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Influence of Marble Powder and Fly Ash in Fresh and Hardened Properties of Self Compacting Concrete

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Abstract : Self-compacting concrete has gained wide use since it has the advantage of compacting on its own weight[8]. This study leads to the use of marble powder which comes as an industrial waste and fly ash to partially replace cement in self-compacting concrete. The use of marble powder as replacement of cement gradually enhances both fresh and hardened properties of concrete especially with lower w/p ratio. The main objective of the study is to utilize the marble powder in self-compacting concrete, as filler material and to study the effect of marble powder and fly ash on fresh and hardened properties of self-compacting concrete.
Keywords : Marble powder, Fresh concrete, Compressive strength and Split tensile strength.

1.0 Introduction:

Self-compacting concrete has gained a great development in the field of construction since it's first developed in Japan by Okamura and Ozawa. The main property of self-compacting concrete to compact under its own weight without vibration is its high fluidity[9]. In order to obtain high fluidity use of high powder content, super plasticizers and admixtures seems to be a good solution. Marble powder comes as a byproduct from marble cutting industry in large amount. About 30% to 40% of the marble comes as waste during its whole process of dressing, cutting and polishing. This industrial byproduct is used as filler in self-compacting concrete to reduce its void content. The established benefits obtained by replacing cement by marble powder and fly ash are economic, saving landfill; reduce CO_2 emission by the use of less cement[2].Use of marble stone as ornamental work in buildings is increasing day by day. There by their wastes create disposal problem. Therefore, the use of marble powder seems to be a better alternative of cement, ecological balance as well as economy[3,5].In this study, it is aimed to investigate the effect of marble powder on the fresh and hardened properties of self-compacting concrete. Fresh concrete tests such as slump flow, V-funnel, U-box, L-box and hardened concrete tests such as compressive strength, split-tensile strength, young's modulus and flexural strength were attempted to this objective achieved and determine the optimum marble powder that can replace cement in self-compacting concrete[4,7].

2.0 Materials:

2.1 Cement:

Ordinary Portland Cement (OPC) of 53 grade conforming to IS: 12269-1987was used. The cement bags were stored in humidity-controlled room to prevent it from being exposed to moisture. The chemical composition of cement is shown in table 1 and physical properties are shown in table 2.

2.2 Marble powder:

Marble powder was collected from the dressing and processing unit in Namakkal. It was initially in wet form (i.e., slurry) which is dried and sieved to get the powder. The chemical composition is shown in table 1 and physical properties are shown in table 2.

Table 1: Chemical composition of Marble powder and Cement

S.No	Composition	Proportion	
		Marble Powder (%)	Cement (%)
1	Silicon dioxide (SiO_2)	1.12	21.92
2	Alumina (Al_2O_3)	0.73	3.30
3	Calcium oxide (CaO)	83.22	63.0
4	Magnesium oxide (MgO)	0.52	3.07
5	Sodium oxide (Na_2O)	1.12	0.96
6	Potassium oxide (K_2O)	0.09	0.27
7	Ferric oxide (Fe_2O_3)	0.05	1.20

Table 2: Physical properties of Marble powder and Cement

S.No	Materials	Fineness (%)	Specific Gravity
1	Marble powder	3	2.67
2	Cement	2	3.15

2.3 Fly ash:

Fly ash conforming to IS: 3812-2003 is a fine inorganic material with pozzolanic properties, which can be added to improve the properties of self-compacting concrete.

2.4 Fine Aggregate:

River sand was used as fine aggregate which conforms to IS: 383-1970 and grading zone II. The sand was made to pass through 4.75mm sieve to remove any particles greater than 4.75mm.

2.5 Coarse Aggregate:

Coarse aggregate used in the investigation is angular aggregates with rough surfaces of nominal size of 20mm and conforming to IS: 383-1970. Normally, coarse aggregates occupy 70%-80% of the total volume of concrete but self-compacting concrete have only 50% of the total volume of concrete.

2.6 Water:

Normal tap water available in the laboratory was used for concreting and curing.

2.7 Super plasticizer:

High Range Water Reducing Admixture (HRWRA) Conplast SP430 from Fosrac Chemicals was used to produce high workability. It is a chloride free, super plasticising admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water.

3.0 Experimental Program:

3.1 Slump test:

A slump cone in the shape of a truncated cone with internal dimensions of 200mm diameter at the base, 100mm diameter at the top and a height of 300mm was used. The slump flow test was a simple, rapid test which was used to assess the horizontal free flow of concrete in the absence of obstructions. Before conducting the test the slump cone was oiled and placed in a horizontal surface. About 6 liters of concrete was filled in the cone without compacting manually and the concrete was leveled at the top using trowel. The cone was lifted vertically and the concrete was allowed to flow out freely. The flow diameter formed by self-compacting concrete was noted.

3.2 V-funnel test:

The equipment consists of a v-shaped funnel mounted on a stand. This test was used to assess the filling ability of the concrete. About 12 liters of concrete was filled in the apparatus without compacting manually and the concrete at the top was leveled using trowel. Open the trap door within 10 seconds after filling and start the stopwatch and allow the concrete to flow through the trap door under gravity. The time taken for the concrete to flow under gravity was noted.

3.3 U-box test:

The equipment consists of a u-shaped box mounted on a stand. This test was used to assess the passing ability of the concrete. Reinforcing bar with nominal diameter of 12mm were fixed at the bottom of u-box with centre to centre spacing of 50mm. About 20 liters of concrete was filled in the left hand section of u-box and then the sliding gate was opened and the concrete was made to pass through the reinforcements and fill in the right hand section. Now, measure the height of the concrete in the compartment that has been filled (H1). Measure also the height in the other compartment (H2). Calculate the filling height by calculating the height difference H1-H2.

3.4 L-box test:

L-box test was used to assess the filling ability of the self-compacting concrete and also the extent to which it was subjected to blocking by reinforcement. The apparatus consists of a rectangular L-shaped box with a sliding gate and reinforcing bar of diameter 12mm at the bottom with centre to centre spacing of 40mm. About 14 liters of concrete was filled in the vertical section of the apparatus and sliding door was lifted to allow the concrete to flow in the horizontal section. When the concrete stops flowing, the heights of concrete in vertical section (H1) and in the horizontal section (H2) were measured. The ratio of the height H2/H1 was calculated and noted.

3.5 Compressive strength test:

The test specimens of size 150mm X 150mm X 150mm were cast. Compression tests were made at recognized ages of the test specimens, the most usual being 7 and 28 days. At least three specimens, preferably from different batches, were made for testing at each selected age. Specimens after casting were allowed in the mould for about 24 hours and removed from mould and stored in water for curing. After the selected age the cubes were removed from water and allowed to dry and then tested. The cube was placed in the machine in such a manner that the load was applied to opposite sides of the cubes as cast. The load was applied at constant rate of approximately 140 kg/cm^2/min until the specimen failed. The maximum load applied to the specimen until failure, was recorded. The compressive strength of concrete was measured in tones and denoted in N / mm^2.

The compressive strength of the concrete cube = Maximum load at failure/ area of concrete cube

3.6 Split tensile strength:

The cylindrical specimens of dimension, 150mm diameter and 300mm long were cast. The test was made at specific ages, most usual being 7 and 28 days. Specimens were removed from mould after 24 hours and placed in water for curing. After specific age the specimens were removed from water and dried before testing. One of the plywood strips was centered along the center of the lower plate of the testing machine. The specimen was placed horizontally on the plywood strip with its axis perpendicular to the loading direction. The second plywood strip was then placed lengthwise on the cylinder centrally. The load was then applied at a rate to produce approximately a splitting tensile stress of 14 to 21 $kg/cm^2/min$ until failure occurred. The maximum load applied to the specimen was noted in N / mm^2.

The splitting tensile strength of concrete cylinder = 2P/3.14LD

4.0 Results and Discussion:

In this study, fresh and hardened properties of self-compacting concrete were investigated by using different mix proportions of marble powder and fly ash.

4.1 Fresh properties:

The main requirements for a concrete to be self-compacting are filling and passing abilities. Also segregation resistance must be fulfilled in order to provide ease of flow. The increase in values of fresh properties with the increase in marble powder is due to its pore-filling effect (4). Because of this filling effect there is good spacing between the aggregates which in turn increases the workability (5). Due to the partial replacement of cement with fly ash, there is an increase in the paste volume because of its lower density which in turn reduces the friction between aggregates and improves workability (6). According to EFNARC guidelines, the minimum values of all the fresh property tests are given in the table 3 and also it should occur without any segregation of coarse aggregates. In slump flow test, the flow must be uniform with a diameter of at least 650mm. If the water content is more, then segregation of coarse aggregates occur which get accumulated at the centre. The flow ability and stability of self-compacting concrete was assessed by performing V-funnel test. The inverted cone shape of V-funnel restricts flow and the time taken for complete flow is given in table 3 for different mix proportion of marble powder. The increase in coarse aggregate content increases the flow time. L-box ratio indicates the passing and filling ability of self-compacting concrete. If the ratio is below 0.8 there is a risk of blocking of concrete (6). U-box test is used to assess the self-compactability of the concrete. If the concrete flows as free as water then the difference in height H_1-H_2 will be zero.

Table 3: Fresh property test values with different mix proportion of Marble powder.

Test Method	Recommended values(Based on the values given by Okamura and Ozawa)	SCC0	SCC1	SCC2
Slump flow	650-800mm Average flow diameter	677mm	690mm	704mm
V-funnel	6-12 sec Time for emptying of funnel	12secs	10secs	8.5secs
U-box	0-30mm Difference in heights in two limbs	27mm	20mm	13mm
L-box	0.8-1.0 Ratio of heights at beginning and end of flow	0.902	0.915	0.923

4.2 Hardened properties:

The compressive and split tensile strength values are provided in table 4. When compared to the control mix increasing amount of marble powder decreases the strength. But, differences of compressive strength and split tensile strength between control specimen and specimens containing 10% Marble powder were not too much. With the increase in marble powder content the average capillary pore size of concrete was higher due to increase in specific surface area of fine materials and because of this higher capillarity coefficient compressive and split tensile strength tends to decrease (4). Therefore, the maximum and optimum usage amount of marble powder that can be replaced with cement is 10%.

Table 4: Hardened properties test values of different mix proportion of Marble powder

Mix proportion	Compressive strength		Split tensile strength (MPa)
	7 days (MPa)	28 days (MPa)	
SCC0	21.36	32.35	3.38
SCC1	20.58	30.48	3.23
SCC2	17.88	27.34	3.02

5.0 Conclusion:

Based on the investigation reported on this study, the following conclusions can be drawn:

1. All the self-commpacting concrete mixes had a satisfactory performance in the fresh state. Also it satisfies the criteria given in EFNARC.
2. In general the use of mineral admixture improved the performance of SCC in fresh state and also reduced the superplasticizer content.
3. The use of marble powder and fly ash has no negative efffect on workability of self-compacting concrete.
4. Also it may prove eco-friendly because it controls the production of cement.
5. In hardened property test values, compressive strength decreased by 5.78% and split tensile strength decreased by 4.43%. But both the values lies within the limit for 10% replacement of cement with marble powder.
6. Therefore, 10% replacement of cement with marble powder produces satisfactory results.

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