacement of MD as compared with conventional concrete. Again strength is decreased when addition of percentage of MD.

5.2 Flexural Strength

Beams of size 10cm*10cm*50cm are casted for determining flexural strength. Test on beams are performed at the age of 7 days, 14 days & 28 days of the specimen. Placement of specimen in machine is done as per IS: 516-1959 in the clause no 8.3.1 page no 17. Load is applied at increasing rate of 108KN/min. Load is applied until specimen fails and load at which specimen fails is recorded. As specified in the IS code flexural strength is calculated and tabulated below:

Table 5.2: Variation of flexural strength with age

% of MD	0%	5%	10%	15%	20%
7 Days	3.8MPa	4.21 MPa	4.56MPa	4.38MPa	4.28MPa
14 Days	4.46MPa	4.90 MPa	5.58 MPa	5.26 MPa	5.22 MPa
28 Days	5.34 MPa	5.56MPa	6.54MPa	5.96MPa	5.60MPa



Graph: 2 Flexural Strength in N/mm^2 at various age (Days)

Discussion:

As shown in the graph: 2 (7 days strength), when cement is partially replaced 10% by MD i.e. flexural strength is increased by 20%. Afterwards when % of MD is increased the strength starts decreasing

As shown in the graph: 2 (14 days strength), when cement is partially replaced 10% by MD i.e. flexural strength is increased by 25.11%. Afterwards when % of MD is increased the strength starts decreasing

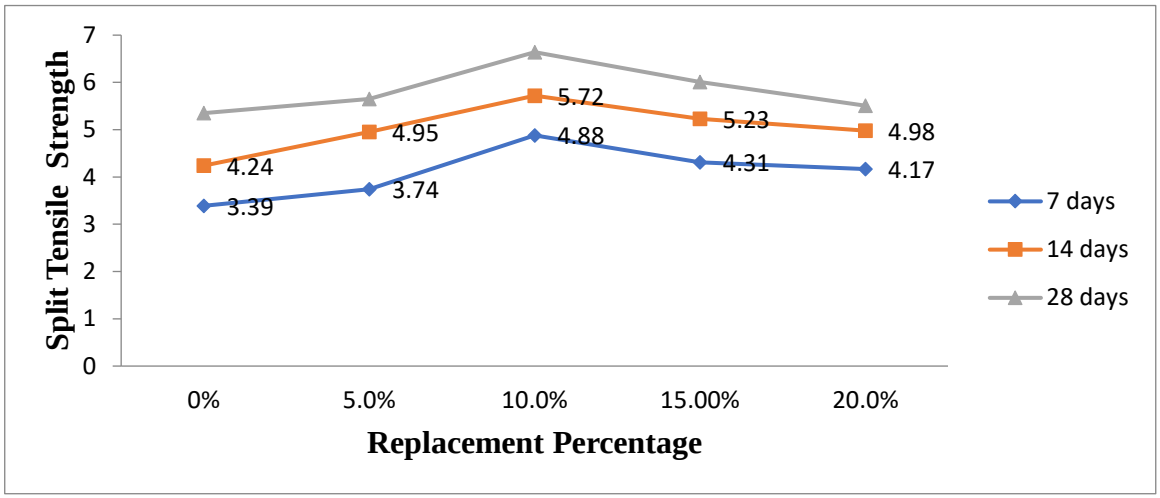
When graph: 2 (28 days strength) is analyzed, 10% replacement of MD gives 22.47% more flexural strength when compared with normal concrete. Here also, when % of MD is increased, strength starts decreasing.

5.5.3 Split Tensile Strength

Cylinders of size 15 cm diameter and 30 cm height are casted for determining Split Tensile Strength. Test on cylinders are performed at the age of 7days, 14 days & 28 days of the specimen. Placement of specimen in machine is done as per IS: 516-1959. Load is applied until specimen fails and load at which specimen fails is recorded. As specified in the IS code Split Tensile Strength is calculated and tabulated below:-

Table 5.3: Variation of Split Tensile strength with age

% of MD	0%	5%	10%	15%	20%
7 Days	3.39 MPa	3.74MPa	4.88 MPa	4.31MPa	4.17 MPa
14 Days	4.24 MPa	4.95 MPa	5.72 MPa	5.23 MPa	4.98 MPa
28 Days	5.35 MPa	5.65 MPa	6.64 MPa	6.01 MPa	5.51 MPa



Graph: 3 Split Tensile Strength in N/mm^2 at various age (Days)

Discussion:

As shown in the graph: 3 (7 days strength), when cement is partially replaced 10% by MD i.e. split tensile strength is increased by 43.95%. Afterwards when % of MD is increased the strength starts decreasing

As shown in the graph: 3 (14 days strength), when cement is partially replaced 10% by MD i.e. split tensile strength is increased by 34.90%. Afterwards when % of MD is increased the strength starts decreasing

When graph: 3 (28 days strength) is analyzed, 10% replacement of MD gives 24.11% more split tensile strength when compared with normal concrete. Here also, when % of MD is increased, strength starts decreasing.

6. CONCLUSIONS:

Based on the various tests conducted on concrete with varying proportion of MD the results were obtained and discussed in previous chapter from which the following conclusions are drawn.

1. Maximum compressive strength was observed 25.73 N/mm^2, 29.40 N/mm^2 & 36.51 N/mm^2 (for 7,14 & 28 days) when Marble Dust replacement is about 10% for M-30 grade concrete and after that there is decrease in compressive strength of concrete with further replacement of cement.
2. Maximum flexural strength was observed 4.56 N/mm^2, 5.58 N/mm^2 & 6.54 N/mm^2 (for 7, 14 & 28 days) when Marble Dust replacement is about 10% for M-30 grade concrete and after that there is decrease in flexural strength of concrete with further replacement of cement
3. Maximum split tensile strength was observed 4.88 N/mm^2,5.72 N/mm^2 & 6.64 N/mm^2 (for 7,14 & 28 days) when Marble Dust replacement is about 10 % for M-30 grade concrete and after that there is decrease in split tensile strength of concrete with further replacement of cement.

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