Effect on Mechanical Properties of Concrete by Partial Replacement of Cement with Marble Powder and Its Cost Effectiveness

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Abstract: **Construction industry plays an important role in the development of infrastructure of a society. Concrete is the utmost used construction material in modern construction industry having high strength, durability, stability and resistance to withstand severe weather and environmental conditions. Cement as a binder, provides strength properties to concrete. Marble is also used in the modern age as supplementary/additive in the concrete industry. This research was carried out to check the properties of concrete when cement was replaced with waste marble powder. In this research work, water to cement ratio was selected as 0.56. All other requirements were met according to the related international standards. The mixed samples of concrete were prepared by partial replacements as 0%, 3%, 6%, and 9% of ordinary Portland cement (OPC) with marble powder. Observations revealed that slump value of mixed samples were reduced by increasing the percentage of marble powder, moreover, it was found that compacting factor also has the adverse effect after the partial replacement of cement with marble powder. The compressive strength of concrete increased with the increase in marble powder content up to 6% and then reduced. Overall, the compressive strength of concrete increased due to low workability caused by the addition of marble powder. It is also concluded from this research that the marble powder, as an additive enhanced the properties of fresh and hardened concrete and reduced the overall cost of research work up to certain level. This research work fully endorses that marble powder is environmental friendly material in nature and can be used as a potent partial replacement of cement in construction industry.**

Keywords: **Marble Powder, Concrete, Workability, Compressive Strength, Cost Analysis**

I. INTRODUCTION

There are many types of materials used in the construction industry. The most commonly used materials are steel, cement, concrete, bricks, stone, clay and sand. Recently, Normal-strength concrete (NSC) has gained broad acceptance among stack holders. Several types of concrete available nowadays are made by changing the amounts and proportions of the main ingredients to acquire desired properties of concrete which make concrete more durable to temperature and other environmental effects. It is stated that globally twelve 12 billion tons of concrete is consumed each year [1]. With the increasing use of concrete considerable research work has been carried out on its properties. A lot of research is being done by the researchers to use waste materials and other by-products which are generated from several processes in industries in concrete as additives to enhance the properties of concrete and to clean the environment [2]. The incorporation of industrial by-products in concrete can significantly enhance the basic properties of concrete in fresh and hardened states. They can improve strength, durability, depletion of cement alkalis, resistance to chloride, sulphate penetration and continued micro-structural development through a long-term hydration [3]. The study presents the results of experimental work on mechanical properties of normal strength concrete in fresh and hardened state, containing different replacement levels of marble powder. After success in result, it is expected that marble powder can be used as alternative of cement [4]. It was observed that the workability of concrete decreases by adding the marble powder but concrete gains the compressive strength. Increasing demand of cement all over the world needs a fractional replacement of cement with industrial and agricultural waste which can provide the gainful benefits and environment friendly solution [5-6]. Marble powders makes concrete to maintain the mix stability and reduces the bleeding and segregation [7].

II. BACKGROUND

Marble, a metamorphic rock available beneath the earth originated from the transformation of pure limestone. White marble is formed when limestone is merely composed of calcite. The marble is broadly used for the construction and ornamental purposes. It is durable and has a venerable appearance. A significantly large volume of marble powder is obtained during the cutting processes [8-9]. Marble powder is being used as an additive in ceramic industry, reinforced polyester glass fiber, leather cloth and flooring applications. Apart from these applications, it can be employed as the partial substitution of cement in concrete to some extent [10]. The research showed that high volumes of waste powders can be used as mineral additives in production of Self Compacting. Addition of marble powder in concrete in hardened state showed minor effect on performance [11].

III. LITERATURE RIEVIEW

The classification of marble powder in mortar and concrete is important to study the effects on their strength and other properties which affect the overall performance of concrete. It was observed that high fineness of the marble powder is very precious and assuring good reliable properties in mortar and concrete. In terms of mechanical concert, 10% replacement of sand by the marble powder in the existence of a super plasticizing admixture gave maximum compressive strength at the

same workability level [12]. Granite and marble dust were used as filler in Asphalt Concrete. Adding up of marble and granite powder in asphalt concrete created the qualities which were comparable to conventional asphalt concrete mixes with stone dust filler. The fillers could be used up to 7 % in asphalt concrete mixes. The uses of these materials in road construction would create the problem of discarding and environmental pollution [13]. Recycling of marble waste powder for the production of cement and concrete had been studied. The results showed that by replacing cement with 20% marble powder decreased the slump of concrete mixes and in contras substitution of sand by 20% marble powder increased the slump values. Replacement of 5% cement by marble powder increased the compressive and flexural strength as compared for the marble powder free specimens, however; beyond 5% addition resulted in strength reduction. That indicated the marble waste could be integrated in Portland limestone production [14].

Sufficiently high strength concrete was attained by using10% marble powder. Marble powder decreases the workability of content if beyond 10%. Strength properties were very much influenced by the best possible addition of marble powder, as it showed superior reactivity with cement hydration products and demonstrated constantly better mechanical property as compared to controlled concrete [15]. It was observed that the addition of marble powder to self- compacting concrete with an increase in water/cement ratio lead to reduction in compressive strength at 28 days [16]. Based on results, it is found that compressive strength of concrete increases with increase of marble powder content in it. Compressive strength increases with 30% replacement [17]. Marble slurry utilization in black cotton soil proved best ways of improving soil properties and protecting environment to some extent from the harmful effects of disposal on land and in water [18]. It was evident from results that compressive strength of cubes and split tensile strength of cylinders improved with the addition of 10% by weight of cement with waste marble powder and beyond that limit, any further addition decreased the compressive strength of samples. Thus it was exposed from the research that the optimum percentage for substitution of marble powder with cement was 10% of the total cement for all samples [19].

IV. OBJECTIVES

Keeping in view the application and uses of marble powder, the specific objectives of the present research were set as under.

- To introduce marble powder in percentages and to quantify the optimum usage of marble powder as a replacement of Ordinary Portland Cement.
- To study the combined effect of marble powder and ordinary Portland cement in fresh and hardened state of concrete.
- To check the effect on workability of concrete incorporated with marble powder.

V. EXPERIMENTAL WORK

Different materials used and tests were performed on the specific material that has been used in production of normal strength concrete and the concrete incorporated with marble powder. Cement, fine and coarse aggregate were procured from local supplier while marble waste was obtained from marble industry Rahim Yar Khan.
Consistency of cement**,** initial setting time and final setting time of cement were studied and calculated during the research work. Specific gravity, water absorption, and moisture content of fine and coarse aggregates were calculated however sieve analysis and fineness modulus of fine aggregates were measured only. The tests performed on fresh concrete were slump test and compacting factor test. The tests were performed to check the workability of concrete specimens as per ASTM standards, listed in **Section 5.** The tests performed on hardened concrete were the compressive strength test as per international standards.

A. Mix Design:

For the whole work, water to cement ratio selected as 0.56. Concrete specimens (cylinders) were prepared by the ratio of 1:1.5:3. Total thirty-six (36) numbers of cylindrical molds of size 6"x12" were prepared for the determination of compressive strength of concrete at various replacement levels of marble powder. Nine (9) among them were casted with only cement as binder, From the remaining twenty-seven (27) cylinders, nine cylinders each were replaced with marble powder with the amounts 3%, 6% and 9% by weight of cement. Three cylinder each were cured for seven (7), fourteen (14) and twenty-eight (28) days respectively. Detailed Mix design is tabulated in Table 1. Specific tests of fresh concrete were performed such as, slump test and compacting factor test. The tests were done to check the workability of concrete mixes. After fresh properties, molding, placing and curing of concrete were done accordingly. After specified period of curing, compressive strength of concrete cylinders was determined according to ASTM C-39. Special care in placing and transporting of sample was done so that no any damage may not occur to fresh concrete. In this way, total thirty-six cylinders were prepared.

Table.1: Mix proportion for 0.0424 m^3 at 0%, 3%, 6% and 9% replacement with cement

Ingredients used in different specimens (Kg)	Replacement of cement with Marble Powder (%)			
	0.0%	3.0%	6.0%	9.0%
Total No. of Cylinders casted	9	9	9	9
Water	10.926	10.926	10.926	10.926
Cement	19.51	18.92	18.33	17.75
Marble powder	0	0.59	1.17	1.76
Fine Aggregate	29.264	29.264	29.264	29.264
Coarse Aggregate	58.53	58.53	58.53	58.53

VI. RESULTS AND DISCUSSION

The results of study and discussion are mentioned in this section. All observations cited, observed, calculated and measured are expressed in details in the section. **Table 2** shows the chemical composition and physical properties of cement. Chemical composition of cement was obtained from literature reviewed and other tests such as consistency, initial setting time and final setting time of cement were carried out in the laboratory. Consistency of cement was observed by ASTM C-187. Whereas, initial setting time and final setting time of cement were examined by ASTM C-191. Consistency, initial setting time and final setting time of cement observed were 28%, 30mins and 126mins respectively.

Table 2 Chemical composition and physical properties of cement [15]

Sr. No.	Chemical composition of cement	Amount (%)	Physical Properties of cement	Results
1.	SiO_2	17.0-25.0	Consistency	28%
2.	Al_2O_3	3.0-8.0	Initial setting time	30mins
3.	Fe_2O_3	0.5-6.0	Final setting time	126mins
4.	CaO	60.0-70.0	--	--
5.	MgO	0.1-4.0	--	--
6.	SO_3	1.0-3.0	--	--
7.	K_2O	0.5-1.3	--	--

Table 3 shows the physical properties of fine and coarse aggregates. The results of physical properties of fine aggregate such as fineness modulus, bulk specific gravity (SSD), apparent specific gravity, Bulk specific gravity (OD) and water absorption were 2.24, 2.30, 2.44, 2.35 and 2.96% respectively and bulk specific gravity (SSD), apparent specific gravity, bulk specific gravity (OD), water absorption and moisture content of coarse aggregate observed were 2.14, 2.22, 2.09, 4.77% and 0.70% respectively.

Table 3 Physical properties of fine and coarse aggregates

Sr. No.	Physical Properties	Fine Aggregate		Coarse Aggregate	
		Obtained Results	ASTM Standards	Results Obtained	ASTM Standards
1.	Fineness Modulus (FM) / Sieve Analysis	2.24	C 136	--	--
2.	Bulk Specific Gravity (SSD)	2.30	C 128	2.14	C 127
3.	Apparent Specific Gravity	2.44	C 128	2.22	C 127
4.	Bulk specific gravity (OD)	2.35	C 128	2.09	C 127
5.	Water Absorption (%)	2.96	C 128	4.77	C 127
6.	Moisture Content (%) / Evaporable Moisture Content	--	--	0.70	C 566

Table 4 shows the sieve analysis of fine aggregates. The results of sieve analysis showed that 99% cumulative weight of fine aggregates passed from No. 4 sieve, whereas 1% cumulative weight of fine aggregates retained on No. 4 sieve. The test was performed according to ASTM C 33.

Table 4 Sieve analysis of fine aggregate/ Lawrencepur sand

Sieve No.	Sieve Size (µm)	Weight Retained (gm)	% Weight Retained	% Cumulative Weight Retained	% Cumulative Weight Passing
4	4750	5.2	1	1	99
8	2360	13.5	3	4	96
16	1180	56.25	11	15	85
30	600	110.3	22	37	63
50	300	176.4	35	72	28
100	150	114.2	23	95	5

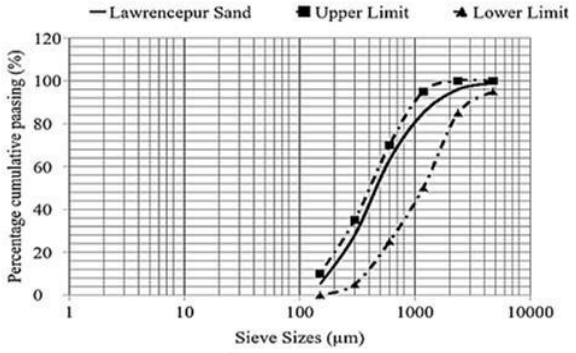

Fig 1 Gradation curve for Fine Aggregate/ Lawrencepur Sand

Table 5 contains slump values and compact factor test values of different concrete mixes. Slump and compact factor values are decreasing with the increasing amount of marble powder content. The lowest value of slump at 9% shows that lowest workability. The slump cone test was performed according to ASTM standards C 143.

Table 5 Slump value and compact factor test of marble powder concrete samples

Sr. No.	Mix ID	Percentage Replacement (%)	Slump value (mm)	Compact Factor test values
1.	MPC0	0	63.5	0.92
2.	MPC3	3	55.88	0.90
3.	MPC6	6	38.1	0.89
4.	MPC9	9	35.5	0.88

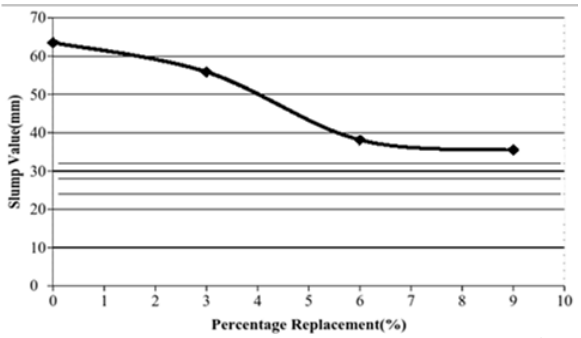

Fig. 2 Relationship between Slump values and percentage replacement of Marble Powder

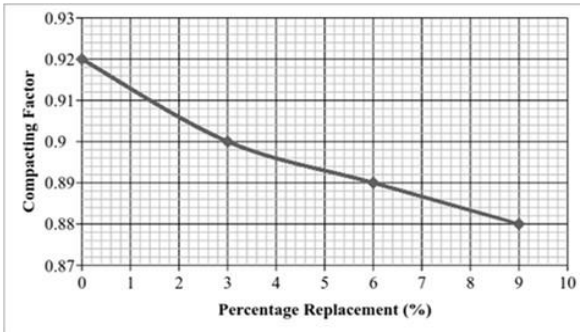

Fig 3 Relationship between compact factor values and percentage replacement of Marble Powder

Table 6 elaborates the compressive of concrete specimens containing different replacements of marble powder percentages. Concrete specimens were tested after curing of 7, 14 and 28 days. Compressive strength of different concrete specimen increased with the increase in marble powder contents up to 6% and further increase of amount reduces the strength. The compressive strength of all the cylinders was performed according to ASTM C 39.

Table 6Compressive strength of marble powder concrete at 7 and 28 days of curing

Sr. No.	Mix Designation	Percentage Replacement (%)	Compressive Strength (MPa)		
			7days	14days	28days
1.	MPC0	0	13.75	13.85	14.22
2.	MPC3	3	17.9	18.6	20.76
3.	MPC6	6	20.3	21.7	23.72
4.	MPC9	9	6.44	7.24	8.67

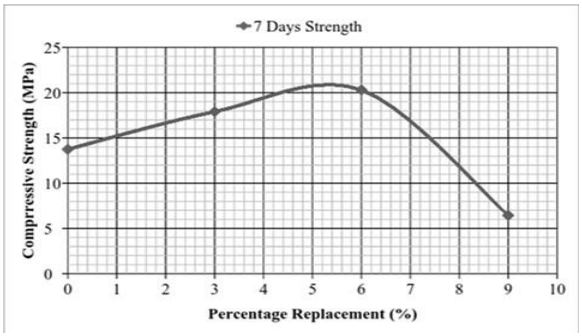

Fig 4 Compressive strength of Marble Powder Cubes at 7 days of curing age

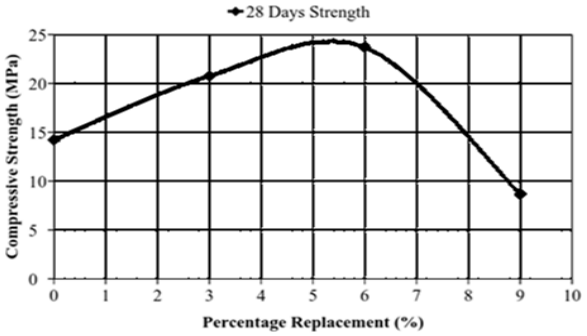

Fig 5 Compressive strength of Marble Powder Cubes at 28 days of curing age

Fig 4 and 5 show the graphical representation of compressive strength of concrete specimens with 0%, 3%, 6% and 9% marble powder percentages content replaced with cement. The relationship shows that the compressive strength is gradually increasing up till 6% replacement of marble powder and then decreases.

Table 7 shows the detail calculation of cost of 1 cubic feet concrete specimen at a replacement of 0%, 3%, 6% and 9% of marble powder with cement respectively. From the table, it can be observed that the cost reduces as the amount of marble powder increases in the mix.

Table 7 Cost of 1ft^3 concrete using 0%, 3%,6% and9%marble powder

Sr. No.	Materials	(0%) Marble powder			(3%) Marble powder			(6%) Marble powder			(9%) Marble powder		
		Volume (ft^3)	Unit Rate (Rs/ ft^3)	Cost (Rs.)	Volume (ft^3)	Unit Rate (Rs/ ft^3)	Cost (Rs.)	Volume (ft^3)	Unit Rate (Rs/ ft^3)	Cost (Rs.)	Volume (ft^3)	Unit Rate (Rs/ ft^3)	Cost (Rs.)
1.	Cement	0.16	375	60	0.155	375	58	0.15	375	56	0.145	375	54
2.	Lawrencepur Sand	0.33	60	20	0.33	60	20	0.33	60	20	0.33	60	20
3.	Marble powder	0	180	0	0.0048	180	1	0.0096	180	2	0.014	180	3
4.	Coarse Aggregates	0.55	65	36	0.55	65	36	0.55	65	36	0.55	65	36
	Total Cost			116	Total Cost		115	Total Cost		114	Total Cost		113

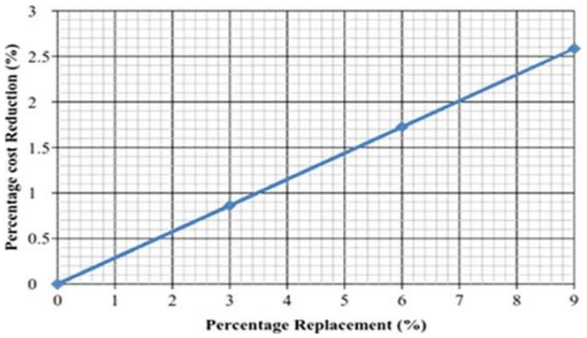

Fig 6 Cost benefit analysis for NSC with Marble powder replacement

VII. CONCLUSION

After studying all experimental work and results obtained from these test, following are the major conclusions:

- Slump reduces with the increase in percentage of marble powder.
- Compacting factor also has adverse effect with the increase in percentage replacement of marble powder.
- Strength of concrete will increase due to low workability.
- Compressive strength of concrete up till 6% replacement of marble powder increases and reduces at 9% replacement.
- Optimum moisture content (OMC) is 6% and more than 50% strength improves.
- Marble powder concrete is economical as it reduces the cost due to utilization of waste material.
- It's a contribution to save environment from pollution.

VIII. RECOMENDATIONS

As discussed in conclusion that strength improves with the mixing of marble powder in replacement of cement up to some limit and then reduces. Following are some future recommendations to make it useable in our projects:

- Study should be done with the use of plasticizers and super plasticizers to maintain workability.
- Long term effects on strength should be studied.

- Test should be done to check the splitting tensile strength and modulus of rupture of marble powder concrete.
- Behavior of marble powder concrete in high strength concrete should be observed.
- Use of marble powder in self-compacting concrete should be checked.

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