

Experimental Investigation on Strength Characteristics of Concrete Using Waste Marble Powder as Cementitious Material

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ABSTRACT: Concrete is a construction material consisting of cementitious material, fine aggregate, coarse aggregate and water. Now a days the cost of these materials are increased so, we need to look at a way to reduce the cost of building materials especially cement. One of the recent advancement in construction industry is replacement of materials in concrete. The replacement of materials offers cost reduction, energy savings and protection of environment. To achieve the above objective we are partially replacing the cement with waste marble powder (WMP) produced from marble industries. The present investigation is aimed to study the fresh and hardened properties of concrete when cement is partially replaced by waste marble powder. The work is focused on M_{20} , M_{30} , M_{40} grades of concrete. The percentage of Waste marble powder that replaced cement in this investigation are 0%, 5%, 10%, 15% and 20%. The fresh proprieties are workability and hardened properties are compressive strength at the age of 7, 28 days of curing, split tensile strength, and flexural strength of concrete are at the curing age of 28 days are to be determined. Results shows that the workability and compressive strength, flexural, and split tensile strengths of concrete are increased with partial replacement of cement by waste marble powder between 10% to 15%.

KEYWORDS: Waste marble powder, Workability, compressive strength, split tensile strength, flexural strength.

I. INTRODUCTION

Marble is a metamorphic rock resulting from the transformation of a pure limestone composed solely of calcite (100% $CaCO_3$). Chemically, marbles are crystalline rocks composed predominantly of calcite, dolomite or serpentine minerals. The main impurities in raw limestone (for cement) which can affect the properties of finished cement are magnesia, phosphate, leads, zinc, alkalis and sulphides. A large quantity of powder 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 problems.

The advancement of concrete technology can reduce the consumption of natural resources and energy sources which in turn further lessen the burden of pollutants on the environment. One of the logical means for reduction of the waste marble masses calls for utilizing them in building industry itself. Some attempts have been made to find and assess the possibilities of using waste marble powder in mortars and concretes and results about strength and workability were compared with control samples of conventional cements concrete. Marble powder can be used as filler in concrete and paving materials and helps to reduce total void content in concrete. Marble powder can be used as an admixture in concrete, so that strength of the concrete can be increased. The Indian marble industry has been growing steadily at an annual rate of around 10% per year. Cutting of stones produces heat, slurry, rock fragments and dust. 20% to 30% of marble blocks are converted in to powder. 3,172 thousand tons of marble dust was produced in year 2009-10.

Waste Marble powder can be used to improve the mechanical and physical properties of the conventional concrete. The possibility of utilizing WMP as cementitious material in the production of concrete will also induce a relief on waste disposal issues. Now-a-days the demand for cement is quite high in developing countries owing to rapid infrastructural

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growth which results supply scarcity and the cost of material is increased, if we use the waste material in the production of the concrete the construction cost decreases.

II. BACKGROUND

According to **Md Mahaboob ali, Prof S.M.Hashmi(2014)**, The work is directed towards developing a better understanding on strength characteristics of concrete using marble powder as a partial replacement of cement. The Dissertation work is carried out with M₃₀ grade concrete for which the marble powder is replaced by 0%, 5%, 10%, 15%, 20% by weight of cement. The result of this investigation indicate that marble dust incorporation results insignificant improvements in the compressive, flexural and split tensile strengths of concrete up to 10% of replacement. **Aliabdo et al (2013)**, investigated the possibility of utilizing waste marble dust (MD) in cement and concrete production by discussing the properties of concrete contained marble dust as a cement replacement and as a sand replacement (cement addition). The replacement ratios which have been studied were 0.0%, 5.0%, 7.5%, 10.0% and 15% by weight. Water to cement ratio (w/c) were 0.50 and 0.40 in case of cement replacement and in case of sand replacement, respectively. It was observed that the higher values of marble dust decreases the C3A content compared to plain cement. For 15% marble dust, there was a decrease of 10% in the compressive strength of concrete. At w/c of 0.5, in all levels of marble dust as a cement replacement, the concrete compressive strength slightly decreases, due to the reduction in cementing material (C3A and C2S) which is mainly responsible for concrete strength. But at the w/c of 0.4 there was slightly increase to the 10% MD. This could be due to the pore-filling effect of fine marble dust that enhances the properties of the transition zone (TZ) surrounding aggregate. In the investigation by **Er.Tanpreet Singh and Er.Anil Kumar Nanda (June 2012)**, tests were conducted on the mortars and concrete mix cured for different times in order to determine their workability, flexural as well as compressive strength. Partial replacement of cement by varying percentage of marble powder reveals that increased with increase of WMP the strength falls when the WMP is 15% or 20%.

III. OBJECTIVE OF EXPERIMENTAL STUDY

The main objective of the present investigation is to study the effects of marble powder on properties of fresh and hardened concrete when cement is partially replaced by waste marble powder, and to compare the compressive, split and tensile strength of M 20, M30, M40 grades of concrete. We are also trying to find the percentage of marble powder replaced in concrete that makes the strength of the concrete maximum. Nowadays marble powder has become a pollutant. So, by partially replacing cement with marble powder, we are proposing a method that can be of great use in reducing pollution to a great extent.

IV. EXPERIMENTAL METHODOLOGY

4.1 MATERIALS USED:

Cement: The ordinary Portland cement of 53grade manufactured by the JP Cement Company was used in the study, which is in accordance with IS 8112:1989. Properties of this cement were tested and shown in table-1.

Fine aggregate: Locally available fresh river sand, free from organic matter, was used. The result of sieve analysis confirms to zone-I (according to IS: 383-1970). The other properties of fine aggregate are determined and shown in table -2.

Coarse aggregate: Crushed aggregate of 20mm size is brought from quarry. Aggregates of more than 20mm size are separated by sieving. Tests are carried out in order to find out properties of it. The test results are presented in table- 2.

Waste marble powder (WMP): The Waste Marble powder was collected from the local market in Warangal. It was sieved by IS-90 micron sieve before mixing in concrete. Tests are carried out in order to find out the properties of waste marble powder. The test results are presented here.

- Fineness of waste marble powder = 13%
- Specific gravity = 1.5

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Table-1 physical properties of cement

Properties	Results
Fineness	7%
specific gravity	3.16
standard consistency	31.5
initial setting time	150min
final setting time	270min

Table-2 properties of fine aggregate & coarse aggregate

Properties	Fine aggregate	Coarse aggregate
Bulk density	1.44g/cc	1.44g/cc
Porosity	37.42%	71.11%
Void ratio	0.59	1.07
specific gravity	2.29	2.99
Fineness modulus	3.62	6.45

Chemical admixture: CONPLAST SP337 was used in the present work, it is a high range water reducing admixture conforms to ASTM C494 and complies with IS: 9103-1999. It is used for improving workability at decreased water-cement ratio without affecting the compressive strength.

Concrete mix proportions: Mix design was carried out using conceptual Mix design adopted and is presented in Table-3.

Table-3 Mix proportions

Grade of concrete	Cement (kg/m ³)	F.A (kg/m ³)	C.A (kg/m ³)	SP 337 (lit/m ³)	Water (lit/m ³)
M ₂₀	320	650	1310	-----	173
	1	2.03	4.1		0.53
M ₃₀	360	610	1290	2.16	165
	1	1.7	3.58		0.46
M ₄₀	415	580	1250	3.32	172
	1	1.4	3		0.41

Water: In this investigation fresh potable water was used for mixing as well as curing of concrete.

V. RESULTS AND DISCUSSION

5.1 FRESH CONCRETE: Each batch of concrete was tested for consistency after mixing, using slump and C.F. tests. Provided that care was taken to ensure that no water or other material was lost, the concrete used for the consistency tests was remixed with the remainder of batch before making the test specimens.

Slump test: After mixing the concrete properly, workability of concrete is determined by slump cone apparatus. The following table-4 shows the slump values for different grades of concrete for various proportions of Waste Marble Powder and represented in Graph-1.

Compaction factor test: The degree of compaction is measured by the density ratio i.e., the ratio of the density actually achieved in the test to the density of the same concrete fully compacted. The results are shown in table-5 and represented in Graph-2 below.

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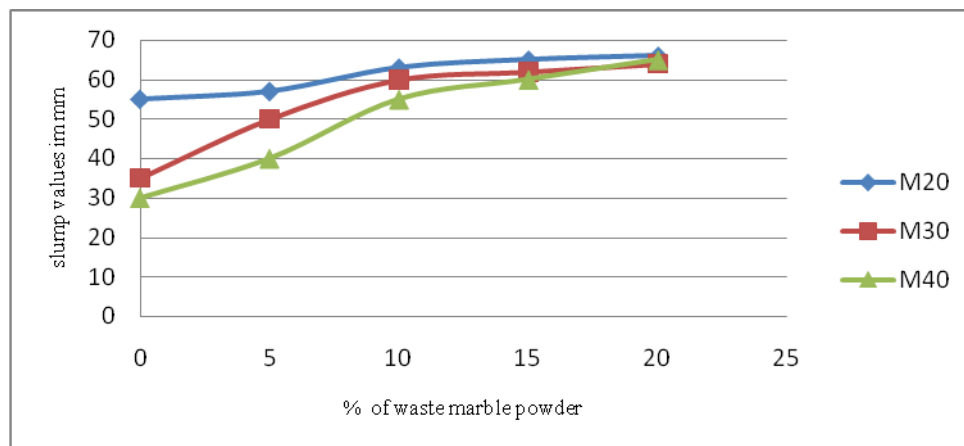
Table-4 slump values for M₂₀-M₃₀, M₄₀ grade concrete

% of Replacement	Slump value for M ₂₀ grade (mm)	Slump value for M ₃₀ grade (mm)	Slump value for M ₄₀ grade (mm)
0	55	35	30
5	57	50	40
10	63	60	55
15	65	62	60
20	66	64	65

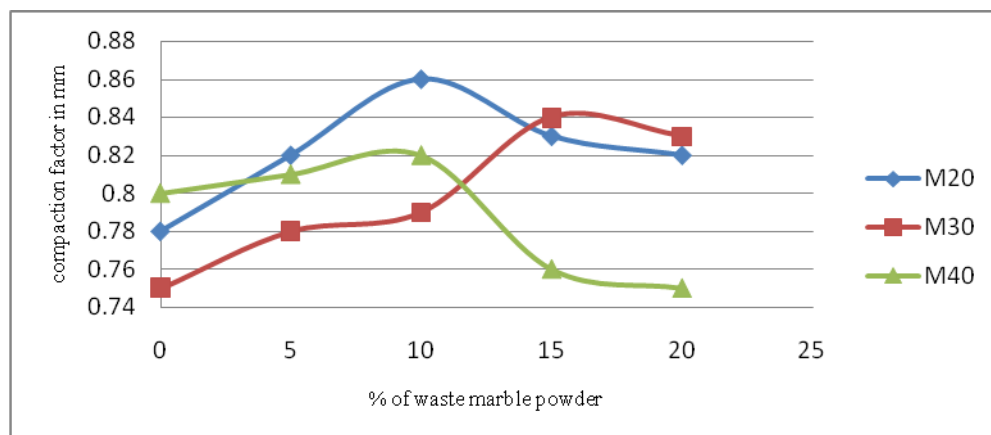
Table-5 C.F for M₂₀-M₃₀, M₄₀ grade concrete

% of Replacement	C.F for M ₂₀ grade concrete	C.F for M ₃₀ grade concrete	C.F for M ₄₀ grade concrete
0	0.78	0.75	0.8
5	0.82	0.78	0.81
10	0.86	0.79	0.82
15	0.83	0.84	0.76
20	0.82	0.83	0.75

*(C.F-COMPACTION FACTOR)



Graph-1 shows various slump values for M₂₀, M₃₀, M₄₀ grades of concrete



Graph-2 -Compaction factor for M₂₀, M₃₀, M₄₀ grades of concrete

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5.2 HARDENED CONCRETE: After curing at 7 and 28 days in fresh water, the specimens were made dried and then tested to evaluate strength characteristics.

Compressive strength: Compressive strength of concrete is evaluated by the concrete at 7 and 28 days cube strength. Compressive strength of concrete for various proportions of waste marble powder is shown in table-6 and represented in Graph-3 & 4.

Split tensile strength: The split tensile strength of concrete for cylinders, all mixes at 28 days of curing is presented in table-7 and shown in Graph-4. Three cylinders were casted for various percentage replacements of cement by WMP and they are tested by placing them horizontal in CTM. The split tensile strength test set up is shown in fig-2.

The following equation is used to evaluate the split tensile strength of cylinder.

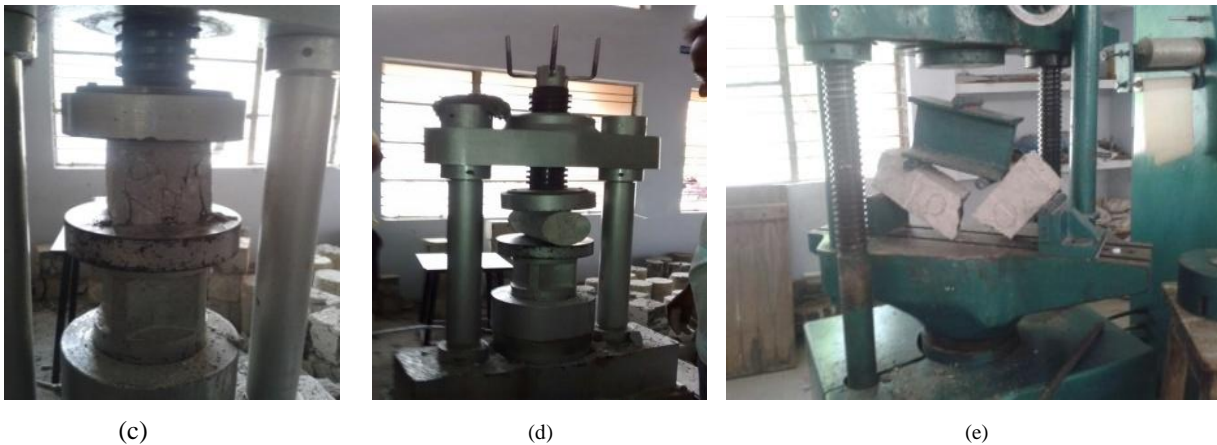


Fig-2 c) Compressive strength test on cube of 28 days curing for M20 grade at 15% replacement of cement with Waste Marble Powder
d) Split tensile strength test on cylinder of 28 days curing for M20 grade at 10 % replacement of cement with Waste Marble Powder
e) flexural test on prism of M20 grade at 0% replacement of cement with WMP

Flexural strength of concrete: The flexural strength of concrete for prisms, all mixes at 28 days of curing is presented in table-8 and shown in graph-6. Three prisms were cast for various percentage replacements of cement by Waste Marble Powder and tested in UTM of 40T capacity by applying two point loads. These point loads acted at equidistance from centre of prism. Prism was placed in the Universal Testing Machine and load is applied at rate of 140kg/cm²/min.

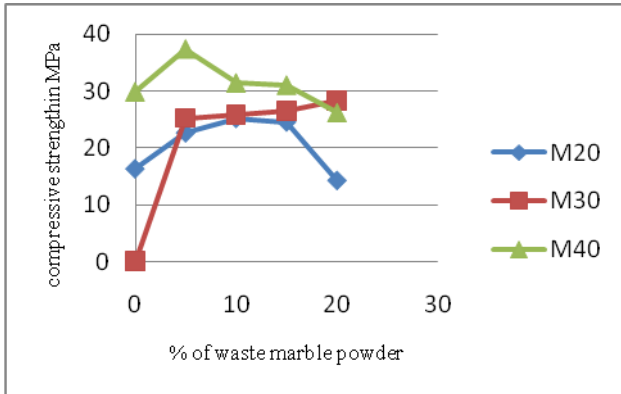
Table 6: Compressive Strength of M₂₀, M₃₀, M₄₀ Grades of concrete specimens at 7, 28 days of curing

S.no	% of Waste Marble powder	Compressive strength for M ₂₀ grade(MPa)		Compressive strength For M ₃₀ grade(MPa)		Compressive strength for M ₄₀ grade (MPa)	
		7 days	28 days	7 days	28 days	7 days	28 days
1	0	16.36	24.93	25.18	38.36	29.88	45.51
2	5	22.66	34.52	25.81	39.32	37.43	57.01
3	10	25.18	38.36	26.44	40.28	31.44	47.89
4	15	24.55	37.4	28.33	43.16	31.06	47.31
5	20	14.31	21.8	23.29	35.48	26.2	39.91

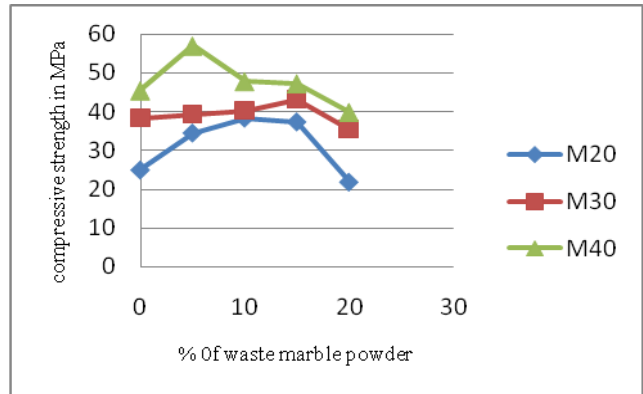
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Graph-3- Compressive Strength at 7 days of curing for various percentage replacement of cement with WMP



Graph-4 Compressive strength at 28 days of curing for various percentages replacement of cement with WMP

Table-7: Split Tensile Strength of concrete specimens at 28 days of curing

S.no	% of Waste Marble powder	Split tensile strength of M ₂₀ grade of concrete (MPa)	Split tensile strength of M ₃₀ grade of concrete(MPa)	Split tensile strength of M ₄₀ grade of concrete (Mpa)
1	0	2.16	3.33	3.24
2	5	2.99	3.41	4.16
3	10	3.33	3.75	3.49
4	15	3.24	3.45	3.45
5	20	2.08	3.08	2.91

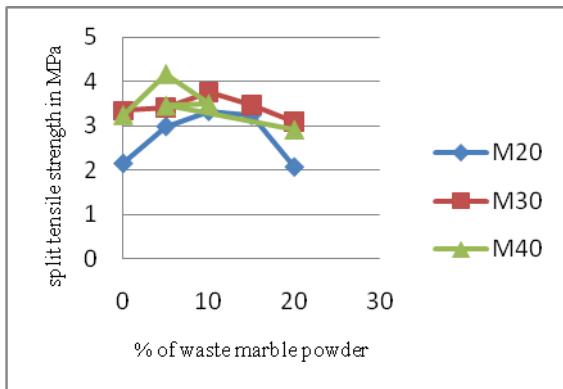
Table-8: Flexural Strength of concrete specimens at 28 days of curing

S.no	% of Waste Marble powder	Flexural strength for M ₂₀ grade of concrete (MPa)	Flexural strength for M ₃₀ grade of concrete (MPa)	Flexural strength for M ₄₀ grade of concrete (MPa)
1	0	2	4.6	2.96
2	5	2.94	4.71	3.03
3	10	3.4	4.83	3.25
4	15	3.52	5.17	4.71
5	20	3.46	4.25	4.25

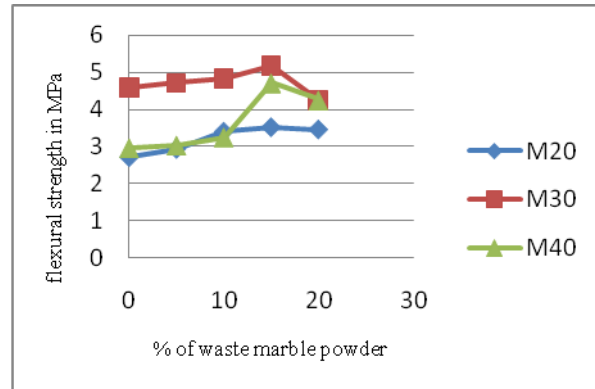
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Graph-5 shows split tensile strength of concrete specimens at 28 days of curing for various percentage of cement replacement with WMP



Graph-6 shows flexural strength of concrete specimens at 28 days of curing for various percentages of cement replacement with WMP

VI. CONCLUSION

- The workability for M₂₀, M₃₀, M₄₀ grades of concrete increased with increase in % of waste marble powder up to 20% replacement by cement. From Graph-2 the compaction factor for different grades of concrete, it is understood that the workability increases with increase in percentage of waste marble powder up to 10%. This increase in workability is due to greater surface area contact, smooth texture of wmp, and spherical shape of WMP particles.
- The test results showed in table-6 shows, with the percentage increase in the waste marble powder the compressive strength values for M₂₀, M₃₀, M₄₀ grades concrete tends to increase at each curing age upto 10 to 20% replacement. This increase in the strength of concrete can be due to the presence of calcium carbonate content in Marble Powder. The additional surface area provided by the calcium carbonate in Marble Powder may provide sites for the nucleation and growth of hydration products that leads to further increase in strength. Furthermore, the early strength of concrete mixes with marble powder was 5-10% higher than the conventional concrete. However, there is a slight decrease in compressive strength in 20% replacement concrete mix. When WMP replaced by cement exceeds 15% by weight, the less reactive calcite has a dilution effect on the more reactive cement; the amount of cement paste is considerably reduced, resulting in lower compressive strength.
- From Graph-3 for M₃₀ grade concrete at lower water cement ratio there was slight increase in compressive strength, this could be due to the pore-filling ability and pozzolanic activity of WMP that enhances the properties of the transition zone (TZ) surrounding aggregate.
- The flexural strength of concrete for M₂₀, M₃₀, M₄₀ grades of concrete increases with addition of waste marble powder up to 15% replacement by weight of cement and further any addition of waste marble powder there was slight decrease in strength as compared to conventional concrete. Hence, the improvement of flexural strength may be attributed to the nucleation around the fine particles of waste marble powder that replace the large and oriented crystals of calcium hydroxide with numerous, small and less oriented crystal.
- From the results obtained for the split tensile strength of concrete for M₂₀, M₃₀, M₄₀ grades concrete, it is observed that the split tensile strength of concrete increased up to 10% replacement of cement by waste marble powder and decreased with further increase, this may be due to its filling effect and growth of hydration products in concrete.
- Thus for present investigation on M₂₀, M₃₀, M₄₀ grades of concrete, it is found that the optimum percentage for replacement of marble powder with cement ranges from 10% to 15%. Hence test results shows that waste marble powder is capable of improving hardened concrete performance up to 15% replacement.
- Further, the cost of construction can be minimized with usage of marble powder which is freely or cheaply available and the environmental pollution can be reduced by using waste marble powder as replacement of cement in concrete.

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