Experimental Evaluation on Partial Replacement of Cement with Marble Powder

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Abstract - *Leaving the waste materials to the environment directly can cause environmental problem. Hence the reuse of waste material has been emphasized. Waste can be used to produce new products or can be used as admixtures so that natural resources are used more efficiently and the environment is protected from waste deposits. Marble industry generates both solid waste and stone slurry. Solid waste results from the rejects at the mine sites or at the processing units whereas stone slurry is a semi liquid substance consisting of particles originating from the sawing. These industrial wastes are dumped in the nearby land and the natural fertility of the soil is spoiled. Therefore, the scientific and industrial community must commit towards more sustainable practices. In this project our main objective is to study the influence of partial replacement of cement with marble powder, and to compare it with the compressive and tensile strength of ordinary 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.*

Key Words*: *Cement, Concrete, Compressive Strength, Marble Dust Powder, Partial Replacement, Tensile Strength.

1. INTRODUCTION

Civil engineering is a professional engineering discipline that deals with the design, construction and maintenance of the physical and naturally built environment, including works like roads, dams, parks and recreation, bridges etc. It is broken into several sub- disciplines including environmental engineering, geotechnical engineering, infrastructure and construction techniques and many more. Development of city is governed by its infrastructure. This project deals with the advanced construction technique by concrete technology replaced by different waste materials. Concrete is an essential building material that is widely used in the construction of infrastructure such as buildings, bridges, highways, dams and many other facilities. The production of ordinary Portland cement produces 7% approximately of the total greenhouse gas emitted to the atmosphere.

Environmentally, when industrial wastes are recycled not only the CO_2 emissions are reduced but residual products from other industries are reused and therefore less material is dumped as landfill and more natural resources are saved. Fly ash, blast furnace slag and silica fume are most widely used industrial wastes in place of cement for concrete production attributed to their reactivity nature called pozzolanic behavior. In addition to pozzolanas, other inert by-products and waste materials have been used in concrete and mortar production as inert filler for similar reasons. Among these, marble waste powder which using marble waste powder in cement and concrete production is a by-product of marble processing factory was studied by many researchers for its use in concrete and mortar production as sand replacing or cement replacing material. Marble is a metamorphic rock resulting from the transformation of a pure limestone. Waste marble powder is generated as a byproduct during cutting of marble. The waste is approximately in the range of 20% of the total marble handled. The waste generated every year is in tones, which is dumped in open space. This leads to serious environmental and dust pollution. This may also lead to contamination of underground water reserves. The environmental problems attributed by waste marble powder impose threat to ecosystem, physical, chemical and biological components of environment. It is therefore very important to reuse the waste marble powder which shall solve most of the problem. This report describes the feasibility of using the waste marble powder as a partial replacement of cement.

The purity of the marble is responsible for its color 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 consequently in great demand Marble Dust Powder is an industrial waste produced from cutting of marble stone. The result is that the mass of marble waste which is 20% of total marble quarried has reached as high as millions of tons. Marble as a building material especially in places 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. One of the logical means for reduction of the waste marble masses calls for utilizing them in building industry itself.

Marble powder is not available in all the places. Despite this fact, concrete production is one of the concerns worldwide that impact the environment with major impact being global warming due to CO2 emission during production of cement. Waste Marble dust can be used to improve the mechanical and physical properties of the conventional concrete. Now-a-days the cost of material is increasing so if we use the waste material in the production of the concrete so we decrease the price. If the waste is disposed on soils, the porosity and permeability of topsoil will be reduced, the fine marble dust reduces the fertility of the soil by increasing its alkalinity. Presently, large amount of marble dust is generated in natural stone processing plants with an important impact on the environment and humans.

In India, marble dust is settled by sedimentation and then dumped away which results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health. Therefore, utilization of the marble dust in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment. Hence the reuse of waste material has been emphasized. Waste can be used to produce new products or can be used as admixtures so that natural resources are used more efficiently and the environment is protected from waste deposits.

2 Literature Review

S Suthandra Devi, R.Ramya and R.Keerthika (2018) conducted an experimental study on concrete by partial replacement of fly ash and marble powder for the cement to find out mechanical properties of concrete. The fly ash and marble powder were replaced within the percentage of 0%, 5%, 10%, and 15% and20%. The strength of concrete has been found for both M20 and M25 mixes. The compressive and split tensile strength of concrete was evaluated after 28 days curing periods. The replacement 0%, 5%, 10%, 15%and 20%cement by fly ash and marble powder showed 24.5, 26.7, 27.3, 25.6and24.4 N/mm2 increase in compressive strength at 28 days of curing for M25. The replacement 5%, 10%, 15%and 20%cement by fly ash and marble powder showed 1.52, 1.78, 1.98, 1.89and1.76 N/mm2 respectively increase split tensile strength at 28 days of curing for M25. Finally, it was observed that the compressive and split tensile strength of M25 will be high at 10% replacement of marble powder and fly ash by the weight of cement.

Neha Yadav, Navinderdeep Singh (2018) presents a review on the concrete mix by adding marble waste powder and fly ash. The aim of the study was to check the compressive strength, spilt tensile strength and flexural strength of concrete by replacing cement and fine aggregates by Fly Ash and waste marble powder with constant water cement ratio 0.38. It was observed that increase in water cement ratio decreases the strength of concrete. Up to 20%, compressive strength is increased in Marble Waste Powder as a partial replacement of fine aggregates. With the addition of Fly Ash initial and final setting time gets decreased.

Virendra Singh, Pratik Gajjar, P.N. Nimodiya (2017) carried out an experimental study to enhance the strength properties of self-compacting concrete using waste marble dust and fly ash. The experimental work was carried out for M30 grade of self-compacting concrete mix with the replacement of cement with different proportions of marble dust (10%, 15%, 20% and 25%) and 30% of fly ash. The main aim of the study was to identify the best proportion of marble dust with fly ash, which can be replaced with cement to get the desired strength. In the study work process of the development of the concrete for strength aspects in various proportions varying from 0%, 10%, 15%, 20% and 25% marble dust as a replacement of cement along with fly ash. Final results from the compressive test represent that for replacement of cement by marble dust up to 10% and fly ash up to 30% gives comparatively higher results than Control mix. It was observed that the splitting tensile strength of the SCC for the replacement of cement by 30% and 10% marble dust gives almost same results as control mix at both 28th day and 56th day. The further addition of the marble dust content reduces the splitting tensile strength of the concrete. At finally by experimental results of compressive strength test and splitting tensile strength test, it can be concluded that the best proportion of marble dust and fly ash are 10% and 30% respectively with 28 days of curing.

Professor Mallesh M and Abhilash K (2017) conducted an experimental investigation on strengths properties of concrete by partial replacement of cement with mineral admixture. By this investigation, it was observed that the ideal trade proportion for M20 review solid blend is the substitution of Cement by 10% of Fly Ash and 10% of Marble Powder, which gives about 20% more Compressive strength than the consequences of customary cement of M20 blend.

Darzi Musaib ,Bhumre Shivkumar (2016) provide a review paper on "effective partial replacement of cement and sand with fly-ash and marble powder to make green concrete". In the experimental investigation, cement was replaced with fly ash in percentages of 5, 10 and 15 % and sand with marble powder in percentages of 20, 40 and 60 %. The objective of the study was to assess compressive and split tensile strength of concrete and find the optimum percentage of replacement to gain the maximum strength and compare it with the strength of ordinary M20 concrete. After studying of review papers, it was expected that optimum proportion of replacement of cement with fly ash will be 10 %, and that of sand with marble powder will be between 40 to 50 %.

Krishna P Pala, Krunal J Dhandha (2015) presents an experimental study on use of marble powder and fly ash on self-compacting concrete. The main objective of the study was to determine the behavior of SCC with marble powder and fly ash and understand the effect on fresh property, Harden property, and Durability of concrete. The slump and V- Funnel test was carried out on the fresh self-compacting concrete. The compressive strength of concrete was also determined at 7days, 14 days and 28 days' time intervals. The final results show that self-compacting concrete with 10% of marble powder and 25% of fly ash gives a higher value of compressive strength at 7days, 14 days and 28 days' time intervals for the M30 grade concrete mix.

3 Aim & Objective

- To study the influence of partial replacement of cement with marble powder and to compare the strength of original mix with the partial varied marble powder in concrete mix
- To determine and to find the optimum percentage of marble powder which can be economically used to get a stronger concrete
- To reduce to Environmental Pollution causing by the waste product of marble to make use in cement industries and to reduce to Co2 Emission.
- To find economical solution for high-cost construction material.

4. Materials

4.1 Cement

Ordinary Portland cement is used in the project work, as it is readily available in the local market. The cement used in the project work has been tested for various preparations as per IS: 4031-1988 and found to be conforming to various specifications of IS: 1489-1991. The specific gravity was 3.05.

4.2 Fine Aggregate

The natural sand is used as fine aggregate for the study purpose. Normal river sand locally available in the market and confirming to Zone II as per BIS (IS 383:1970).

4.3 Coarse Aggregate

The fractions of 20mm are used as course aggregate. CA was 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 -1: Physical properties of Fine and Coarse aggregate

Physical properties of Fine and Coarse aggregate	**FA**	**CA**
Specific Gravity	2.69	2.79
Bulk Density (Loose) (gm./cm3)	1.494	1.71
Bulk Density (compacted) (gm./cm3)	1.617	1.85
Water absorption (%)	0.97	0.54
Flakiness Index (%)	-	11.80
Elongation Index (%)	-	10.13
Fineness Modulus (%)	2.449	6.687

4.4 Water

Water which is free from salts is generally considered for making concrete.

4.5 Marble Dust Powder

Marble powder of 90Micron passing is used. This waste marble Waste powder is replaced in increasing percentage from 0% to 30%.

Table -2: Chemical constituents 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: Comparison between Cement and Marble Powder

Chemical compound [Sources: Lab Testing Sucofindo 2013]	Test value of MDP in %	Standard of Natural cement Content (%)
Calcium oxide (CaO)	55.09	31-57
Silica dioxide (SiO2)	0.48	22-29
Magnesium oxide (MgO)	0.40	1.5-2.2
Iron oxide (Fe2O3)	0.12	1.5-3.2
Aluminum dioxide (Al2O3)	0.17	5.2-8.8
Sodium oxide (Na2O)	0.20	-
Potassium oxide (K2O)	0.06	-
Sulfur trioxide (SO3)	0.06	-
Lost on ignition in %	43.48	-
Total amount	100	-

5. Methodology - Tests Conducted on Materials

5.1. Cement:

a) Initial & final setting time
b) Standard & normal consistency
c) Specific gravity

5.2. Fine & coarse aggregate:

a) Specific gravity
b) Moisture content
c) Particle size distribution

5.3. Concrete:

a) Slump test
b) Compaction factor
c) Compression test
d) Split tensile test

6. Mix Design

Table -4: Design Stipulation for Proportioning of M30

Grade Designation	43 Grade
Type of Cement	OPC
Max size of aggregates	20mm
Max water/cement ratio	0.53
Workability	Good

6.1 Target Strength for Mix Proportioning

f'ck = fck + 1.65 S
Where,
f'ck = Target average compressive strength at 28 days,
fck = Characteristic compressive strength at 28 days,
S= Standard deviation From Table 1 standard deviation, s = 5 N/mm2,
Therefore, target strength = 30+ 1.65 x 4 = 36.6 N/mm2

6.2 Water Cement Ratio

Selection of water cement ratio From Table 5 of IS:456-2000
Maximum water cement ratio = 0.50, Hence ok
Selection of water content From Table-2 of IS:456-2000 Maximum water content = 186 liters (for 25mm – 50mm slump range and for 20 mm aggregates)

6.3 Calculation of Cement Content

Water-cement ratio = 0.5
Cement content = Maximum water content
Water –cement ratio = 186 x 0.5 = 372 kg/m3 > 300 kg/m3, Hence Ok.
Proportion of volume of coarse aggregate and fine aggregate Fine aggregate = Zone I Coarse aggregate = 20mm (down size)
W/C = 0.5 For every decrease of 0.05 w/c, CA raised by 0.01 for 0.5 w/c
Volume of coarse aggregate = 0.6+0.01 = 0.61
Volume of fine aggregate = 1-0.61 = 0.39

6.4 Mix Calculations

The mix calculations per unit volume of concrete shall be as follows:
a) Volume of concrete = 1 m3
b) Volume of cement = (Mass of cement/Specific gravity of cement) x (1/1000) = 372 3.11 x 1 1000 = 0.119 m3
c) Volume of water = (Mass of water/specific gravity of water) x (1/1000) = 186 1 x 1 1000 = 0.816 m3
d) Volume of all in aggregates = [a-(b+c)] = [1-(0.119+0.186)] =0.695m3
e) Mass of coarse aggregate = d x Volume of coarse aggregate x Specific gravity of coarse aggregate x 1000 = 0.695 x 0.610 x 2.51 x 1000 = 1064.11 kg
f) Mass of fine aggregate = d x Volume of fine aggregate x Specific gravity of fine aggregate x 1000 = 0.695 x 0.39 x 2.59 x 1000 = 702.01 kg

6.5 Mix Proportion

Mix proportion / m3
Cement = 372 kg/m3
Water = 186 kg/m3
Fine aggregate = 702.01 kg/m3
Coarse aggregate = 1064.11 kg/m3
Water/ cement ratio = 0.5

Ratio = 1: 1.88: 2.86

Table -5: Mix Design

W/C Ratio	Cement	Sand	Aggregate
0.5	1	1.88	2.86

7. Test Procedure – Harden Concrete

7.1 Compression Test:

For compressive strength test, the cubes of size 150 x 150 x 150 mm were cast and tested under compression testing machine of 2000 kN capacity as per IS: 516-1959

Procedure:

The following procedure is adopted to conduct the Compressive strength test.
1. Size of the test specimen is determined by averaging perpendicular dimensions at least at two places.
2. Place the specimen centrally on the compression testing machine and load is applied continuously and uniformly on the surface perpendicular to the direction of tamping.
3. The load is increased until the specimen fails and record the maximum load carried by each specimen during the test.
Compressive stress was calculated as follows
Compressive strength= P/A x 1000
Where,
P = Load in KN
A = Area of cube surface = 150 x 150 mm2.

Table -6: Compressive Strength Test Data

Marble powder % of replacement	3 days N/mm2	7 days N/mm2	15 days N/mm3
0%	7.97	16	22.40
5%	8.16	16.88	23.11
10%	11.21	18.22	25.08
15%	11.34	18.30	25.36
20%	10.41	16.92	22.67

7.2. SPLIT TENSILE STRENGTH TEST:

For splitting tensile strength test, the cylinders of 150 mm diameter and length 300 mm were cast and were tested under compression testing machine as per IS: 5816-199

Procedure:

The following procedure is adopted to conduct the tensile strength test.
1. Draw diametrical lines on two ends of the specimen so that they are in the same axial plane.
2. Determine the diameter of specimen to the nearest 0.2 mm by averaging the diameters of the specimen lying in the plane of pre-marked lines measured near the ends and the middle of the specimen. The length of specimen also shall be taken be nearest 0.2 mm by averaging the two lengths measured in the plane containing pre-marked lines.
3. Centre one of the plywood strips along the center of the lower platen. Place the specimen on the plywood strip and align it so that the lines marked on the end of the specimen are
4. Vertical and centered over the plywood strip. The second plywood strip is placed length wise on the cylinder centered on the lines marked on the ends of the cylinder.
5. Apply the load without shock and increase it continuously at the rate to produce a split tensile stress of approximately 1.4 to 2.1 N/mm2/min, until no greater load can be sustained. Record the maximum load applied to specimen as shown in fig.
6. Computation of the split tensile strength was as follows.

Split tensile strength = 2P/πdL x 1000
Where,

P = Load in KN
Π= 3.142
d = Diameter of cylinder = 150 mm
L = Length of cylinder = 300 mm

Table -7: Split Tensile Strength Test Data

Marble powder % of replacement	3 days N/mm2	7 days N/mm2	15 days N/mm3
0%	5.97	9.03	16.0
5%	6.16	10.11	16.89
10%	8.21	12.23	18.40
15%	8.34	12.56	18.94
20%	7.58	11.07	17.56

8. CONCLUSIONS

Due to marble dust, it proved to be very effective in assuring very good cohesiveness of mortar and concrete. From the above study, it is concluded that the marble dust can be used as a replacement material for cement; and 15% replacement of marble dust gives an excellent result in strength aspect and quality aspect and it is better than the control concrete. The results showed that the substitution of 15% of the cement content by marble stone dust induced higher compressive strength, higher splitting tensile strength, and improvement of properties related to durability.

Mechanical behavior of concrete cubes prepared without chemical admixtures was studied by compressive & split tensile tests (Grade M30 and curing time of 3,7,15 days. It can be noticed that 15% replacement of cement with marble dust in mild condition are showing increase in compressive strength & split tensile strength.

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