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Experimental Investigation on Strength and Durability Parameters of Concrete Replacing Cement by Marble Powder

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Abstract: The waste generated from the industries cause environmental problems. Hence the reuse of this waste material can be emphasized. Marble Dust Powder (MDP) is a developing composite material that will allow the concrète industry to optimise materiel use, generate economic benefits and build structures that will strong, durable and sensitive to environnement. Marble Dust Powder is by-product obtained during the quarrying process from the parent marble rock; which contains high calcium oxide content of more than 50%. The potential use of Marble Dust Powder can be an ideal choice for substituting in a cementitious binder as the reactivity efficiency increases due to the presence of lime. In this research work, the waste Marble Dust Powder passing through 90 microns, has used for investigating of hardened concrete properties. Furthermore, the effect of different percentage replacement of Marble Dust Powder on the compressive strength, splitting tensile strength (Indirect tensile strength) & flexural strength has been observed. In this experimental study, the effect of Marble Dust Powder in concrete on strength is presented. Five concrete mixtures containing 0%, 5%, 10%, and 20% Marble Dust Powder as cement replacement by weight basis has been prepared. Water/cement ratio (0.43) was kept constant, in all the concrete mixes. Compressive strength, split tensile strength & flexural strength of the concrete mixtures has been obtained at 7 and 28 days. The results of the laboratory work showed that replacement of cement with Marble Dust Powder increase, up to 10% for compressive strength, & up to 15% for split tensile strength & flexural strength of concrete.

Keywords: Marble Dust Powder (MDP), cement, Compressive strength, Tensile strength, flexural strength

1. Introduction

It has been estimated that several million tons of MDP are produced during quarrying worldwide. Hence utilization of marble powder has become an important alternative materials towards the efficient utilization in concrete for improved harden properties of concrete. Marble is a metamorphic rock resulting from the transformation of a pure limestone. The purity of the marble is responsible for its colour and appearance it is white if the limestone is composed solely of calcite (100% $CaCO_3$). Marble is used for construction and decoration; marble is durable, has a noble appearance, and is consequently in great demand. Chemically, marbles are crystalline rocks composed predominantly of calcite, dolomite or serpentine minerals. The other mineral constituents vary from origin to origin. The main impurities in raw limestone (for cement) which can affect the properties of finished cement are magnesia, phosphate, leads, zinc, alkalis and sulfides. A large quantity of MDP is generated during the cutting process. The result is that the mass of marble waste which is 20% of total marble quarried has reached as high as millions of tons. Leaving these waste materials to the environment directly can cause environmental problem.

Moreover, there is a limit on the availability of natural aggregate and minerals used for making cement, and it is necessary to reduce energy consumption and emission of carbon dioxide resulting from construction processes, solution to this problem are sought through usage of MDP as partial replacement of Portland slag cement. In India, MDP is settled by sedimentation and then dumped away which results an environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health. Therefore, utilization of the MDP in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment. Waste can be used to produce new products or can be used as admixtures so and the environment is protected from waste deposits.

1.1. Research significance

In this study MDP collected from the nearby source was used for the investigation. Concrete mixtures were prepared using fine& coarse aggregate and different replacement levels of MDP.

1.2 Objective of investigation

In this project our main objective is to study the influence of partial replacement of cement with MDP. The compressive strength, tensile strength & flexural strength of ordinary M25 grade of concrete are obtained. Similarly compressive strength, tensile strength & flexural strength were obtained for 5%, 10%, 15%, & 20% replacement of cement with MDP by weight. The water cement ratio (0.43) kept constant throughout the

investigation of this project work.

- To study the physical properties of Marble dust powder
- To characterize the particle size of Marble dust powder
- MDP as a replacement of cement material.
- To study the effect of MDP inclusion on the properties of concrete.

2. Literature Review

The aim of this research is to develop high strength concrete with the utilization of a waste product MDP. MDP possesses good pozzolanic activity and is a good material for the production of concrete. Also now a day's one of the great applications of MDP is in various structural fields as in reinforced cement concrete, which is gaining popularity because of its positive effect on various properties of concrete.

Although deep interest in studies of MDP utilization has been developed during last six to seven decades, the latest research work is given below.

A. Manju Pawar et.al (2014) A Study has been conducted on Periodic Research, The Significance of Partial replacement of Cement with Waste Marble Powder. They found that the effect of using marble powder as constituents of fines in mortar or concrete by partially reducing quantities of cement has been studied in terms of the relative compressive, tensile as well as flexural strengths. Partial replacement of cement by varying percentage of marble powder reveals that increased waste marble powder (WMP) ratio result in increased strengths of the mortar and concrete .Leaving the waste materials to theenvironment directly can cause environmental problem. Hence the result, The Compressive strength of Concrete are increased with addition of waste marble Powder up to12.5 % replace by weight of cement and further any addition of WMP the compressive strength decreases. The Tensile strength of Concrete are increased with addition of waste marble powder up to 12.5 % replace by weight of cement and further any addition of WMP the Tensile strength decreases. Thus they found out the optimum percentage for replacement of MDP with cement and it is almost 12.5 % cement for both compressive & tensile strength. [1]

B. V.M. Sounthararajan et.al (2013) A Study has been conducted on Effect of the Lime Content in MDP for Producing High Strength Concrete. They found that the MDP up to 10% by weight of cement was investigated for hardened concrete properties. Furthermore, the effect of different percentage replacement of MDP on the compressive strength, splitting tensile strength and flexural strength was evaluated. It can be noted that the influence of fine to coarse aggregate ratio and cement-to- total aggregate ratio had a higher influence on the improvement in strength properties. A phenomenal increase in the compressive strength of 46.80 MPa at 7 days for 10% replacement of MDP in cement content was noted and also showed an improved mechanical property compared to controlled concrete [2]

C. Corinaldesi V et al., (2010) Marble as a building material especially in palaces and monuments has been in use for ages. However the use is limited as stone bricks in wall or arches or as lining slabs in walls, roofs or floors, leaving its wastage at quarry or at the sizing industry generally unattended for use in the building industry itself as filler or plasticizer in mortar or concrete. The result is that the mass which is 40% of total marble quarried has reached as high as millions of tons. This huge unattended mass of marble waste consisting of very fine particles is today one of the environmental problems around the world. [3]

3. Experimental methodology and Investigations

3.1. Concrete mix constituents

Concrete is a composite material, made by mixing Coarse aggregate (CA) & Fine aggregate (FA), Cement & Water.

3.1.1. Cement

Portland Slag Cement with conforming to BIS (IS: 455-1989) was used in the entire experimental study. The detail of physical properties of cement is presented in table 3.1. This cement is used for the MDP and corresponding convectional concrete. The cement used in the test is Portland slag cement manufactured by "LAFARGE CONCRETO".

Table 3.1 Physical Properties of cement

Properties	Test method	Results	Standard Limits (IS: 455:1989)
Normal Consistency	Vicat Apparatus (IS: 4031 Part - 4)	32%	_

Soundness	Le- Chatlier method (IS: 4031 Part –3)	Expansion 3 mm	<10mm
Initial Setting Time (Minimum)	Vicat Apparatus (IS: 4031 Part -5)	75 minutes	>30 min
Final Setting time		255 minutes	<600 min
Specific Gravity	Specific. gravity bottle (IS:4031 Part - 4)	3.14	_
Fineness	Sieve test on sieve no.9 (IS: 4031 Part –2)	2.83% Retain on 90 µ I.S sieve	<10%
Compressive Strength 3days 7days 28 days	(IS: 4031 Part-6)	N/mm^2 19.85 23.45 35.98	N/mm^2 >16 >22 >33

3.1.2. Aggregate

Normal river sand locally available in the market and confirming to Zone II as per BIS (IS 383:1970) and CA were used in this experiment. CA used as 60% by weight of 20 mm size & 40% of 10 mm size of total aggregate may be taken.

Table 3.2 Physical properties of Fine and Coarse aggregate

Properties	FA	CA
Specific Gravity	2.69	2.79
Bulk Density (Loose) (gm./cm^3)	1.494	1.71
Bulk Density (compacted) (gm./cm^3)	1.617	1.85
Water absorption (%)	0.97	0.54
Flakiness Index (%)	-	11.80
Elongation Index (%)	-	10.13
Fineness Modulus (%)	2.449	6.687

Table 3.3 Mechanical properties of Coarse aggregate

Property	CA	BIS(IS: 383-1970) limits
Impact value (%)	20.80	Less than 30% for wearing surfaces and less than 45% for other than wearing surface
Crushing value (%)	25.29	Less than 30% for wearing surfaces and less than 45% for other than wearing surface
Los Angles Abrasion resistance (%)	22.26	Less than 30% for wearing surfaces and less than 50% for other concretes.

3.1.3. Water In this research potable water free from organic substance was used for mixing as well as curing of concrete

3.2. Marble Dust Powder (MDP)

One of the major wastes produced in the stone industry during cutting, shaping, and polishing of marbles is the MDP. During this process, about 20-25% of the process marble is turn into the powder form. India being the third (about 10%) top most exporter of marble in the world, every year million tons of marble waste form processing plants are released. Due to the availability of large quantity of waste produced in the marble factory, this project has been planned and preceded.

Snap short of used MDP is figure no.3.1
The physical & chemical properties of MDP are given in table 3.4 & 3.5 respectively.

Table 3.4 Physical Properties of MDP

Properties	Test Result
Specific Gravity	2.63
Colour	white
Form	Powder
Odour	Odourless
Moisture Content (%)	0.60
sieve	0.90mm
hardness	3 on Mohr's scale
Water absorption	0.97%

Table 3.5 Chemical constituents of MDP

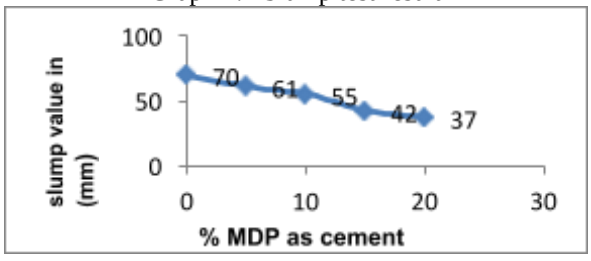
Chemical compound	Test value of MDP in %	Standard of Natural cement Content (%)
Calcium oxide (CaO)	55.09	31-57
Silica dioxide (SiO_2)	0.48	22-29
Magnesium oxide (MgO)	0.40	1.5-2.2
Iron oxide (Fe_2O_3)	0.12	1.5-3.2
Aluminum dioxide (Al_2O_3)	0.17	5.2-8.8
Sodium oxide (Na_2O)	0.20	-
Potassium oxide (K_2O)	0.06	
Sulfur trioxide (SO_3)	0.06	-
Lost on ignition in %	43.48	-
Total amount	100	-

[Sources: Lab Testing Sucofindo 2013]

To test the results obtained MDP content of Calcium Oxide (CaO) was 55.09 % for the marble is in Conformity with the standards as natural cement that is 31-57%. But for the content of other elements such as Silicon Dioxide (SiO_2), Aluminum dioxide (Al_2O_3), Iron Oxide (Fe_2O_3), Magnesium Oxide (MgO) do not fit into standard natural cement. This means that Based on the Indian Standard (IS: 10262-2009), design mix for M25 grade of concrete was prepared by partially replacing cement with five different percentages by weight of MDP (0%, 5%, 10%, 15%, and 20%). The mix proportion for M25 Grades of concrete with varying percentage of MDP is presented in Table 4.2.

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. It is also observed that, as the percentage of MDP increases from 0% to 20%, the mix becomes stiffer, and workability results in low slump value. Low slump value may have great impact on the workability of concrete.

Graph 4.1 Slump test result



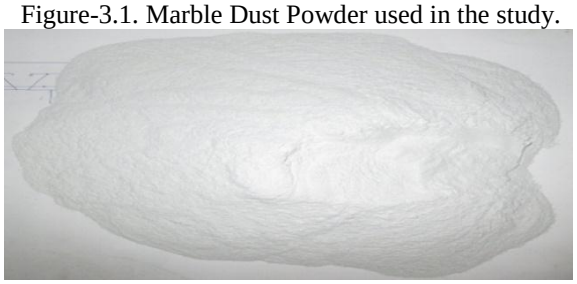
4.2 Hardened Concrete Testing

The most valuable property in concrete is the compression strength because it gives the overall quality of hardened concrete. The hardened concrete tests conducted were the compressive test, split tensile test & flexural test. The mechanical property of hardened concrete depends upon the cementitious material available in the mix.

4.2.1 Compressive strength test

MDP characterized as natural cement but not fully functioning as natural cement.

Figure-3.1. Marble Dust Powder used in the study.



4. Methodology

Compressive strength test is done as Per IS 516- 1959. The test is conducted on Compression testing machine of capacity 2000 KN as shown in Fig. 4.2 Mechanical behavior of concrete was studied for M25 grade of cubes were casted and cured for 7 and 28days. Compressive strength of concrete is tested on cube at different percentage of MDP content in concrete. The strength of concrete has been tested on cube at 7 days curing and 28 days. And the results obtained are reported in table 4.3 & also shown in graph 4.2. With replacement of MDP in %age, in concrete 7 days test has been conducted to check the gain in initial strength of concrete & 28 days test gives the data of final strength of concrete at 28 days curing. Compression testing machine is used for testing the compressive strength test on concrete.

4.2.2. Split Tensile Strength

Testing for split tensile strength of concrete is done as Specimen details of the work at B.I.T, Sindri Dhanbad, Jharkhand, India.

Split tensile strength is done as per IS 5816- 1999. The test is conducted on Compression testing machine of capacity 2000 KN as shown in Fig. 4.3, and the results obtained are reported in Table 4.4 & shown in graph 4.3. The cylinder is placed horizontally between the loading surfaces of compression testing machine and the load is applied till failure of the cylinder. Packing material such as plywood is used to avoid any sudden loading. During the test the platens of the testing machine should not be allowed to rotate in a plane perpendicular to the axis of cylinder. The Split tensile strength is computed from the following formula.

$$T = \frac{2P}{\pi LD}$$

Where; T: Tensile Strength

P: Maximum load in Newton's applied to the Specimen,

L: length of the specimen in mm

D: C/S dimension of the specimen in mm

4.2.3. Flexural Strength

Flexural strength test is done as per IS: 516- 1959. Prisms are tested for flexure in Universal testing machine of capacity 500 KN as shown in Fig. 4.4 & and the results obtained are reported in Table 4.5 & also shown in graph 4.4. The bearing surfaces of the supporting and loading rollers are wiped clean before loading. The prisms are placed in the machine in such a manner that the load is applied to the upper most surface along the two lines spaced 13.30 cm apart. The axis of the specimen is aligned with the axis of the loading device. The load is applied at a rate of 180 kg/min without shock on the specimen till it fails and the maximum load (P) applied to the specimen during test is noted. Flexural strength f_{bt} (N/mm^2) = $\frac{PL}{bd^2}$

Where, P = maximum load at failure in N, and L = length of the beam specimen (400mm)

b = Width of the beam specimen in mm, d = Depth of beam specimen in mm

Table 4.1 Quantity estimation and planning of testing work

Descriptio n	Compressive strength test	Split tensile test	Flexural test
Specimen	Cube	Cylinde r	Beam
Specimen Size (mm)	150x150x15 0	D=150 & H=300	100x100x50 0
No.of Specimen	3	3	3
Days of testing	7,28	7,28	7,28
Total No.of Specimen for one series	6	6	6
Volume of each Specimen (m3)	0.003375	0.0053	0.005
Volume for all Specimen (m^3)for one series	0.02025	0.0318	0.030
Total specimens for all series	6x5=30	6x5=30	6x5=30
Total volume for all series(m^3)	0.101	0.159	0.150
Total weight of concrete = 1021.13 kg Total volume of concrete = 0.410 m^3			

Figure 4.1 Mixing Process in Standard drum type mixer

Table 4.2 Details of mix proportions for MDP (kg/m^3)

Amount of MDP in %	Cement (kg)	MDP* (Kg.)	Fine aggregate (kg)	Coarse aggregate(kg)		w/c ratio	Slump (mm)
				CA 10mm down	CA 20mm down		
0	445.58	0	651.76	468.96	703.44	0.43	70
5	423.30	22.28	651.76	468.96	703.44	0.43	61
10	401.02	44.56	651.76	468.96	703.44	0.43	55
15	378.74	66.84	651.76	468.96	703.44	0.43	42
20	356.46	89.12	651.76	468.96	703.44	0.43	37

*percentage by weight of cement

Table 4.3: Analysis of test results (Compressive strength N/mm^2) of concrete

Mix Id.	Compressive strength (N/mm^2)		% increase or decrease in strength over Normal concrete, M25	
	7 days	28days	7 days	28days
MDP0	22.97	33.18	-	-
MDP5	23.85	34.67	(+) 3.83	(+) 4.49
MDP10	24.44	35.85	(+) 6.40	(+) 8.05
MDP15	20.89	30.22	(-) 9.06	(-) 8.92
MDP20	20.00	29.19	(-) 12.93	(-) 12.03

Table 4.4: Analysis of test results (Split tensile strength N/mm^2) of concrete

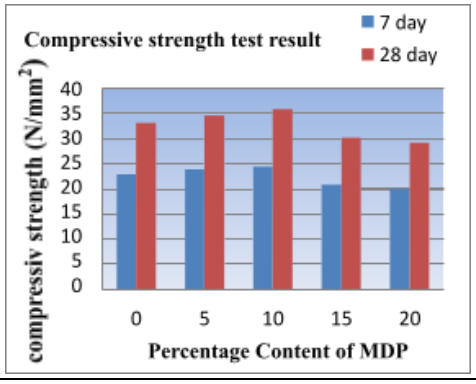
Mix Id.	Split tensile strength (N/mm^2)		% increase or decrease in strength over Normal concrete, M25	
	7 days	28 days	7 days	28 days
MDP0	2.92	3.91	-	-
MDP5	3.11	4.00	(+) 6.11	(+) 2.30
MDP10	3.13	4.04	(+) 7.19	(+) 4.09
MDP15	3.16	4.27	(+) 8.22	(+) 9.21
MDP20	2.52	3.30	(-) 13.70	(-) 15.60

Table 4.5: Analysis of test results (Flexural strength N/mm^2) of concrete

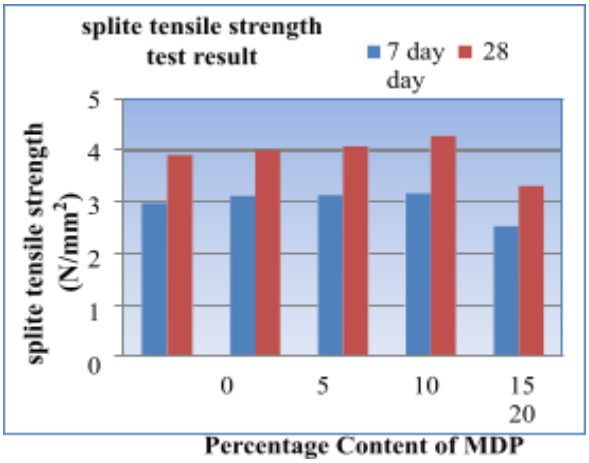
Mix Id.	Flexural strength (N/mm^2)		% increase or decrease in strength over Normal concrete, M25	
	7 days	28days	7 days	28days
MDP0	3.07	5.33	-	-
MDP5	3.17	5.43	(+) 3.26	(+)1.88
MDP10	3.20	5.63	(+) 4.23	(+) 5.63
MDP15	3.30	5.73	(+) 7.49	(+) 7.50
MDP20	2.70	4.70	(-) 12.05	(-) 11.82

Description:-
MDP0-Concrete mix with 0% Marble Dust Powder replacement MDP5- Concrete mix with 5% Marble Dust Powder replacement MDP10-Concrete mix with 10% Marble Dust Powder replacement MDP15- Concrete mix with 15% Marble Dust Powder replacement MDP20-Concrete mix with 20% Marble Dust Powder replacement
MDP- Marble Dust Powder

Graph 4.2: (BAR CHART) %age replacement of MDP vs Compressive strength (N/mm^2) of M25 grade of Concrete



Graph 4.3 (BAR CHART) %age replacement of MDP vs Split tensile strength (N/mm^2) of M25 grade of concrete



Graph 4.4 (BAR CHART) %age replacement of MDP vs Flexural strength (N/mm^2) of M25 grade of concrete

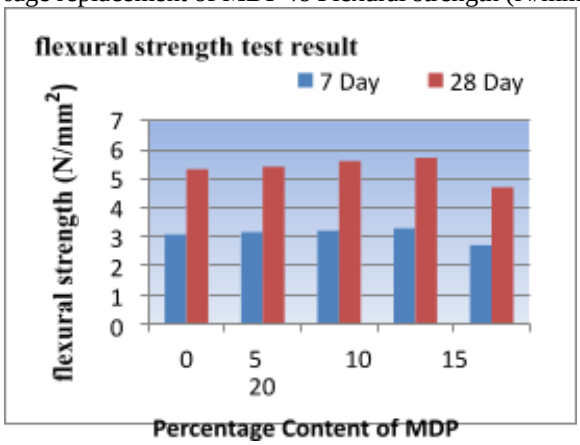


Fig. 4.2 Experimental setup for compressive strength machine

Fig. 4.4 Experimental setup for flexural testing machine

Table 4.11: Abstract of the test result of 7 days.

Mix Id.	Compressive Strength (N/mm^2)	Split tensile strength (N/mm^2)	Flexural strength (N/mm^2)	Fracture strength (N/mm^2) $0.7\sqrt{f_{ck}}$
MDP0	22.97	2.92	3.07	3.35
MDP5	23.85	3.11	3.17	3.42
MDP10	24.44	3.13	3.20	3.46
MDP15	20.89	3.16	3.30	3.20
MDP20	20.00	2.52	2.70	3.13

Table 4.12: Abstract of the test result of 28 days.

Mix Id.	Compressive strength (N/mm^2)	Split tensile strength (N/mm^2)	Flexural strength (N/mm^2)	Fracture strength (N/mm^2) $0.7\sqrt{f_{ck}}$
MDP0	33.18	3.91	5.33	3.50
MDP5	34.67	4.00	5.43	4.12
MDP10	35.85	4.04	5.63	4.19
MDP15	30.22	4.27	5.73	3.84
MDP20	29.19	3.30	4.70	3.78

5. Conclusion

The usage of MDP in concrete improved its quality in terms of strength. The following conclusions were based on the study on the test result.

a) The Compressive strength of Concrete increases up to 10% replacement of cement by MDP and further increasing of percentage of MDP leads to decrease in compressive strength of concrete.
b) The Split tensile strength of concrete increases up to 15% replacement of cement by MDP & further increasing of percentage of MDP leads to decrease in Split tensile strength of concrete.
c) The Flexural strength increases up to 15% replacement of cement by MDP and further increases in the percentage of MDP leads to decrease in flexural strength.
d) It is concluded that the MDP can be used as a replacement material of cement, and 10% replacement of cement with MDP gives an excellent result in strength, as compared to the normal concrete.
e) Use of these waste material leads to sustainable development in construction industry.
f) To save the environment, MDP may be used as better partial substitute as a replacement of cement in concrete.

6. Scope of the Future Work

This project was mainly focused on the partial replacement of Portland slag cement with MDP at different percentage in concrete. Research may be conducted on other properties and uses of MDP in the near future to make this product a precious building material to improve the quality of building construction industry. Other types of study that can be included with MDP may be listed below;

a) MDP concrete as an acoustic building structure.
b) The chemical attack on MDP concrete structure.
c) The durability of MDP concrete as an underwater structure.
d) Earthquake effect on MDP concrete structure for low cost building.
e) MDP concrete with plasticizer for higher grade of concrete.
f) Study of MDP concrete varying the water cement ratio.
g) Only the basic study of use of MDP in concrete production is investigated; therefore, further investigation is required on the study of durability of concrete made by MDP blended cement.
h) Further study can be done for determining the deflections and durability of concrete containing MDP.
i) Further study on the seepage characteristics of the MDP concrete.
j) In future the flexural strength of beam may be observed by increasing the sizes of beam.
k) The characteristics strength of concrete can be studied with control mix of MDP & glass powder.
l) To study the behavior of MDP concrete under biaxial and multiaxial stresses.
m) To study the factors affecting dry shrinkage and creep of MDP concrete.

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