



AN EXPERIMENTAL STUDY ON PROPERTIES OF WOLLASTONITE CEMENT CONCRETE – A MODEL STUDY

Engineering

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ABSTRACT

Concrete is the most important constructing material in the world prepared with a combination of cement, aggregates and required amount of water, the bond between these three materials will be formed due to the characteristic feature of cement which makes them to hold tightly each other, at the beginning of immediate preparation it is named as fresh concrete which can be used based on the need and requirement, after the hydration properties of cement is completed it becomes hardened and makes bond strong called as hardened concrete the main role of cement in the concrete is for producing strength and durability. For manufacturing cement at huge quantities to meet the need and requirement as part of basic needs and developmental activities it invites large scale environmental degradation in the society, as the studies reveals that for producing one ton of Portland cement it releases about one ton of carbon-di-oxide gas into the atmosphere, at the other side due to the rapid developmental activities the cost of manufacturing cement keep on increasing. To overcome this scenario the alternative material is highly essential by keeping this in view this study is initiated as a pilot study by partial replacement of cement with wollastonite material in concrete to bring down the cement consumption, environmental degradation as well as cost expenditure of cement to promote sustainable development in the field of construction technology.

KEYWORDS

Concrete, Constructing Material, Wollastonite, Alternative Material, Construction Technology.

1. INTRODUCTION

The wollastonite is majorly used in the ceramic industries as an a principle ingredient to manufacture floor and wall tiles, these are white in color and these fibers are very fine having the aspect ratio ranges from 3:1 to 20:1, with an average length between 0.4-0.6 mm and the diameter is 25-150µm. these are also used in many synthetic and ceramic products as they are inert, and its fibres are cheaper than carbon or steel micro-fibres. These are the most efficient materials to be used for enhancing high performance repair cement composites. They are relatively cheap when compared with steel or other carbon micro-fibres which are highly cost effective. Along with these the major advantage of adding the wollastonite micro fibres is they increases the durability of concrete with reduced permeability by influencing the pore structure of cement based composite materials. The chemical composition of wollastonite fibres is 90% of CaO, SiO₂, 1% of K₂O, Fe₂O₃, MgO, and Al₂O₃ along with the traces of titanium dioxide and manganese oxide. The wollastonite fibres are characterised in non uniform size which are similar to ordinary Portland cement with loose acicular particles having varying range in modulus of elasticity about 300–530 GPa, with and tensile strength at a range of 2700 and 4100 MPa. They can be used as a best alternative to asbestos materials. The pure wollastonite is highly considered as it is thermally and chemically resistant.

2. OBJECTIVES OF THE STUDY

The objectives of present study are

- To determine performance of wollastonite and fly-ash in cement concrete by determining their compressive strength, tensile strength, bond strength, Acid attack, Alkali attack and Rapid Chloride Penetration Test (RCPT)
- The results are correlated and presented in terms of their strength and durability.

3. METHODOLOGY

In the present experimental analysis, investigation has done on the development, fresh and hardened properties of Concrete by adopting standard procedures. The total study was carried out in three phases and they are as follows

- Procurement of materials and conducting tests to find out their properties.
- Preparations of wollastonite cement concrete to examine their fresh and hardened properties.
- Specimen casting and durability tests to find their strength.

3.1 Procedure for Mix Design:

- Estimate the mean target strength f_t from the specified characteristic compressive strength at 28-day f_{ck} and the level of quality control.

$$f_t = f_{ck} + 1.65 S$$

Where S is the standard deviation obtained from the Table of approximate contents given after the design mix.

- By using empirical relationship between compressive strength and water cement ratio the desired mean target of water cement ratio will be find and checked against the limiting water cement ratio for the durability requirement given in the table and consider the two lower values.
- From the table the amount of entrapped air for normal aggregate size will be estimated
- Estimation of required water for required workability from the table
- Estimation of required fine aggregate in total aggregate
- There should be adjustment in the values of water content and the provided sand percentage in the table by considering the differences observed in workability and water cement ratio
- From the water cement ratio and final water content after the adjustment the cement content will be calculated for estimating the durability
- From the quantities of cement per unit volume of concrete the required sand which is determined in the above steps the content of coarse and fine aggregate per unit volume of concrete will be calculated with following formula

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p} \frac{f_a}{S_{fa}} \right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p} \frac{C_a}{S_{ca}} \right] \times \frac{1}{1000}$$

Where:

V = absolute volume of concrete = gross volume (1m³) minus the volume of Entrapped air

S_c = specific gravity of cement

W = Mass of water per cubic metre of concrete, kg

C = mass of cement per cubic metre of concrete, kg

p = ratio of fine aggregate to total aggregate by absolute volume

f_s, C_a = total masses of fine and coarse aggregates, per cubic metre of concrete

S_{s_a}, S_{c_a} = specific gravities of saturated surface dry fine and coarse aggregates

9. The concrete mix proportions will be determined for trial mix
10. The prepared concrete at required portions will be casted in three blocks of 150mm size and then they will be cured for 28 days and then they will be checked to estimate the strength
11. To reach the final mix proportions trial mixes will be prepared with suitable adjustments

4. RESULTS AND DISCUSSIONS

4.1 Mix Quantities

The mix proportions from Nan-su method are applied for this study and quantities of various materials of 5 different mixes are taken as pilot study and they are given in the below table. For this study the American Concrete Institute Method ACT 211.4RACI was selected for Mix design which states the relationship between compressive strength and water cement ratio.

4.2 Mortar mix

Mortar mixes were observed to assess the feasibility of Wollastonite with cement and super plasticizer, the strength is estimated as per the IS-4031 (Part 6) – 1988 The mix proportion used are given in Table 1 .

Table 1: Mix proportion for Mortar

Mix ID	Cement (g)	Wollastonite (g)	Sand (g)	Sp (ml)	Water (gm)
0% W	2000	0	6000	50	800
5% W	1850	150	6000	50	850
10% W	1800	200	6000	50	750
15% W	1700	300	6000	50	750
20% W	1650	350	6000	50	700

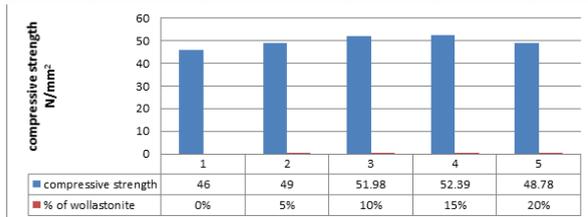


Fig.1: 28 days Compressive Strength of Mortar Cubes

The wollastonite used in the mortar is compatible with the cement and SP, which are used for the present study. The cement mortar strength is found as 49 MPa, and at 5% replacement there is no big difference but when increased to 10%, 15% and 20% replacement levels of cement respectively. The highest strength is noted at replacement of 15% and it gradually decreased at 20%.

4.3 Studies on Concrete

The concretes are tested as two sets. The first set is estimation of concrete by replacing cement with 5, 10, 15% & 20% wollastonite and in the second set cement was replaced with Fly ash and Wollastonite simultaneously. All the replacements mentioned above were done in a normal concrete for M60 grade. The coarse aggregate and fine aggregate contents were maintained to be 1200 kg/m³ and 725 kg/m³. The water content was 160 kg/m³ and the SP content was 4.75 kg/m³. The proportions of cement and mineral admixtures are as listed in Table.

Table: 2 Proportions of cement and mineral admixtures

Mix ID	Cement (kg/m ³)	Wollastonite		Fly ash	
		%	Weight (kg/m ³)	%	Weight (kg/m ³)
M1	390	0	0	0	0
M2	375	5	20	0	0
M3	350	10	39	0	0
M4	330	15	59	0	0
M5	320	10	39	10	35
M6	300	10	39	15	55

4.3.1 Compressive strength results

The concrete mixes are prepared in such a way that the cement was replaced partially with 5, 10, 15 and 20% wollastonite. And Fly ash was included in the mix which corresponded to 15% wollastonite replacement as it yielded the highest strength and gradually decreased at 20% in mortar tests. The compressive strengths of all these cubes are estimated at the end of 7, 28 and 56 days. The concretes with 15% wollastonite yielded the highest strength and gradually decreased at 20% and the mixes with fly ash resulted in relatively lower strengths which are still above 50MPa. The increase in the compressive strength could be attributed to the fibrous nature of wollastonite.

Table3: Values of Compressive strength

Mix ID	Compressive strength (N/mm ³)		
	7 days	28 days	56 days
M1	47.19	61.44	64.84
M2	43	53.12	64.7
M3	44.18	63.22	64.83
M4	40	53.78	60
M5	44.72	52.11	57
M6	40	53.82	57.72

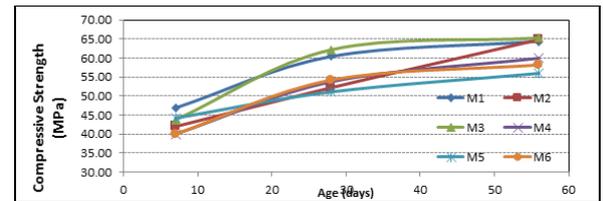


Fig2: Variation of Compressive Strength with age

4.3.2 Split Tensile Strength

The variation in split tensile strength is measured at the end of 7 days and 28 days curing. The split tensile strength of the concretes was found to increase with the addition of wollastonite in concrete. Adding of Fly ash in wollastonite concrete reduced the tensile strength when compared to the concrete with only wollastonite, but it is performed efficient when compared to normal concrete.

Table4: Split tensile strength values

Mix ID	Split tensile strength (N/mm ²)	
	7 days	28 days
M1	2.32	3.5
M2	2.7	3.69
M3	2.73	3.47
M4	2.57	3.99
M5	2.32	2.9
M6	2.3	3.24

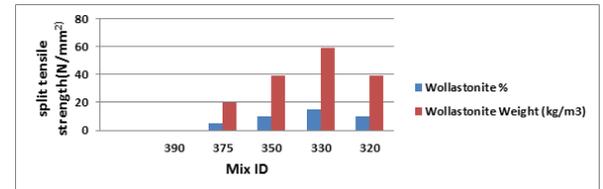


Fig3: Split Tensile Strength Variation

4.3.3 Bond Strength Evaluation

The bond stress was evaluated by keeping a 16mm diameter bar in a 150mm cube at the center. The bond strength is obtained by out by pull out test which is shown in Figure 4, it was observed that the bond strength is improved when the wollastonite is added it is also found that the concretes with fly ash and wollastonite showed improvement when compared to Normal concrete

Table 5: Values of Bond strength

Mix ID	Bond strength28 days(N/mm ²)
M1	9.67
M2	11.49
M3	13.97
M4	13.68
M5	11.62
M6	14.07

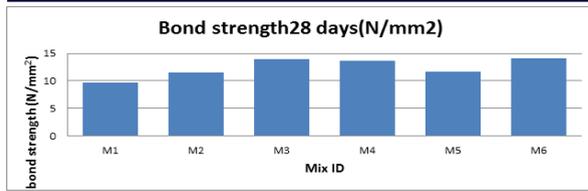


Fig.4: Differentiation in Bond Strength

4.3.4 Acid & Alkali Attack

The concrete specimens were exposed with acid (5N H₂SO₄) and Alkali (5% NaOH). The loss of weight and strength due to exposure has shown in the figures 5 & 6 respectively. The efficiency of wollastonite and fly-ash wollastonite concretes looks to be of great significance as the reduction in weight and strength is very low due to the addition of mineral admixtures and the performance of fly ash -wollastonite concretes seems to more effective than the binary concretes with wollastonite.

Table 6: Values of acid attack test

Mix	Acid attack (5% H ₂ SO ₄ Solution)	
	% Weight (Loss) after 28 days	% Strength (Loss) after 28 days
M1	0.34	68
M2	0.3	44
M3	0.29	52
M4	0.24	51
M5	0.34	53
M6	0.37	54

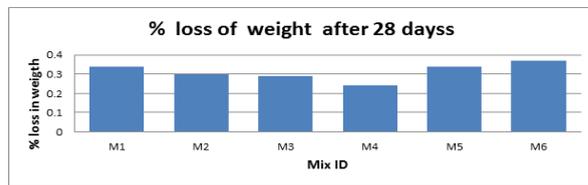


Fig.5 Results of concretes exposed to Acid Attack %Loss in Weight

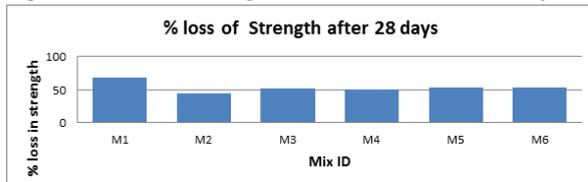


Fig.6 Results of concretes exposed to Acid Attack Loss in strength

Table7: Values of alkali attack test

Mix	Alkali attack (3N NaOH Solution)	
	% Weight (Gain) after 28 days	% Strength (Loss) after 28 days
M1	2.35	44
M2	2.12	10
M3	1.16	5
M4	0.63	12
M5	0.51	14
M6	0.41	9

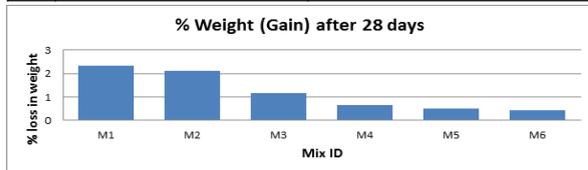


Fig.7 Results of concretes exposed to alkali attack % of Loss in Weight

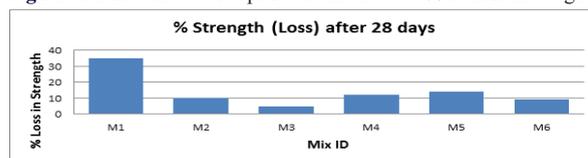


Fig.8 Results of concretes exposed to alkali attack % of Loss in strength.

Conclusions:

The present study reveals that addition of wollastonite enhances the bond strength which is noticed as 14.07 Mpa. The replacement with fly ash-wollastonite system proved that there is a increase in the strength when compared to the concrete where the cement was replaced with Wollastonite. As it is designed for High strength concrete of 60Mpa, when compared with OPC in 28days, the wollastonite concrete has given higher strength of 63.22 Mpa. It has given effective bonding with cement and water which is noted as 14.07 Mpa. The compressive strength is noted as maximum when the 15% of cement is replaced with wollastonite, the same pattern is noticed for split tensile and bond strength also.

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