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Mechanical Behavior of High-Volume Fly Ash Concrete

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Abstract: Experimental studies on use of High Volume Fly ash Concrete inclusion of Calcium Carbonate particles to improve the mechanical behavior in concrete with M 40 grade. The testing specimens are casted and tested as per IS specifications for 7, 14, 28, 56 and 90 days, cubes of 150mm. an attempt has been made in order to reduce the Carbon dioxide percentage in the atmosphere by adding fly ash and calcium carbonate in concrete. $Caco_3$ acts as a filler material and also it binds the concrete matrix. The experimental studies shows that there is a significant improvement in compressive strength when fly ash and $Caco_3$ is added as a replacement for cement

Key words: Calcium Carbonate ($CaCo_3$), High Volume Fly ash (HVFA), SEM

1. INTRODUCTION

The cement industry has a significant role in the emission of carbon dioxide, the majority of this emission is due to the heating of limestone during the calcination process. Portland cement reacts with water and binds natural rocks as aggregates to form concrete. Since the invention of Portland cement, it has become an indispensable material for buildings and civil infrastructures, and it is now the cornerstone of modern society. Fly ash is the most abundant of all siliceous materials available throughout the world. Only a very small proportion of this available fly ash is used in concrete construction. The aim of this project is to explore the possibilities of extending the level of cement replacement to much higher amounts so that a much higher proportion of the available fly ash can be utilised in construction. Reduction in the volume of large pores was observed with the progress of the pozzolanic reaction. Higher HVFA concrete strength was generally associated with a lower volume of large pores in the concrete. A decrease in the levels of calcium hydroxide was seen with progressive water curing and age in all the HVFA concretes, providing evidence of continued pozzolanic reactivity of the fly ashes. The studies of new sustainable materials which can decrease and replace the amount of cement in the production of concrete. This type of concrete has been increasingly used worldwide in order to evaluate its behaviour in different application areas. There are two major factors which influence the properties of fly ash

concrete- its intrinsic variation in chemical and mineralogical composition, and the philosophy of mix proportioning adopted to produce the concrete incorporating fly ash.

1. LITERATURE REVIEW

Portland cement was replaced with three percentages (40%, 45%, and 50%) of Class F fly ash. [1] Test results indicated that the use of high volumes of Class F fly ash as a partial replacement of cement in concrete decreased its 28-day compressive, splitting tensile strength and flexural strengths of the concrete. Based on the test results, it was concluded that Class F fly ash can be suitably used up to 50% level of cement replacement in concrete for use in precast elements and reinforced cement concrete construction. [2] Cement is replaced by FA at various levels (0%–55%) to its weight. significant effect on compressive strength and splitting tensile strength of all concrete mixes at all curing periods was observed. It is concluded that 55% FA blended mix attained the desired 28 days strength of M 25 grade of CC with 0.25% NAD dosage and can be considered as M 25 grade of FA blended concrete. [3] The validation of reactive transport models requires the understanding and quantification of the chloride sorption by C-S-H, use of SEM-EDX to quantify the chloride sorption in hydrated C_3S paste. The chloride sorption is weakly linked to the calcium concentration in the solution [4] the effect of Calcium Carbonate Filler was studied on the compressive strength and the workability of self-compacting Concrete (SCC) at different grades (M60, M65 and M70) Calcium Carbonate Filler were added in percentages of 2.5% and 5% to check its effect on the workability and strength properties. The use of Calcium Carbonate Filler improved the strength and densities for SCC design mix and decreased its workability. [5] The effect of incorporating two types of micro particles micro CaCO3 and micro SiO2 on mechanical properties and durability of concrete. Micro materials were added in four different dosages of 1%, 2%, 3% and 4% by weight as partial replacement of cement in concrete mixture. The results showed that incorporation of micro CaCO3 and micro SiO2 particles lead to increase the packing and enhance the mechanical properties and durability of concrete. A significant performance was observed in case of micro silica addition to the concrete in comparing with other micro particles.

2. RESEARCH SIGNIFICANCE

The research work signifies the investigation of High volume fly ash concrete incorporated along with calcium carbonate particles in cement to obtain maximum desired strength to be used in different actual practices, the main objective of the present study is to check the hardened properties of HVFA concrete such as compressive strength at normal temperature and also to examine the morphology using Scanning electron microscope (SEM) analysis, and EDAX performed for Mix 1, Mix 2, and Mix 3 under consideration.

3. MATERIALS

In this present investigation Ordinary Portland Cement (OPC- 53 Grade) Birla Super cement, Manufactured sand (M-Sand) passes through a 4.75 mm sieve (zone II), High Volume Fly ash (HVFA) (0.5 micros to 100 microns), Calcium Carbonate micro particles (pH 9to 10 and water (ordinary potable water) are used with HVFA concrete.

4. TEST SPECIMENS

For the experimental program three different mixes with series testing specimen Cubes consists of (150 mm), with concrete grade M 40. Further to study the surface morphology of the concrete. The final mixes used in the main experimental program are as follows

MIX 1 = (Cement 100% + M Sand 100% + Coarse Aggregate 100%)

MIX 2 = (Cement 50% + M Sand 100% + Coarse Aggregate 100% + Fly ash 50%)

MIX 3= (Cement 50% + M Sand 100% + Coarse Aggregate 100% + Fly ash 44% + $Caco_3$ 6%)

5. TEST PROGRAM

Mechanics qualities are determined by experimental research for HVFA concrete mixes namely Mix1 (Control Mix), Mix2, and Mix3 for Compressive Strength for 7, 14, 28, 56 and 90 days and the results are tabulated.

6. RESULTS AND DISCUSSIONS

Hardened properties of M 40 grade concrete Compressive Strength

Table 1 Average Compressive Strength of Mix 1

M40 GRADE CONVENTIONAL CONCRETE					
Age in Days	**No. of Samples**	**Load (kN)**	**Area (mm^2)**	**Compression Strength (N/mm^2)**	**Average Compression Strength (N/mm^2)**
7 days	1	750.00	22.5	33.33	32.81
	2	725.00	22.5	32.22	
	3	740.00	22.5	32.89	
14 days	1	900.00	22.5	40.00	41.04
	2	950.00	22.5	42.22	
	3	920.00	22.5	40.89	
28 days	1	1110.00	22.5	49.33	48.74
	2	1085.00	22.5	48.22	
	3	1095.00	22.5	48.67	
56 days	1	1090.00	22.5	48.44	49.33
	2	1130.00	22.5	50.22	
	3	1110.00	22.5	49.33	
90 days	1	1120.00	22.5	49.78	49.85
	2	1110.00	22.5	49.33	
	3	1135.00	22.5	50.44	

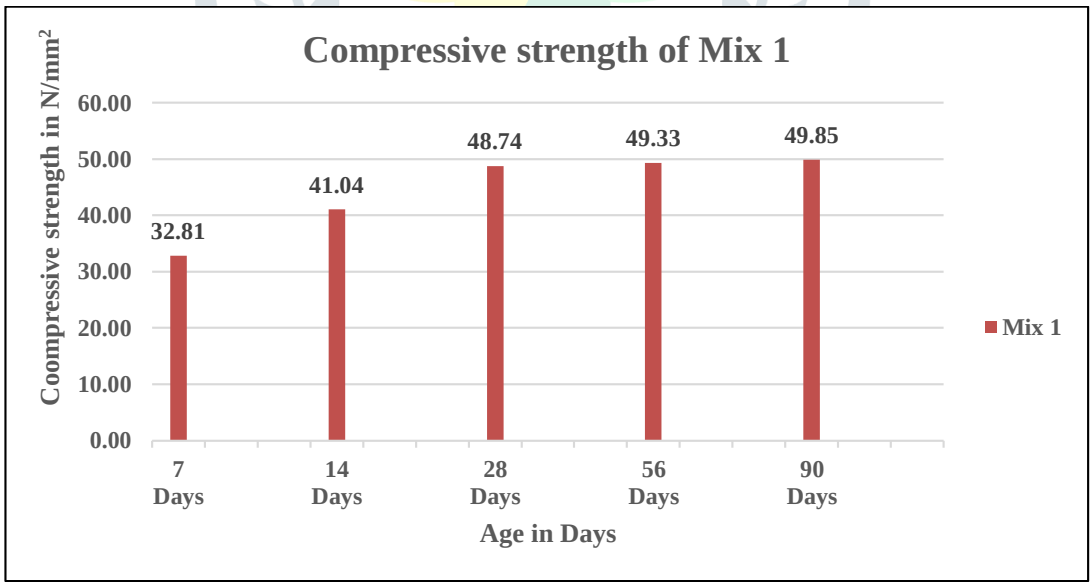

Fig: 1 Comparison of Compressive Strength of Mix 1

It is noticed that for 3 days, 7 days, 28 days, 56 days and 90 days increase in compressive strength for Mix 1 was observed. It is also found that there is not much increment in strength once it reaches its maximum peak load for 28 days

Table 2 Average Compressive Strength of Mix 2

M40 GRADE 50% FLY ASH CONCRETE					
Age in Days	**No. of Samples**	**Load(kN)**	**Area(mm2)**	**Compression Strength (N/mm^2)**	**Average Compression Strength (N/mm^2)**
7 days	1	540	22500	24.00	24.15
	2	520	22500	23.11	
	3	570	22500	25.33	
14 days	1	615	22500	27.33	27.33
	2	635	22500	28.22	
	3	595	22500	26.44	
28 days	1	870	22500	38.67	39.56
	2	895	22500	39.78	
	3	905	22500	40.22	
56 days	1	940	22500	41.78	43.26
	2	1000	22500	44.44	
	3	980	22500	43.56	
90 days	1	1100	22500	48.89	47.11
	2	1025	22500	45.56	
	3	1055	22500	46.89	

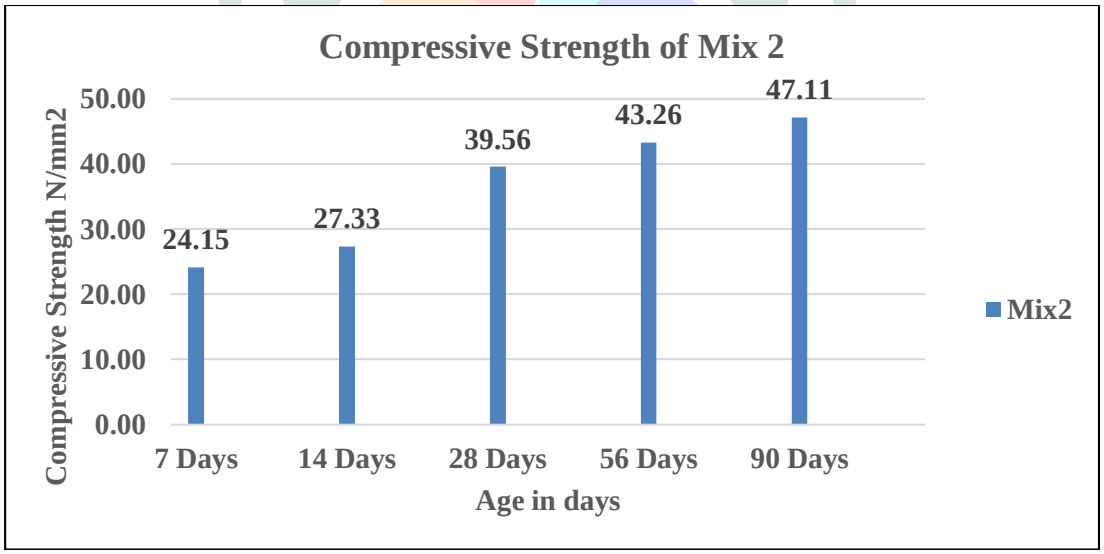

Fig: 2 Comparison of Compressive Strength of Mix 2

It is found that increase in compressive strength for Mix 2 are 24.15 N/mm^2 27.33 N/mm^2, 39.56 N/mm^2, 43.26 N/mm^2 and 47.11 N/mm^2 respectively for 7, 14, 28, 56 and 90 days. It is also observed that there is an incremental increase from 7 days to 90 days.

Table 3 Average Compressive Strength of Mix 3

M40 GRADE FLY ASH CONCRETE (44% FA + 6% $CaCO_3$)					
Age in Days	**No. of Samples**	**Load (kN)**	**Area (mm^2)**	**Compression Strength (N/mm^2)**	**Average Compression Strength (N/mm^2)**
7 days	1	720	22500	32.00	31.41
	2	735	22500	32.67	
	3	665	22500	29.56	
14 days	1	855	22500	38.00	36.96
	2	830	22500	36.89	
	3	810	22500	36.00	
28 days	1	1015	22500	45.11	44.37
	2	980	22500	43.56	
	3	1000	22500	44.44	
56 days	1	1110	22500	49.33	47.48
	2	1060	22500	47.11	
	3	1035	22500	46.00	
90 days	1	1200	22500	53.33	51.33
	2	1115	22500	49.56	
	3	1150	22500	51.11	

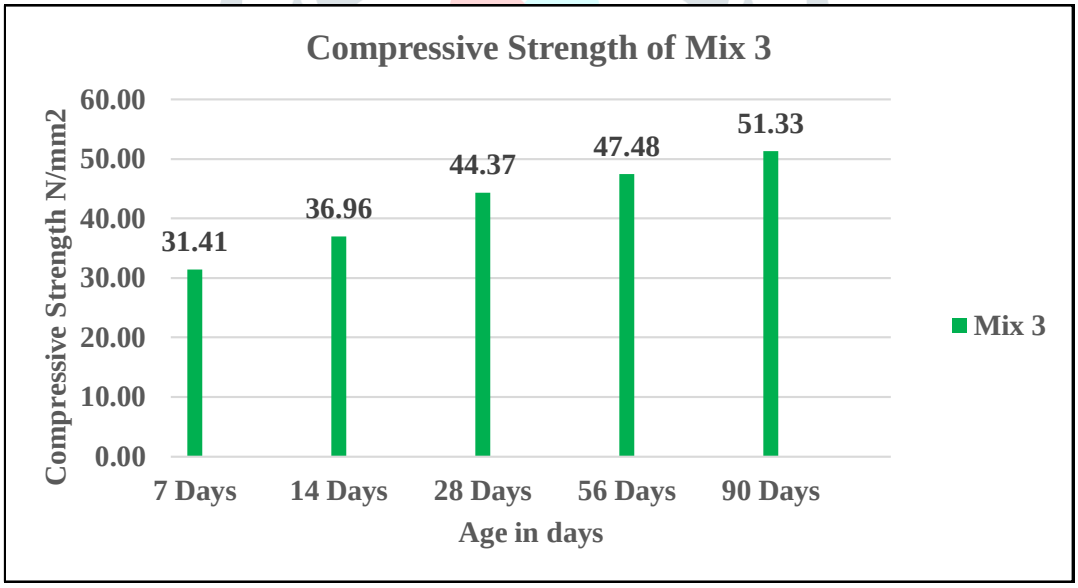

Fig: 3 Comparison of Compressive Strength of Mix 3

It is noticed that for 28 days, increase in compressive strength for Mix 3 are 31.41N/mm^2, 36.96 N/mm^2, 44.37 N/mm^2 and 51.33 N/mm^2 respectively.

Table 4 Average Compressive Strength of all Mixes

Mixes / Days	MIX_1	MIX_2	MIX_3
7 days	32.81	24.15	31.41
14 days	41.04	27.33	36.96
28 days	48.74	39.56	44.37
56 days	49.33	43.26	47.48
90 days	49.85	47.11	51.33

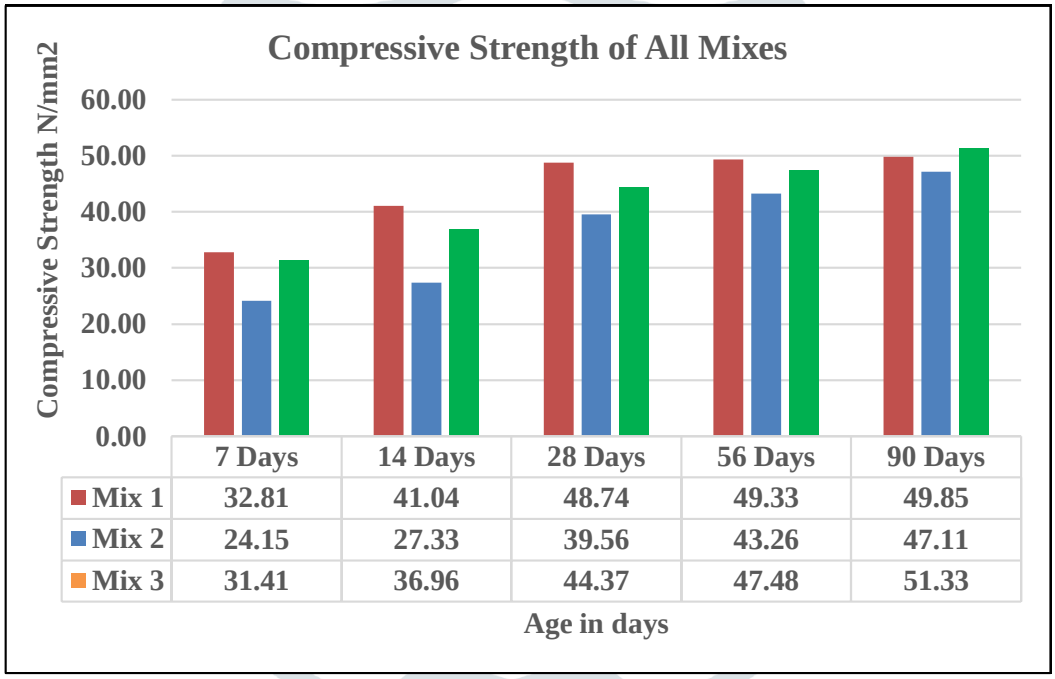

Fig: 4 Comparison of compressive Strength of all mixes

It is noticed that for 7, 14, 28, 56 and 90 days of curing, the compressive strength of Mix 2 has gradually decreased as compared to Mix 1 and Mix 3 because the increase in the fly ash content above its optimised value there will be decrement in compressive strength.

7. MICRO STRUCTURE ANALYSIS

Scanning electron microscopy (SEM) or SEM analysis is a powerful analytical technique to perform analysis on a wide range of materials, at high magnifications, and to produce high resolution images. The sample of the top surface with a focused beam of electrons and it gives magnification with greater depth. The test is performed in BMS College of Engineering Bull Temple Road, Basavanagudi, Bengaluru 560019. The SEM images having magnification of 10X

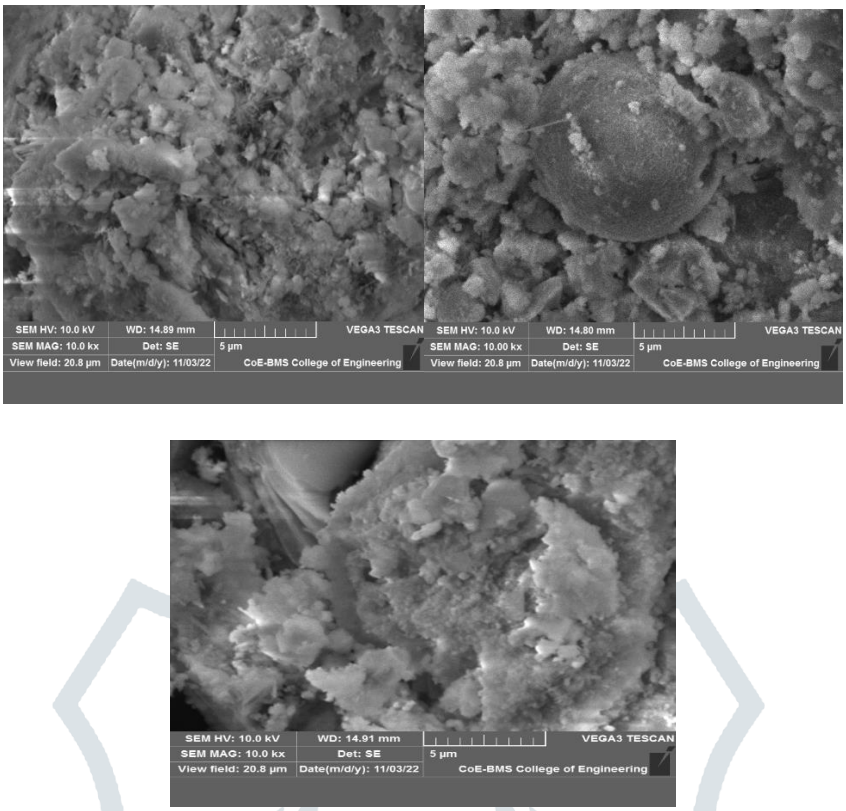

Figure 4: SEM Images of all Mixes with 10X Magnification

From figure 4 S-E-M images, it is noticed that the inclusion of $CaCo_3$ increases the strength The development of more C-S-H Gel is observed in Mix 3 which leads to improvement in bonding of concrete particles between the cement, $CaCo_3$ and Fly ash, the modified cement concrete of Mix 3 gives overall effective compactness in the contribution of strength is more as compared to the other mixes under considerations.

8. CONCLUSION

- The incremental increase in compressive strength for 7, 14, 28, 56 and 90 days is observed.
- The Compressive strength for mix 2 has decreased because may be the absence of calcium carbonate and the production of CSH gel is also less as compared to Mix 1 and Mix 3.
- From SEM analysis it is evident that the maximum percentage of calcium and silicate shows the possibility of more C-S-H Gel production and hence enhancement in the strength for Mix 3 as compared with MIX 1 and Mix 2.