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# EFFECT OF THE LIME CONTENT IN MARBLE POWDER FOR PRODUCING HIGH STRENGTH CONCRETE

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**ABSTRACT**

Marble powder is a 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 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 powder upto 10% (passing through 45 microns) by weight of cement was investigated for hardened concrete properties. Furthermore, the effect of different percentage replacement of marble dust 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 (F/C) and cement-to-total aggregate ratio (C/TA) 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 marble powder in cement content was noted and also showed an improved mechanical property compared to controlled concrete.

**Keywords:** marble, lime, compressive strength, flexural strength, concrete.

## 1. INTRODUCTION

It has been estimated that several million tons of marble powder are produced during quarrying worldwide. Hence utilization of marble powder has become a important face shift towards the efficient utilization in concrete for improved properties. 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 marble powder as partial replacement of Portland cement. Hebhoub H., *et al.*, (2011), carried out research on marble waste as a substituted material as natural aggregates in concrete production with different mixture proportions such as sand substitution mixture, gravel substitution mixture and a mixture of both aggregates and various practical formulations studied. The results showed that mechanical properties of concrete specimens produced using the marble wastes was found upto 75% of any formulation is beneficial of concrete resistance and conform to concrete production. Sounthararajan V.M., and Sivakumar A., (2012), in their research studies showed that the lower water cement ratio (w/c) 0.3 and different stage of fine to coarse aggregate ratio (F/C) 0.6 to 0.8 was studied and also strength was higher than all other concrete mixes due to the effect of chemical and mineral admixtures that is fly ash based concrete with metallic reinforcements. Ali Ergun., (2011), in their research studies concluded that the usage of construction material that is diatomite and waste marble powder (WMP) was used an inert materials, the test result indicated that the replacement by weight of cement for 5% WMP plus 10% diatomite had increased good compressive and flexural strength. Huseyin Yilmaz Aruntas, *et al*., (2010), demonstrated that waste marble dust as an inclusion material 2.5 % to 10% added with blended cement and prepared with cement mortar the size of the specimen was 40 x 40 x 160 mm, the experimental test result showed that better improvement at different curing days than normal cement mortar strength and also concluded that upto 10% addition of waste marble dust had significantly improved and also used as an additive material in cement manufacturing. Valeria Corinaldesi *et al.*, (2010), in another study stated that marble powder showed a very high blaine fineness value of about 1500m$^2$/kg with 90% of particles was finer than 50 micrometers and 50% under 7 micrometers. The experimental test result was used for various types of cement pastes were prepared using marble powder with and without the inclusion of acryclic based super plasticizer based on the water to cementitious materials ratio showed that 10% replacement of either cement or sand with marble powder caused about 10 to 20% compressive strength was marginally decreased in late age. However, marble powder used 10% replacement of sand was significantly increased when compare to controlled concrete, so it was clear evident that marble powder showed a filler effect, does not reactive the chemical hydration process. Cristiana Gonilho Pereira *et al.*, (2009), in their research studies showed that different types of coarse aggregate with different geological sources, basalt, calcareous, granite and marble were used good quality, the experimental result showed that low particle water absorption and relevant mechanical properties produced in specific mix proportions and also concluded that concrete durability properties are not affected by aggregates mineralogy at the same time significantly affected by the aggregate size and its water content. Prassoamakis I.N., and Prassianakis N.I., (2004), demonstrated that the Marble powder is one of the most versatile substances on earth used in many applications and in a wide variety of forms. Marble occurs naturally nowadays can be used with common construction materials, the experimental investigation was made due to effect of marble powder at different replacement level of cement was examined the durability properties of concrete particular the dynamic moduli of elasticity and damage states due to fracture. Southararajan V.M., and Sivakumar A., (2012), showed that the different percentage of mineral admixture added with cement and to evaluate the setting characteristics of fresh cementitious system using ultrasonic pulse velocity techniques for different intervals to monitoring the rate of hardening of the fresh cement paste and also concluded that 30% of mineral admixture in cement with the addition of 3% accelerator dosage recorded a good improvement in the early age strength from that all values satisfied with codal provision for IS 13311 part 1. Several investigators have reported same research works and leads to improve the mechanical and durability properties of concrete.

### 1.1. Research significance

In this study fine marble powder collected from the nearby source was used for the investigation. Concrete mixtures were prepared using different fine to coarse aggregate ratio and different replacement levels of marble dust.

## 2. EXPERIMENTAL METHODOLOGY AND INVESTIGATIONS

### 2.1. Concrete mix constituents

#### 2.1.1. Cement

Ordinary Portland cement 53 grade was used and confirming to IS 12262-1970.

#### 2.1.2. Aggregate

Normal river sand locally available in the market and confirming to Zone II as per IS 383 1970 and specific gravity of 2.62 and coarse aggregates were used in this experiment. Specific gravity of coarse aggregate was 2.93. Coarse aggregate used as 20 mm down size.

#### 2.1.3. Chemical admixture

Polycarboxylic ether based superplasticizer (CONXL-PCE 8860) was used, it is a high range water reducing admixture upto 40% and also 1 to 4 hours slump retention and conforms to ASTM C494 and complies with IS: 9103-1999.

#### 2.1.4. Supplementary cementitious materials

The marble powder was obtained by crushing marble powder forms in a marble industry. The relative density was 2.55 and Blains fineness value of 1500 $m^2$/kg and chemical composition are presented in Table-1 and snap short of marble powder as shown in Figure-2.

#### 2.1.5. Concrete mixture proportions

Mix design was carried out using conceptual mix design was adopted and are presented in Table-2. The main variable was arrived based on the trial and error methods such as water to binder ratio of 0.3 and Fine to Coarse aggregate ratio (F/C) 0.6. Nine different mixes (M1, M2, M3, M4, M5, M6 and M7) were prepared using cement replaced by marble powder at varying percentages of 0, 2.5, 5, 7.5, 10, 12.5 and 15%.

#### 2.1.6. Casting details

The size of specimens 100 x 100 x 100 mm for cube and 100 mm diameter and 150 mm height of the cylinder size and the size of prism 100 x 100 x 500 mm were casted according to the mix proportion and by replacing cement with marble powder in different proportions.

#### 2.1.7. Curing of specimens

The concrete specimens were cured under water free from chlorides and sulphates and tested after required curing as shown in Figure-2.

#### 2.1.8. Testing the specimen details

Concrete specimens were tested using compression testing machine (CTM) of capacity 1000 KN and with a space rate of 2.5 KN/sec for all specimens and were tested at different curing ages for 7 days, 28 days and 56 days. Flexural testing was conducted using a 100kN capacity electrically operated flexural testing machine at a displacement rate of 0.05 mm/sec and snap shot of the flexural testing machine as shown in Figure-3.

## 3. EXPERIMNTAL TEST RESULTS AND DISCUSSIONS

### 3.1. Workability

Fresh concrete workability measurement using slump test values is presented in Table-1 and were observed for different replacement of marble powder in various percentages ranging from 0, 2.5, 5, 7.5, 10, 12.5 and 15%. It is noted that workability of concrete decreased as the marble powder content is increased.

### 3.2. Strength

#### (a) Compressive strength

It can be noted that when marble powder is substituted as binder with cement the strength was found to be higher at lower replacements upto 10% as shown in Table-3 and represented in Figure-4. However, with higher replacements the effect of marble dust on the strength enhancement was noticed. So, it is clearly evident that the increased marbling powder beyond the optimum value of 10% resulted in loss in consistency and eventually leads to poor packing and strength reduction. Compared to controlled concrete, the optimum addition of 10% marble powder in concrete showed an increased compressive strength value of 12%. It can also be noted that for 15% of marble powder replacement the compressive strength was reduced; however, the strength reduction does not restrict the

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applicability of marble powder in field when grade of concrete is designed for M30.

**(b) Split tensile strength**

A similar trend was observed for split tensile strength and the values are presented in Table-3. It can be concluded that the higher addition of marble powder upto 10% (by weight of cement) exhibited higher split tensile value of 4.35 MPa at 28 days and the increased was 24.29% compared to controlled concrete.

**(c) Flexural strength**

The test result of variation of flexural strength of concrete with cement replacement by marble powder at 7 and 28 days are represented in Table-3 and graphically represented in Figure-5. It is noted that the flexural strength of concrete with 10% cement replacement by marble powder showed the flexural strength of 4.21MPa when compared to control concrete an increase up to 16.90% at 28 days testing. It is also concluded that the addition of 12.5% of marble powder the strength was marginally increased upto 7.69%. The test results on the various mechanical properties clearly indicate that the addition of marble powder at optimum dosage of 10% resulted in increased performance and thereafter the strength was pronouncedly decreased at higher dosages.

**Table-1.** Chemical composition of the cement and marble powder.

| **Chemical Composition** (% by mass) | **Cement** | **Marble powder** |
|---|---|---|
| Alumina ($Al_2O_3$) | 4.60 | 0.70 |
| Iron oxide ($Fe_2O_3$) | 3.00 | 0.33 |
| Calcium oxide (CaO) | 61.40 | 51.49 |
| Magnesium oxide (MgO) | 2.30 | 0.36 |
| Sodium oxide ($Na_2O$) | 0.19 | 0.19 |
| Potassium oxide ($K_2O$) | 0.83 | 0.25 |
| Sulphur trioxide ($SO_3$) | 3.80 | 0.10 |
| Loss of ignition | 2.70 | 44.60 |
| Fineness % passing (sieve size) | 45 µm | 90 µm |
| Specific gravity | 3.22 | 2.74 |

**Table-2.** Various mixture proportions of concrete adopted in the study.

| **Mix Id** | **w/b ratio** | **F/C ratio** | **Cement** | **Marble powder** | **Fine aggregate content** | **Coarse aggregate** | **Water** | **Super plasticizer** (%) | **Slump in mm** |
|---|---|---|---|---|---|---|---|---|---|
| | | | (Kg/m$^3$) | | | | | | |
| M1 | 0.3 | 0.6 | 400 | 0 | 672 | 1113 | 120 | 1.50 | 100 |
| M2 | 0.3 | 0.6 | 390 | 10 | 672 | 1113 | 120 | 1.50 | 94 |
| M3 | 0.3 | 0.6 | 380 | 20 | 672 | 1113 | 120 | 1.50 | 91 |
| M4 | 0.3 | 0.6 | 370 | 30 | 672 | 1113 | 160 | 1.50 | 88 |
| M5 | 0.3 | 0.6 | 360 | 40 | 672 | 1113 | 160 | 1.50 | 82 |
| M6 | 0.3 | 0.6 | 350 | 50 | 672 | 1113 | 160 | 1.50 | 76 |
| M7 | 0.3 | 0.6 | 340 | 60 | 672 | 1113 | 160 | 1.50 | 70 |

**Table-3.** Strength values for various concrete mixes.

| Mix Id | Marble powder % (by weight of cement) | Compressive strength (MPa) | | | Split tensile strength (MPa) | Flexural Strength (MPa) | |
|---|---|---|---|---|---|---|---|
| | | 3 days | 7 days | 28 days | | 7 days | 28 days |
| M1 | 0 | 36.90 | 40.20 | 44.90 | 3.50 | 3.50 | 3.60 |
| M2 | 2.5 | 30.90 | 39.90 | 42.10 | 3.20 | 3.62 | 3.64 |
| M3 | 5 | 31.20 | 41.90 | 43.50 | 4.13 | 3.78 | 3.82 |
| M4 | 7.5 | 34.10 | 43.00 | 45.40 | 4.20 | 3.95 | 4.00 |
| M5 | 10 | 34.50 | 46.80 | 49.30 | 4.35 | 4.17 | 4.21 |
| M6 | 12.5 | 27.90 | 33.50 | 35.10 | 3.10 | 3.60 | 3.90 |
| M7 | 15 | 22.10 | 28.50 | 33.90 | 3.00 | 3.30 | 3.60 |

**Figure-1.** Marble powder used in the study.

**Figure-2.** Concrete specimens cured in water.


**Figure-3.** Compression and flexural test setup.

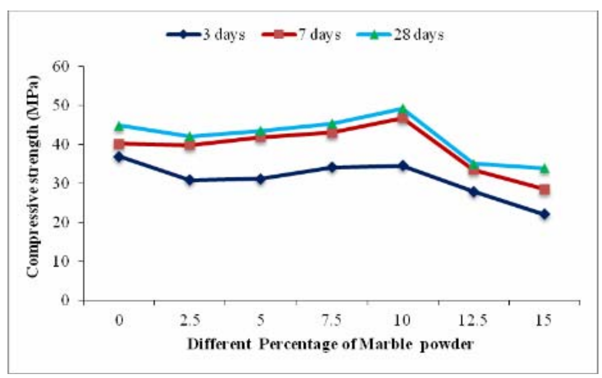


**Figure-4.** Variation of compressive strength development in concrete with marble powder.

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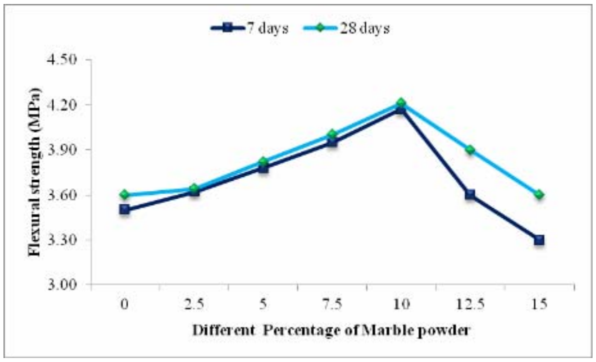


**Figure-5.** Variation of flexural strength for different mixture proportions of concrete.

## 4. CONCLUSIONS

Based on the experimental investigation the following conclusions are drawn:

- High strength concrete was achieved when marble powder was replaced at 10% by weight of cement in concrete.
- The workability decreased as the marble powder content increased. Use of polycarboxylate ether based superplasticizer was found to be necessary to maintain workability at low water cement ratio.
- Considering the strength criteria, the replacement of cement by marble powder is feasible to obtain a maximum compressive strength at 28 days and it is recommended that the utilization of marble powder upto 10% contained in concrete as cement replacement is possible.
- Strength properties were greatly influenced by the optimum addition of marble powder as it exhibited better reactivity with cement hydration products and showed a consistently improved mechanical property compared to controlled concrete.
- The higher replacements of marble powder does not show large reduction in strength and can be suitable for producing grade concrete upto M30.

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