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EFFECT OF PARTIAL REPLACEMENT OF MARBLE DUST ON STRENGTH AND PERMEATION PROPERTIES OF CONCRETE

DANISH MANZOOR[1], ER. ASHISH KUMAR[2]

[1]*Scholar, Department Of Civil Engineering, RIMT University, Mandi Gobindgarh, Punjab, India*

[2]*Assistant Professor, Department Of Civil Engineering, RIMT University, Mandi Gobindgarh, Punjab, India*

ABSTRACT

Quarrying and treating marble stone generates a lot of waste. According to the findings of the research, the compressive strength, flexural strength and permeability of concrete was improved utpo 10% replacement of cement. It can observed due to marble dust have Cao and filler effect. Further replacement of marble dust decrease the properties of concrete. It was shown that using marble dust as the cement replacement reduced permeability as compared to control blends. The density of concrete made using marble dust as was noticeable change. According to the findings of the research, the building sector has a large amount of potential for environmentally friendly large-scale use of marble waste. In addition to solving the issue of disposing of marble waste, the use of this waste conserves natural resources

***KEYWORDS**: Marble, Dust, Effect, Replacement, Properties, Concrete*

1. INTRODUCTION

Concrete is the most versatile and commonly used building material. Concrete is used extensively in the construction of infrastructure facilities such as dams, bridges, under-water structures, water retention structures, highways, and buildings. Concrete's major components are aggregates, cement/binder, and water [1]. The worldwide annual manufacture of concrete in 2020 was predicted to be 7 billion tons, with a 3 percent rise expected in 2018. Aggregates make up around 60 to 75 percent of the elements of concrete. Large-scale concrete manufacturing utilizes massive quantities of coarse aggregate, depleting natural raw material supplies and causing ecological imbalance, climate change, wildlife impacts, air pollution, etc. Due to the abovementioned negative impacts, researchers began employing industrial or mining waste as concrete aggregate. Many researchers have investigated replacing fine aggregate with fly ash, GGBS, copper, and steel slag. Limestone, sandstone mining waste, and cutting waste have also been used to substitute coarse aggregate in concrete mixtures [1-3].

Anson-cartwright (2015) [4] produced normal strength concrete from five Turkish quarries' limestone wastes. Limestone waste aggregates replaced conventional coarse aggregates. Investigators observed that lime stone waste aggregate may substitute conventional coarse aggregate without affecting concrete strength. Rana et al. (2015) [5] investigated the rheology of limestone waste and conventional aggregates (Basalt, Quartz and Sandstone). They concluded that limestone and sandstone concrete mixtures were more workable due to their spherical particles.

Kumar et al. (2016) [6] partially replaced coarse aggregate with sandstone quarry waste. After replacement, they discovered the desired workability. At 40% replacement, compressive strength didn't drop. Marble waste has also been utilized to investigate the viability of partially or completely replacing traditional coarse aggregate.

A few researches have been conducted on the use of marble waste as a substitute in concrete mixtures. Ergün, A., 2011[7] Effects of the usage of diatomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete. Construction and Building Materials, 25(2), pp.806–812. (2020) [7] and colleagues published the findings of a preliminary investigation on the potential use of marble waste as a substitute for traditional coarse aggregate. They found that using coarse aggregate made from waste marble increased the compressive strength by 27.7 percent and the flexural strength by 11.7 percent when it was substituted for 75 percent of the fine aggregate. According to the findings of Binici et al. (2018)[8], increasing the percentage of marble waste used to substitute natural coarse aggregates in concrete mixes boosts the material's compressive strength as well as its flexural strength and split tensile strength. They also noticed an increase in the material's resistance to sulphate, as well as a decrease in the amount of chloride ion penetration. According to Hebhoub et al. (2019) [9], increasing the percentage of coarse aggregate created from marble waste that is substituted for conventional coarse aggregate in concrete leads to improvements in the material's mechanical qualities. Mishra et al. (2013)[10] utilized marble dust as a partial substitute for OPC in concrete mixes with a constant water-cement ratio of 0.46 in percentages ranging from 0% to 10% by weight. They found that the compressive strength of the resultant blended cement concrete mixes rose by 19 % at 10 % replacement level when compared to control concrete. The improvement in compressive strength was caused by an increase in the fineness of blended cements, which aids in the creation of homogeneous pore spaces and hydration products.

According to the findings of another research that was conducted by Ceylan, H., and Manca (2016)[11], concrete that was created by employing marble aggregate as a full substitute for conventional aggregate attained the desired mean strength at all ages of curing. According to the findings of André et al. (2014)[12], the use of marble waste as a partial substitute for conventional coarse aggregate in concrete mixes at varying percentages (ranging from 20 percent to 100 percent) enhances both the mix's workability and its compressive strength. In addition to this, they observed that the chloride ion penetration decreased while the carbonation levels remained about the same in both mixtures. According to Abdul et al. (2019)[13] with increasing the use of marble waste as traditional coarse aggregate in concrete leads to improvements in both the material's physicochemical and mechanical qualities. It was necessary to conduct a long-term comprehensive study on the mechanical and durability properties of concrete mixes using marble waste as coarse aggregate in order to justify its use in infrastructure works and eliminate associated problems regarding waste disposal. The study was to investigate the mechanical and durability properties of concrete mixes using marble waste as OPC.

2. EXPERIMENTAL PROGRAM

2.1 Materials Used

2.1.1 Portland Pozzolana Cement

Portland Pozzolana Cement (PPC) employed in this research meets conforming to IS 1489-1 (1991)[14]. The characteristics of cement were evaluated at the laboratory as shown in Table 1.

Table 1 Physical properties of portland pozzolana cement

Properties	Results
Soundness	2.4 mm
Setting Time	
Initial	52 minute
Final	398 minute
Compressive strength	
7 days	32.60MPa
28 days	44.25MPa
Consistency	27%
Fineness	1.86%
Specific gravity	3.15

2.1.2 Marble Dust

Marble dust was obtained from Makrana in Rajasthan. It was dried in the oven at 100 ±10°C for twenty-four hours and then sieved using a 300-micron sieve. The PPC nearly 60 percent by weight of the marble dust passed through the IS sieve with a 300 micron sieve size. The findings of its physical, and chemical are shown in Table 2.

Table 2 Chemical analysis of PPC and marble dust

Chemical composition	PPC	Marble dust
CaO	46	55.9
SiO_2	32.5	0.8
Al_2O_3	8.6	0.4
Fe_2O_3	4.7	0.2
MgO	1.5	0.1
K_2O	0.45	-
SO_3	0.5	-
$CaCO_3$	-	91
Na_2O	-	-
LOI	1.4	39

2.1.3 Fine Aggregate

The fine aggregate utilized in the experiment meets BIS: 383-1960[15] grading zone II. The specific gravity and water absorption of fine aggregate are 2.66 and 2% respectively. Table 3 shows the particle size distribution of fine aggregate

2.1.4 Coarse Aggregate

For the experiment, river gravel was utilized. For each of the mixes, the same kind and source were employed. Nominal maximum aggregate size is 20 mm. Coarse aggregate has a specific gravity of 2.51 and water absorption of 2.4 percent.

2.1.5 Super plasticizer

A super plasticizer is essential for good workability. They are polymers that dissolve in water to generate lengthy molecules with large negative charges. The combined water between the cement agglomerations is liberated when the cement particles are dispersed by electrical repulsion between these negative charges, considerably improving the workability of concrete. Master Glenium ACE 30, which complied with IS 9103 (2004)[16], was employed as an admixture in this investigation. Table 4 contains a list of the characteristics.

Table 3 Particle size distribution of fine aggregate

Particle size distribution of fine aggregate			
Sl. No.	Sieve size	percentage passing	Cumulative % Retained
1	10 mm	100	0
2	4.75 mm	94.50	5.5
3	2.36 mm	90.40	9.6
4	1.18 mm	77.82	22.18
5	600 μ	60.4	39.6
6	300 μ	15.24	84.76
7	150 μ	1.5	98.5
Grading Zone as per IS 383:1970	Zone II		260.14
Fineness Modulus			**2.6**

Table 4 Properties of super plasticizer

Parameter	Master Glenium ACE 30
Structure of material	Polycarboxylic ether
Color	Light Brown
Relative Density (kg/lt)	1.09 ± 0.01 at 25ºC
Chloride content (%)	<0.2

2.1.6 Water

Tap water was used for mixing and curing purposes.

2.1.7 Mixture Proportions

Table 5 shows the mixture proportions used for the experimental program. The same mixture proportions was used for all samples. The water-cement ratio was 0.45.

Table 5 Mix proportion

Mix	Cement (kg/m^3)	MD (%)	MD (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	Water (kg/m^3)
M1	380	0	0	676	1156	171
M2	361	5	19	676	1156	171
M3	342	10	38	676	1156	171
M4	323	15	57	676	1156	171
M5	304	20	76	676	1156	171

2.2 TEST

2.2.1 Workability (Slump Test)

The slump test determines the consistency of freshly made concrete prior to hardening. It is used to test the workability of newly mixed concrete and, as a result, the ease with which concrete flows. It may also be used to detect a poorly mixed batch. Slump test was conducted on green concrete as per specification of IS 1199-1959[17].

2.2.2 Density of Concrete

An investigation of effect of using marble dust as a partial replacement on the self-weight of concrete was conducted by measuring its density. This test was performed on 28-day cured concrete specimens with dimensions of 150x150x150 mm. The concrete specimens were baked for 24±1 hours to attain a consistent weight. The following formula is used to determine the density:

$$\text{Density of concrete} = \frac{\text{mass of specimen}}{\text{volume of specimen}} \quad \ldots\ldots\ldots 3.1$$

2.2.3 Compressive strength

As per Indian Standard IS: 516-1959[18], the compressive strength of specimens is evaluated after 7 and 28 days of curing, respectively, with surface dry conditions. For compressive strength testing, 150x150x150mm moulds were utilized. For each typical category, three specimens are evaluated, and the average compressive strength of the three specimens is used to determine the compressive strength.

2.2.4 Flexural Strength

Flexural strength of concrete was conducted as per IS: 516-1959[18]. Prisms of size 100x100x500 mm was taken for the experiment.

2.2.5 Water Permeability

A water permeability test was performed to measure the porosity in concrete in accordance with the German standard DIN - 1048 part 5 (1991)[19]. Concrete samples were subjected to steady water pressure of 0.5 N/mm2 acting normal to the mould-filling direction. By checking it often, the pressure in the pressure head is maintained stable for a period of seventy-two hours. After a period of 72 hours, the samples were removed from the apparatus, and these specimens were cut in half to create two parts. The maximum penetration depth was determined from the examination of the three specimens, and the mean of these measurements was then reported as the depth of penetration.

3.3 RESULTS AND DISCUSSION

Initially, concrete mixtures were developed utilizing various amounts of marble dust. Trial studies were conducted to investigate the behaviour of concrete employing marble waste as a partial substitution of PPC. Based on the findings, normal concrete mixes with a water-cement ratio of 0.45 were cast with varied amounts of marble dust as PPC. Mechanical and durability properties were investigated, as indicated in the following sections.

3.1.1 Workability

The slump test was used to assess the workability of all concrete mixtures. Figure 1 depicts the difference in workability of concrete mixes with partial substitution of PPC with marble dust. According to IS 456-2000, the degree of workability is moderate. The slump values of the concretes made from marble dust are in the range of 80-120 mm for different doses of super plasticizer, as shown in Fig.1. It indicates that marble dust having higher surface area as compare to PPC.

3.1.2 Density of concrete

The density (unit weight) of concrete is calculated by mass per unit volume. Ready-mixed concrete is a combination of cement, gravel, sand, and water. Depending on the circumstances, waste materials such as marble dust, slag, fly ash, etc. may also be added as needed. The average density of concrete is about 2400 kilograms per cubic meter. The unit weight or density of concrete varies depending on the mixture's thickness, as well as the quantity of air, water, and cement added to it.

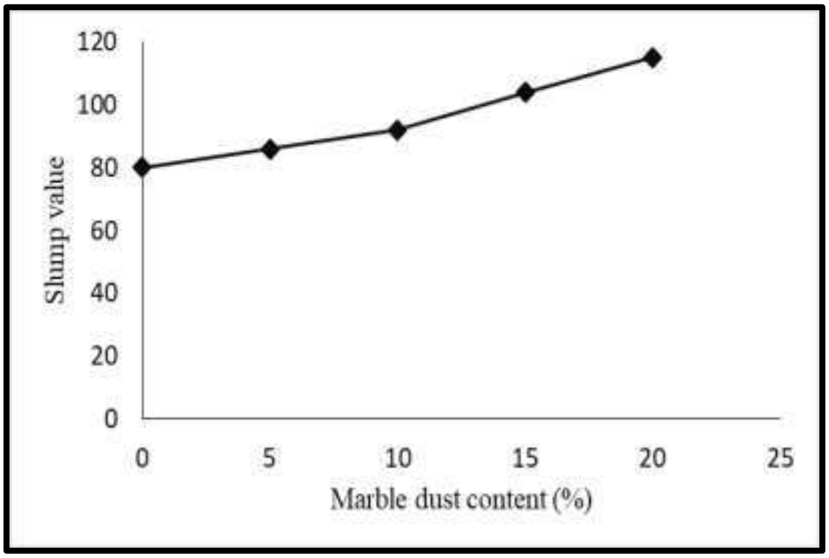

Figure 1 Workability of concrete vs marble dust content

As shown in Figure 2, the density of the concrete was in the range of 2386 kg/m^3 to 2324 kg/m^3 at the age of 28 days. When the densities of concrete containing marble powder were compared with normal concrete, it is slightly reduced. It may possibly due to increasing finer particle substituting in the concrete.

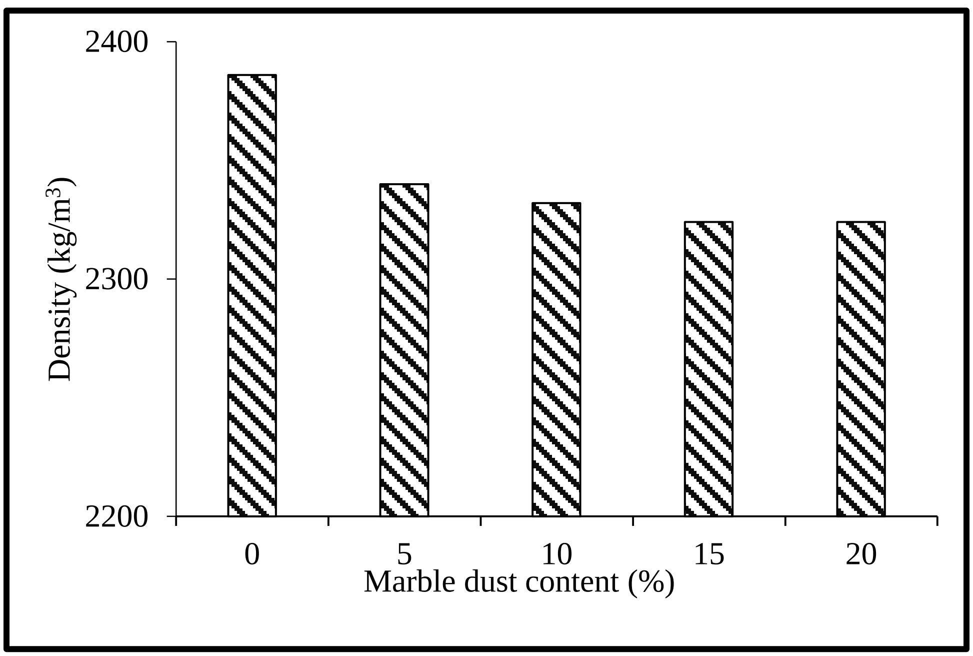

Figure 2 Density of concrete vs marble dust content

3.1.3 Compressive strength

The performance of normal concrete and concrete with marble dust was investigated at 7 , 28 , and 90 days respectively. From the Figure 3, it can be observed that compressive strength of all the mixes increased with respect to ages. The maximum gain was observed for concrete made with 10% marble dust. In contrast, concrete blends M3 and M4 were proportioned using a maximum packing density as compared to normal concrete.

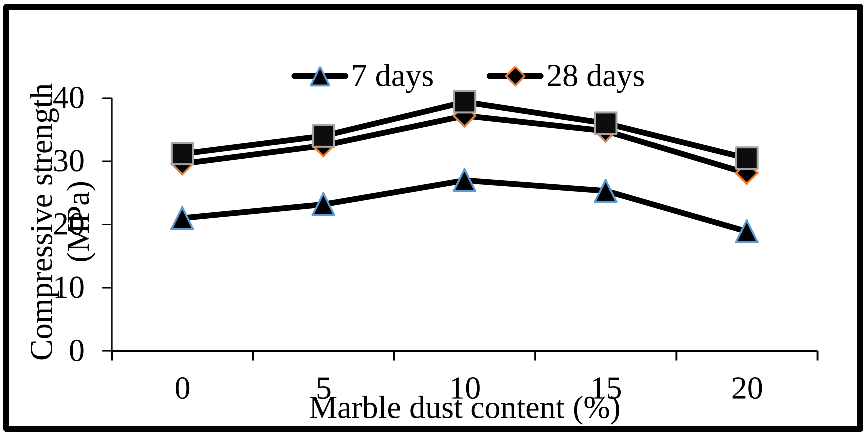

Figure 3 Compressive strength vs marble dust content

3.1.3 Flexural strength

The specimens of concrete were subjected to a flexural strength test, and the results are shown in Figure 4. From Figure 4, it can be seen that minor decrease in the flexural strength of concrete M3, and M4. The flexural strength of 28-day concrete mix M2 was 12 percent higher than that of the control mix M1, and the flexural strength of 90 -day concrete mix M1 was 10 percent lower than that of mix M2.

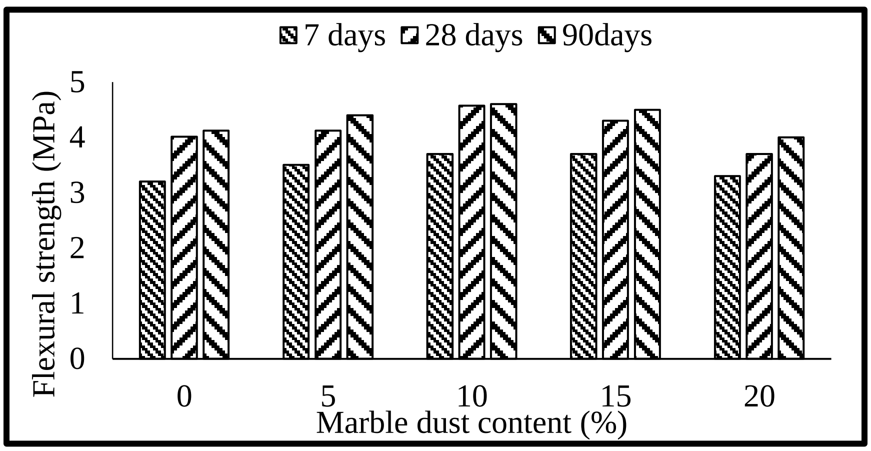

Figure 4 Flexural strength vs marble dust content

3.1.4 Water Permeability

The permeability test was carried out in accordance with German standard DIN-1048-part 5(1991) in order to determine the porosity of concrete. A permeability was determined by the depth of water penetration. Figure 5 depicts the differences in penetration depths across several concrete blends. When marble dust was included in the concrete mixes, it was shown to reduce the permeability of the mix. Permeability is affected by a wide range of variables.

The interconnectivity of pores in the concrete is the most essential component in determining the permeability of concrete. When compared to the control mix M1, the depth of water penetration in concrete mixes M3 and M4 decreased by 24.40 and 17.30% respectively.

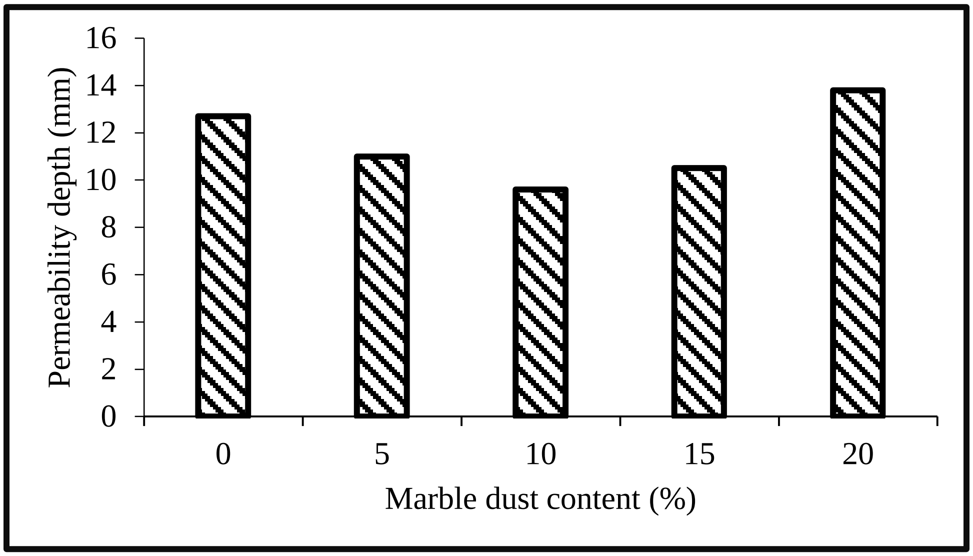

Figure 4.5 Permeability depth vs marble dust content

Marble dust concrete has a lower porosity because of finer particle, which might account for this decrease. Increasing the amount of marble dust in the concrete has a significant role in producing dense particle packing. The clogging of pores is being responsible for the decrease in water penetration depth.

4 CONCLUSIONS

To our knowledge, this is the comprehensive research has been conducted on the use of marble dust as cement replacement in concrete mixtures. In the following paragraphs, a comparison is made between the results of concrete mixes created marble waste dust and control mixes developed in accordance with BIS: 10262-2009.

- The addition of marble dust as cement replacement reduces the workability of concrete mixture due to higher surface area.
- Incorporation of marble dust increases the compressive strength up to 10%.
- Using marble dust as cement replacement in concrete mixes improves the compressive strength value by around 20 percent.
- Also, marble dust has an even more beneficial impact at early age, because of its owing to it filler ability.

- Concrete made with marble dust shows better density and homogeneity of the concrete to that of the control mixes.
- The permeability depth of marble blends concrete was 24.4 percent less than that of control concrete.
- The reduction of permeability depth indicates that durability of concrete has been enhanced.

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