

Study on Marble Dust as Partial Replacement of Cement in Polyvinyl Alcohol Fiber Reinforced Engineered Cementitious Composite

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ABSTRACT: Concrete is good in compression, but when any type of tensile strain is applied on it, it starts to fail. To withstand the tensile stress on the concrete, good condition steel bar is used as reinforcement. It will take up the tensile stress up to its elastic limits. On the other hand, there are various other projects dealing with reinforcing the concrete with different materials instead of using a conventional steel rebar. Among them a notable one is the Engineered Cementitious Composites where fibers are used for reinforcing the concrete and no coarse aggregate will be used, in the view of formation of cracks of larger width. Ductile property of normal concrete can be improved by using Polyvinyl Alcohol fibres in place of coarse aggregate. This project is about an experimental study on the behaviour of Engineered Cementitious Composites, reinforced with Polyvinyl Alcohol Fibers at an optimum percentage of 1% by weight of the Cement content, when the cement content is partially replaced by various proportions of marble dust. Marble dust powder obtained from Marble Industries contains high calcium oxide content of more than 50% by weight. Marble dust can be an ideal choice for substituting in a cementitious binder. For this purpose, studies which involved in experimental investigation of ECC cubes, cylinder and prisms were taken and gone through thoroughly. This project involves analysis of ECC beam model using the results from some recognized International journals.

KEYWORDS: ECC, PVA Fibers, Bendable Concrete, Self-healing property, Micro-cracks, Ductile concrete.

I. INTRODUCTION

Conventional Concrete consisting of cement, water, fine and coarse aggregates is widely used in civil engineering constructions. But its brittle behaviour upon tensile loading is one of its undesirable characteristics and thus leads to the development of fibre reinforced cementitious composites to improve this deficient. On the other hand, development of cracks due to concrete shrinkage, excessive loading, severe environment and poor construction procedure or design error are unavoidable during the lifespan of concrete. Durability of the concrete is greatly affected by development of cracks, and these cracks create pathway to harmful agents to penetrate into the concrete and this can deteriorate the reinforcement in the concrete. Experimental investigation and practical experience have demonstrated that micro-cracks in cementitious material have the ability to seal themselves. To improve the ductility of conventional concrete and to impart self-healing nature to cement matrix, one such material used is "Engineered Cementitious Composite (ECC)". In ECC there is no coarse aggregate used and instead PVA fibers are used in order to reduce the crack width drastically to the order of micro size and hence more cement content is required to bring the self-healing nature matrix. Due to the increase in use of cement content, ECC is not considered as cost efficient one. To overcome this problem, cement content could probably be replaced with some other material which itself has some binding property by virtue and low of cost. One such material with more lime content is Marble and it is industrially processed by being cut, polished, and used for decorative purpose. During the cutting process, 20-30% of a marble block becomes waste marble powder. Since Marble waste leads to a serious environmental problem as well, the use of waste marble in the concrete production as an admixture material or aggregate has no harm to be considered as an alternative for cement. In the present study, effect of different proportions of waste marble on the hardened ECC properties was investigated based on previous studies.

II. OBJECTIVES

- To examine the properties of 1% PVA Engineered Cementitious Composite.
- To examine the properties of 1% PVA ECC with cement replaced by Marble dust (i.e. 5%, 10%, 15%, 20%, 25%, 30%).
- To analyse the variations in different strength parameters of 1% PVA ECC with different Marble dust proportions and find optimum marble content, at different ages (i.e. 7, 14, 28days).

III. CONSTITUENT MATERIALS AND ITS PROPERTIES

1. Ordinary Portland Cement: Ordinary Portland Cement of 43 grade was tested and used for the mortar mix. The physical properties test of the cement, such as Consistency (33%), Initial Setting Time (30 minutes), Final Setting Time (270 minutes), Fineness (4%), Soundness(3mm) and Specific Gravity (3.12), were done in accordance to the procedure laid in IS 8112:1989.

2. Fine Aggregates: The locally available M - sand was used as fine aggregate in cement mortar conforming to grading zone II as per IS: 383-2016. The sand was sieved in 4.75 mm sieve to remove deleterious material and then used. The physical properties which the M-sand was tested for are Specific Gravity (2.62), Loose Bulk Density (1510.288 kg/m³),

Dense Bulk Density (1788.075kg/m³), Fineness Modulus (3.61) and Water Absorption (2.4%).

3. Polyvinyl Alcohol Fiber (PVA): Polyvinyl Alcohol fiber is added to the concrete during batching. Thousands of individual fibers are then evenly dispersed throughout the concrete during the mixing process creating a matrix-like structure. Polyvinyl Alcohol fibers possess similar characteristics as that of reinforcing materials. Collected from a Company called Star India Textile based in Rajasthan. Length, Aspect Ratio and Young's Modulus of the fiber is 12mm, 120 and 19-21 GPa respectively.

4. Marble Dust Powder: Marble Dust is added to the concrete mix as a filler material and to reduce the cement content thereby reducing the environmental impact of dumping the waste marble dust and also it makes the composite more economic by the reduction of Cement Content. As it contains 45% Calcium Oxide, it is actually a good binding material also. Marble dust powder was bought from a Chemical company based in Chennai called Astrra Chemicals. The standard properties such as Moisture content (4.5%), Specific Gravity (2.4) and Loose Bulk Density (1100 kg/m³) were issued by the company.

5. Water: Water is a crucial and important ingredient of the concrete as it actively participates in the chemical reaction with cement and results in hardening of the concrete. Potable water was used for mixing the alkaline activators. Water used in this study confirmed to the requirements of IS 456:2000.

IV. EXPERIMENTAL INVESTIGATION

1. **Compression test (conforming to IS 516):** This test was performed on 100 mm x 100 mm x 100 mm sized PVA ECC concrete cubes casted to determine the compressive strength of the mix. This test was performed on normal 1% Polyvinyl Alcohol fibre reinforced ECC specimens and PVA ECC in which cement is replaced partially with Marble dust. The percentage of Marble dust were varied from 0 to 30%, by weight of cement, with an interval of 5%. The compression test on cube specimens was performed in the compression testing machine.
2. **Split tensile test (conforming to IS 5816-1999):** To determine the tensile strength of PVA ECC concrete mix, split tensile test was carried out on the standard cylindrical test specimens of 100mm x 200mm using the compression testing machine. This method of testing involves in applying a diametric compressive force along the length of a cylindrical specimen.
3. **Flexure test (conforming to IS 516):** Flexural strength of a PVA ECC concrete is a measure of its ability to resist bending (i.e.) Flexure. Flexural strength can be expressed in terms of "Modulus of Rupture". Concrete specimens having 100 mm x 100 mm cross section and 500 mm length are prepared for flexural test. They were supported on two rollers in the flexure testing machine. The specimens were placed on the supports such as the distance between the rollers equals to 390 mm. The specimen was subjected to bending, using Four-point loading until it fails. Four-Point loading setup was achieved by maintaining a distance, equal to one-third of span between the two roller supports, in-between the roller on one side and its nearest loading point & in-between the two loading points itself. Purpose of testing the specimen using Four-Point loading was to remove shear failure from the equation.

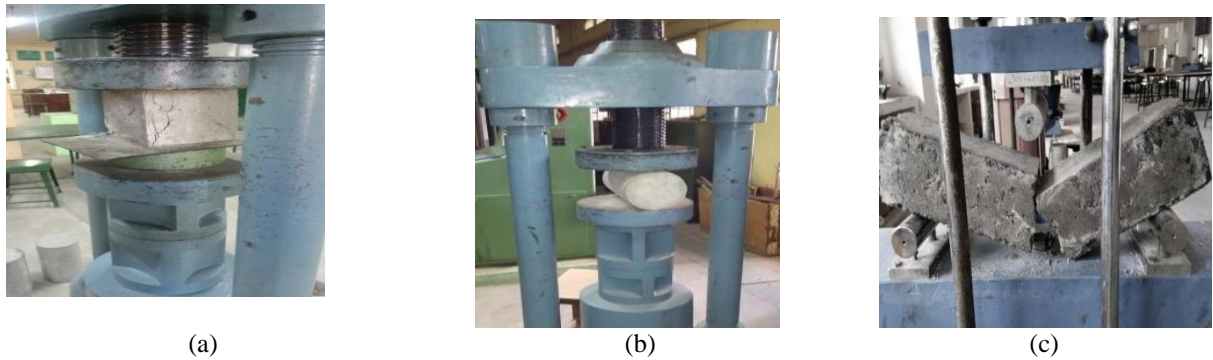


Fig.1 Testing of Mechanical Properties (a) Compressive Strength Test (b) Split-Tensile Test (c) Flexural Strength Test

V. RESULTS AND DISCUSSIONS

1. Compressive Strength

Table below shows the Compressive Strength values of 1% PVA ECC with increasing proportions of marble dust from left to right with an interval of 5% by weight of cement at the ages of 7 Days, 14 Days and 28 Days. The graph plotted with Mix along X-Axis and Compressive Strength along Y-Axis as shown below, the Compressive strength increases almost gradually up to 10% Marble replacement and decreases gradually from 10% to 20%. But above 20% the strength value reduces drastically and appears to be a sudden drop in the curve. Hence we can come to an inference that replacement of cement by marble dust in ECC above 20% produces deteriorating effect due to reduction in Binder to Filler ratio which is due to the fact that Marble dust only contains 45-50% Lime content in it, which acts as binder and remaining materials is just a filler material.

Table 1 Compressive Strength of 1% PVA ECC

Compressive Strength (MPa)	ECC1 - M0	ECC1 - M5	ECC1 - M10	ECC1 - M15	ECC1 - M20	ECC1 - M25	ECC1 - M30
7 Days	18.7	22.45	27.25	25.06	21	13.224	8.703
14 Days	22.4	29.4	35.2	29.6	24.4	16.3	11.9
28 Days	27.0	38.7	43.2	38.9	31.8	20.6	14.6

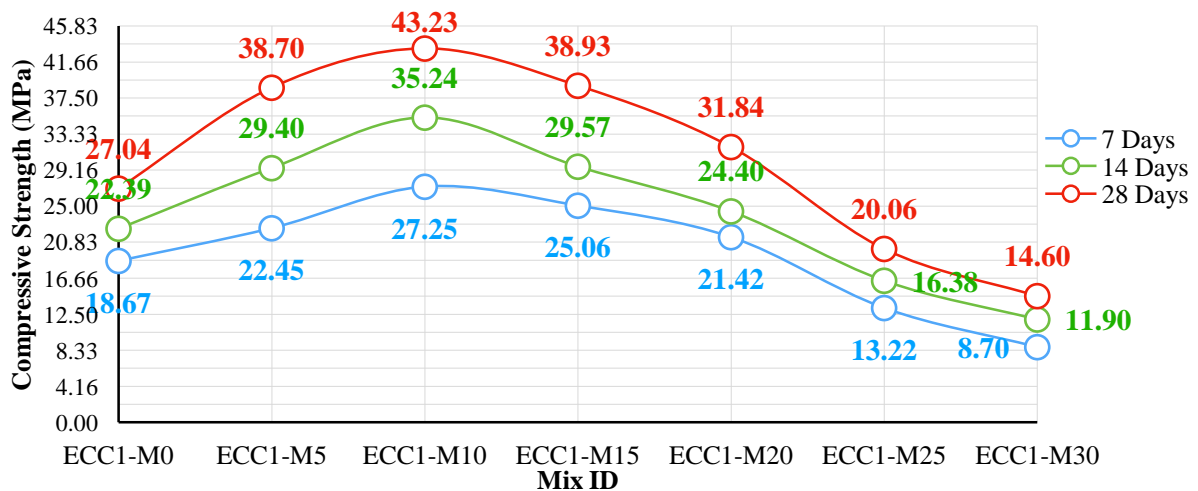


Fig. 2 Graph of Mix ID Vs Compressive Strength of 1% PVA ECC



2. Split Tensile Strength

Table below shows the Split-Tensile Strength values of 1% PVA ECC with increasing proportions of marble dust from left to right with an interval of 5% by weight of cement at the ages of 7 Days, 14 Days and 28 Days. The failure of ECC specimen in Split-Tensile test is along the diameter of the cylinder showing that the specimen failure is due to direct tension along the longitudinal axis. The graph plotted with Mix along X-Axis and Split-Tensile Strength along Y-Axis as shown below, the Split-Tensile strength increases with a low gradient up to 10% Marble replacement and decreases with a higher gradient value from 10% to 20%. But above 20% the strength value reduces drastically and appears to be a sudden drop in the curve as in the case of Compressive strength. Hence replacement of cement by marble dust in ECC above 20% is not at all recommended.

Table 2 Split Tensile Strength of 1% PVA ECC

Split-Tensile Strength (MPa)	ECC1 - M0	ECC1 - M5	ECC1 - M10	ECC1 - M15	ECC1 - M20	ECC1 - M25	ECC1 - M30
7 Days	1.17	1.249	1.404	1.034	0.934	0.776	0.619
14 Days	1.32	1.46	1.60	1.25	1.04	0.85	0.66
28 Days	1.52	1.62	1.78	1.49	1.31	0.97	0.73

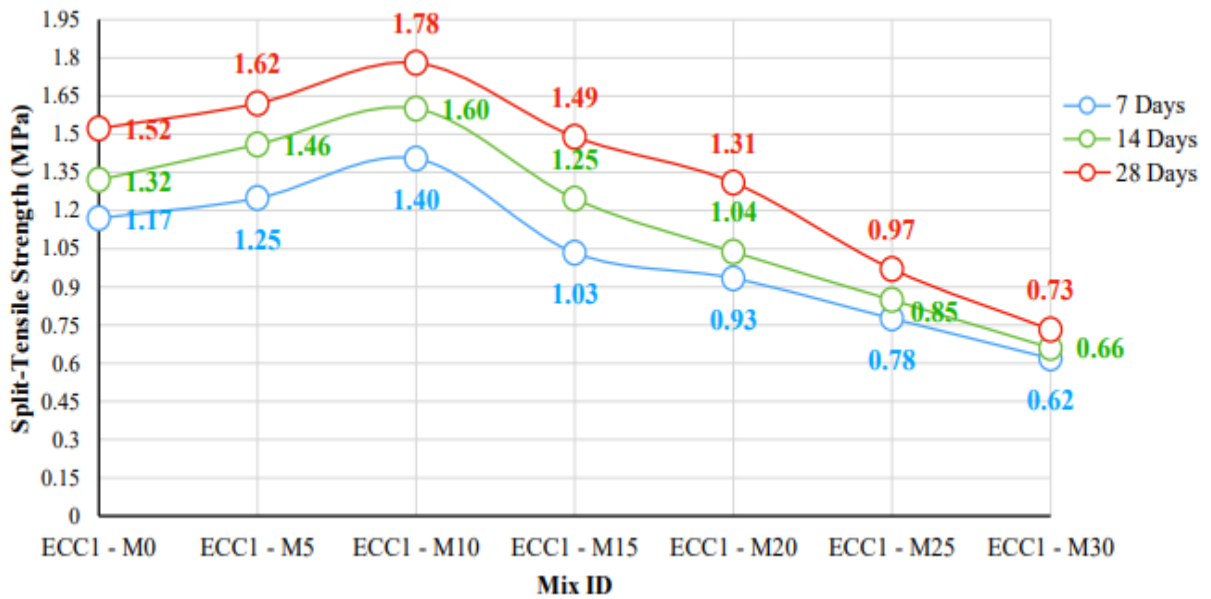


Fig. 3 Graph of Mix ID Vs Split Tensile Strength of 1% PVA ECC

3. Flexural Strength Table below shows the Flexural Strength values of 1% PVA ECC with increasing proportions of marble dust from left to right with an interval of 5% by weight of cement at the ages of 7 Days, 14 Days and 28 Days. The failure in the four-point flexural strength test is in-between the two Point Loads, that shows that the failure is only due to flexure as there is no shear in-between the two point loads. The graph plotted with Mix along X-Axis and Compressive Strength along Y-Axis as shown below, the Compressive strength increases to a minimal extent up to 10% Marble replacement and decreases with a higher gradient from 10% to 25%. But above 25% the strength value reduces drastically and appears to be a sudden drop in the curve. Hence we can come to an inference that replacement of cement by marble dust in ECC above 25% produces deteriorating effect in the aspect of Flexural strength.

Table 3 Flexural Strength of 1% PVA ECC

Flexural Strength (MPa)	ECC1 - M0	ECC1 - M5	ECC1 - M10	ECC1 - M15	ECC1 - M20	ECC1 - M25	ECC1 - M30
7 Days	2.188	2.497	2.731	2.386	2.141	1.962	1.472
14 Days	2.320	2.675	2.945	2.548	2.266	2.060	1.496
28 Days	2.418	2.801	3.091	2.664	2.360	2.139	1.532

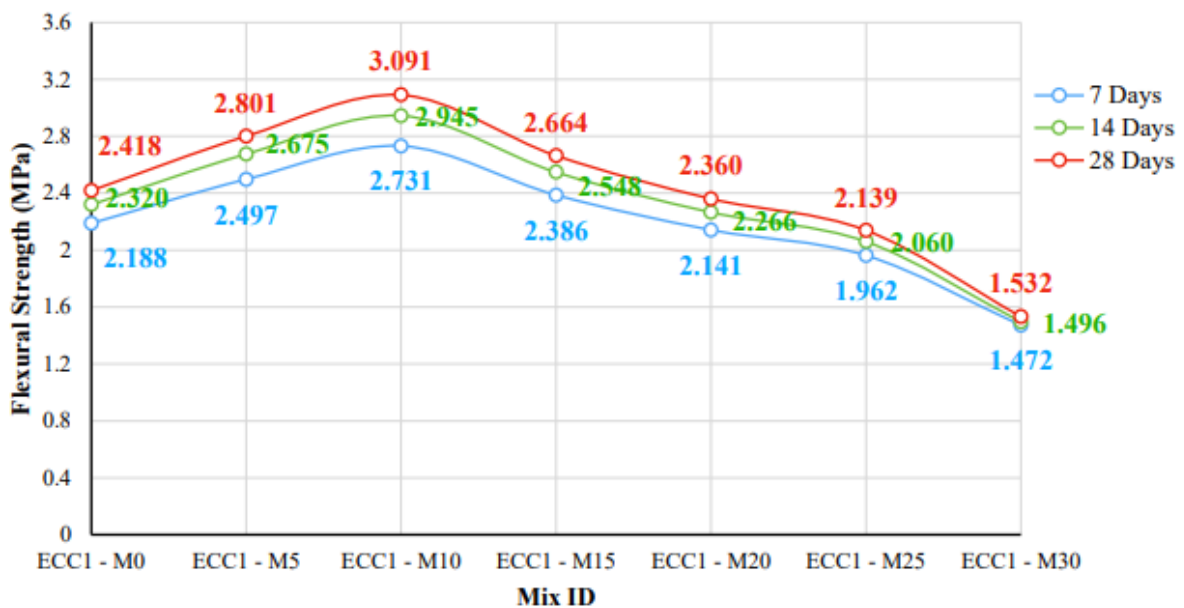


Fig. 4 Graph of Mix ID Vs Flexural Strength of 1% PVA ECC

VI. CONCLUSION

- Compressive Strength curve attains its peak value at 10% Marble dust in PVA ECC. Split-Tensile and Flexural Strength curve too has its peak value at 10% Marble dust replacement.
- Hence 1% Polyvinyl Alcohol Engineered Cementitious Composite with 10% of cement content, by weight, replaced by Marble dust powder is the Optimum Mix in all aspects of strength.
- The gradient of the rising part of the Compressive strength curve is considerably steep till it meets its peak point. This implies that replacing cement with marble dust imparts some additional binding character and increases the compressive strength of ECC by a notable amount.
- The gradients of the rising part of the Split-Tensile strength and Flexural Strength curve are both gradual and not so steep as Compressive Strength curve. But the falling part of the curves has higher gradients than the rising parts of the corresponding curves. This implies that replacement of cement with Marble dust beyond certain extent (>10%) reduces the strength of ECC.
- In the case of Flexural Strength, the curves of 7, 14 & 28 days' strength almost end at the same point (i.e. difference between the end values is very small). This shows that the Flexural strength of ECC with Marble Dust not only declines with the increase in proportion of marble dust but also with the increase in Age of the specimen too. This could be probably due to the deteriorating effect produced by some of the filler

materials present in the marble dust other than that of Lime.

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