An Experimental Study of High Strength-High Volume Fly Ash Concrete for Sustainable Construction Industry

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Abstract: Concrete is the most widely used building material in the construction of infrastructures such as buildings, bridges, highways, dams, and many other facilities. This paper reports the development, the basic idea, the main properties of high strength-high volume fly ash with application in concrete associated with the development and implementation of Sustainable Properties of High Volume Fly Ash Concrete (HVFAC) Mixtures and Early Age Shrinkage and mechanical properties of concrete for 7,28,56 and 90days. Another alternative to make environment-friendly concrete is the development of high strength-high-volume fly ash concrete which is an synthesized from materials of geological origin or by-product materials such as fly ash which is rich in silicon and aluminum. In this paper 6 concrete mixtures were produced to evaluate the effect of key parameters on the mechanical properties of concrete and its behavior. The study key parameters are; binder material content, cement replacement ratios, and the steel fibers used to High Volume Fly Ash mixtures for increasing performance of concrete.

Keywords: high strength concrete, fly ash, HVFAC, shrinkage, Compressive strength, split tensile strength, flexure strength.

1. INTRODUCTION

Many concrete structures suffer from lack of performance of strength as well as shrinkage which has an adverse effect on the resource productivity of the industry, due to this reason concrete construction industry is not sustainable. The high-volume fly ash concrete system addresses all three sustainability issues; its adoption will enable the concrete construction industry to become more sustainable [14]. During the last two decades the development and application of high strength concrete (HSC) has greatly increased all over the last four decades. The process involved is a combination of improved compaction, improved aggregate matrix bond and reduced porosity using special additives[1].It is essential that supplementary cementing materials be utilized to replace huge extents of cement in the concrete structures, and the most available supplementary cementing material worldwide is fly ash. Such higher fly ash concrete will have to indicate performance comparable to that of conventional concrete, and must be practical. While reductions in w/c and use of pozzolanic materials increase strength and reduce permeability, research has recently been preformed to demonstrate

IOP Conf. Series: Materials Science and Engineering **225** (2017) 012247 doi:10.1088/1757-899X/225/1/012247

how this can lead to an increase in shrinkage and an increased potential for shrinkage cracking which would have an adverse effect on overall durability[13]. Improved properties of any concrete composite is achieved by modifying the microstructure, particularly that of transition zone by using chemical or mineral admixtures having pozzolanic characteristics. The mechanism which leads to the desired modification of the microstructure has three components (i) reaction mechanism among ingredients, (ii) physical process, and (iii) curing [2].

2. MATERIALS

2.1 Cement

All mixtures with cement contents between 478 kg/m^3 are to be made for each cement being considered for the research. Ordinary Portland Cement (OPC) meets the requirements conforming to IS: 12269.

2.2 Fly ash

The Pozzocrete 60™ fly ash is used in present work.This supplementary cementing material (fly ash) is to be adding at dosage rates of 15 to 70 % by mass of cementing material.

2.3 Fine aggregate

Locally available river sand were used as fine aggregate. The specific gravity of the sand is 2.60 and it is conforming to Zone-I of IS: 383–1970.The sand is dried before use to avoid the problem of bulking.

2.4 Coarse aggregate

Careful attention is to be given to aggregate size, shape, surface texture, mineralogy, and cleanness. Locally available crushed stone aggregate is using with size 12.5 mm.

2.5 Water

Potable water that confirming to the requirements of IS 456:2000 suitable for making concrete and was used to mix the concrete and cure the specimens.

2.6 Super plasticizer

Super plasticizer based on a polycarboxylic based using high performance water-reducing admixture which confirms to ASTM C-494 type 'G'. It is intended for applications where retardation and long workability retention are require. The Super plasticizer has a specific gravity of 1.085.

2.7 Fibers

A Single types of fiber were used namely steel . Fibers used for this work are 0.5 % in both mixes by the weight of concrete.

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3. EXPERIMENTAL DETAILS

3.1 Concrete Mix:

For the selected concrete mixtures, Six types of concrete mixes were made. Such concrete mixes were made with water-cement ratio 0.33 ; a one with OPC alone as binder and the other 5 mixes with OPC replacing by weight of 15,30,45,60 and 70% of fly ash. Applications of super plasticizer dosage for concrete mix 0 to 45 % fly ash is 1.0 % by weight of cement is recommended, and the dosage may be increased to concrete mix 60 to 70 % fly ash is 2 % to achieve specific slump requirements. Steel fibers 0.5 % of total concrete mix Coded-A were used for 60 % and 70% fly ash concrete mix. All the ingredients of the concrete mixes are kept constant beside the fly ash proportions. Details of concrete mix proportions are shown in Table I.

Table I: Concrete Mix Proportions

S.N	**Concrete Mix Code**	**Water** kg/m^3	**Cement** kg/m^3	**Fly Ash** kg/m^3	**Fine Aggregate** kg/m^3	**Coarse Aggregate** kg/m^3	**Super-plasticzer** kg/m^3	**Steel Fibers** kg/m^3
1	A33FA0	158	478	0	694	1181	4.78	0
2	A33FA15	158	406	72	694	1181	4.06	0
3	A33FA30	158	335	143	694	1181	3.35	0
4	A33FA45	158	263	215	694	1181	2.63	0
5	A33FA60-01	158	191	287	694	1181	2.865	11.76
6	A33FA70-01	158	143	335	694	1181	2.145	11.76

3.2 Concrete specimens Casting, Curing & Testing:

The slumps of fresh concrete were measured in accordance with IS 1199. After testing the fresh concrete, specimens were cast to measure their compressive strength, modulus of elasticity, splitting tensile strength and shrinkage strains i.e. the volume change of concrete apparatus meets the requirements of ASTM - C490 . All specimens were cured in water.

4. RESULT AND DISCUSSION

4.1 Properties for fresh concrete:

The present work, for low w/b ratio different quantities of fly ash concrete prepared with high performance water-reducing superplasicizer and applications of super plasticizer dosage for concrete mix 0 to 45 % fly ash is 1.0 % by weight of cement is recommended, and the dosage may be increased to concrete mix 60 to 70 % fly ash is 2 % to achieve specific slump requirements. A Mix with w/c 0.33, concrete slump 110, 125, 105, 135, 125, 95mm were observed for a fly ash content of 0, 10, 30, 45, 60, 70 % respectively .

IOP Conf. Series: Materials Science and Engineering **225** (2017) 012247 doi:10.1088/1757-899X/225/1/012247

4.2.Effect of Fly Ash Content of different mixtures on Shrinkage Characteristics:

The effect of fly ash content on shrinkage of High Strength Concrete is presented here in Table II. Shrinkage is the decrease of concrete volume with time. This decrease is due to change in moisture content of the concrete and physiochemical changes, which occur without stress attributable to actions external to the concrete. Swelling is the increase of concrete volume with time. Shrinkage and Swelling are usually expressed as dimensionless strain (mm/mm). The interdependence of many factors creates difficulty in isolating causes and effectively predicting shrinkage without extensive testing.

Fig.1 shows the variation of shrinkage strain with increase in percentage of fly ash mixtures of both mixes at different early age curing periods. The strain calculated at every age is the average of three measurements, one from a specimen of each of the three batches of the concrete mixtures. From Figure, it is observed that is a general trend of increase of shrinkage strain with increase in percentage of fly ash for early age all curing periods. It is also observed that the rate of increase of shrinkage strain with increase in fly ash content in relatively at 90 days than 28 and 56 days.

Table II

Test Results of Shrinkage of Concrete Length of Specimen: L=275mm

SN	Mix Design	Fly Ash (%)	Change in Length (ΔL) in mm after days						Shrinkage Strain (ΔL/L) x 10^4 after days					
			1	3	7	28	56	90	1	3	7	28	56	90
1	A33FA0	0	0.012	0.013	0.015	0.033	0.19	0.27	0.044	0.047	0.55	1.20	6.91	9.82
2	A33FA15	15	0.020	0.050	0.052	0.075	0.23	0.24	0.72	1.81	1.89	2.72	8.37	8.73
3	A33FA30	30	0.025	0.042	0.067	0.086	0.24	0.36	0.90	1.53	2.43	3.12	8.72	13.09
4	A33FA45	45	0.022	0.047	0.110	0.112	0.20	0.29	0.80	1.70	4.08	4.07	7.27	10.54
5	A33FA60-01	60	0.039	0.067	0.102	0.110	0.242	0.301	1.42	2.43	3.71	4.00	8.80	10.95
6	A33FA70-01	70	0.036	0.053	0.090	0.138	0.268	0.313	1.31	1.92	3.72	5.01	9.74	11.38

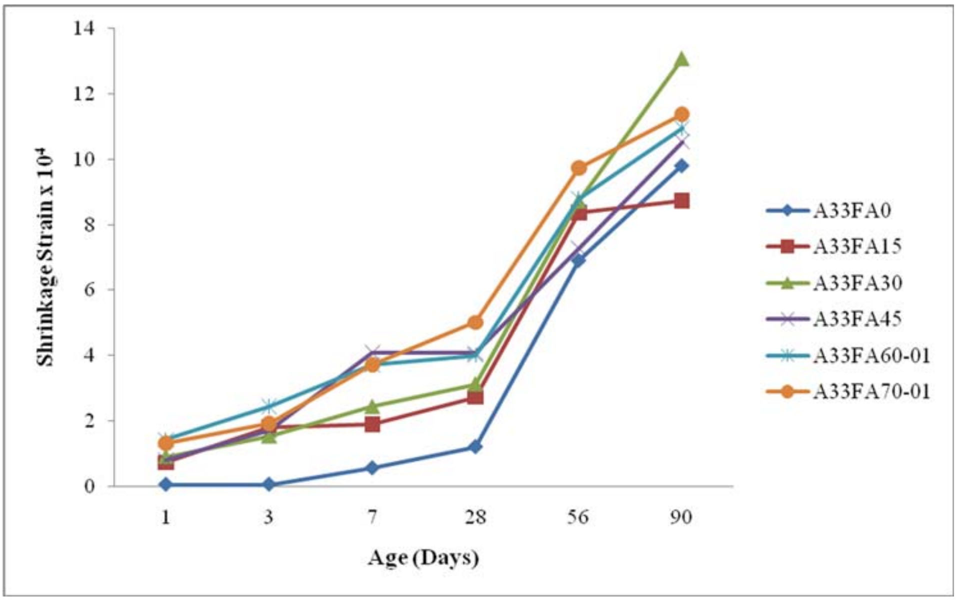

Fig. 1: Effect of Age on Shrinkage with different Quantities of Fly Ash .

4.3 Test result of Compressive Strength

The effect of level of cement replacement with fly ash development of the compressive strength of hardened concrete was investigated with the different fly ash quantities. The results of compressive strength at 7, 28, 56 and 90 days are tabulated in Table III. The additional curing period of 90 days was selected because for high volume fly ash the rate of gain in strength is very slow.

Table III: Test result of Compressive Strength of concrete

S N	Mix Design	Fly Ash (%)	Compressive Strength in N/mm^2 after days			
			7	28	56	90
1	A33FA0	0	48.88	68.28	72.09	74.66
2	A33FA15	15	44.42	63.2	64.31	70.05
3	A33FA30	30	41.06	43.55	62.93	69.16
4	A33FA45	45	38.44	39.11	45.77	67.86
5	A33FA60-01	60	38.08	44.8	49.68	52.66
6	A33FA70-01	70	27.51	38.62	38.75	41.77

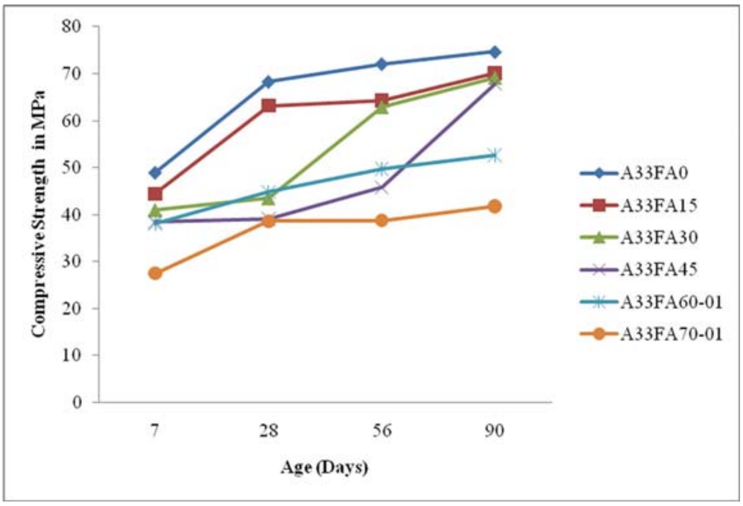

Fig. 2: Effect of % Fly Ash content on Compressive strength

From these test results it is seen that with increase in fly ash content the compressive strength reduces. It is also observed that target strength is not achieved for high volume fly ash. The compressive strength is also presented graphically in Fig.no2. Although the target strength has not been reached by mixes with high volume of fly ash, it is seen that the rate of increase of strength has been steady even after 28 days, which is not observed for low fly ash content, so it is likely that high volume fly ash concrete may reach the target strength at a later stage. This trend is similar for both mix of concrete.

4.4 Test result of flexural Strength

The flexural strength of concrete mixtures was determined at the ages of 7, 28, 56, 90 days. The results are shown in Table IV, Similar to the compressive strength, the flexural strength of the concrete mixtures increased with age. The flexural strength of fly-ash concrete decreased slightly as the percentage of fly ash increased. As expected, the early strength gain of the control concrete without fly ash was superior to that of the fly ash mixtures. In addition, Fig. no. 3 shows that all fly-ash concretes demonstrated larger increases in flexural strength from 28 days to 90 days, indicating that the fly-ash concrete may develop superior flexural strength at the age of 90 days.

Table IV: Test result of flexural strength of concrete

SN	Mix Design	Fly Ash (%)	Flexural strength in N/mm^2 after days			
			7	28	56	90
1	A33FA0	0	4.48	5.19	6.08	7.09
2	A33FA15	15	4.13	4.81	6.1	7.57
3	A33FA30	30	3.84	4.84	7	7.43
4	A33FA45	45	3.51	4.39	5.1	6.61
5	A33FA60-01	60	3.29	3.72	6.1	6.86
6	A33FA70-01	70	2.89	3.54	5.39	6.39

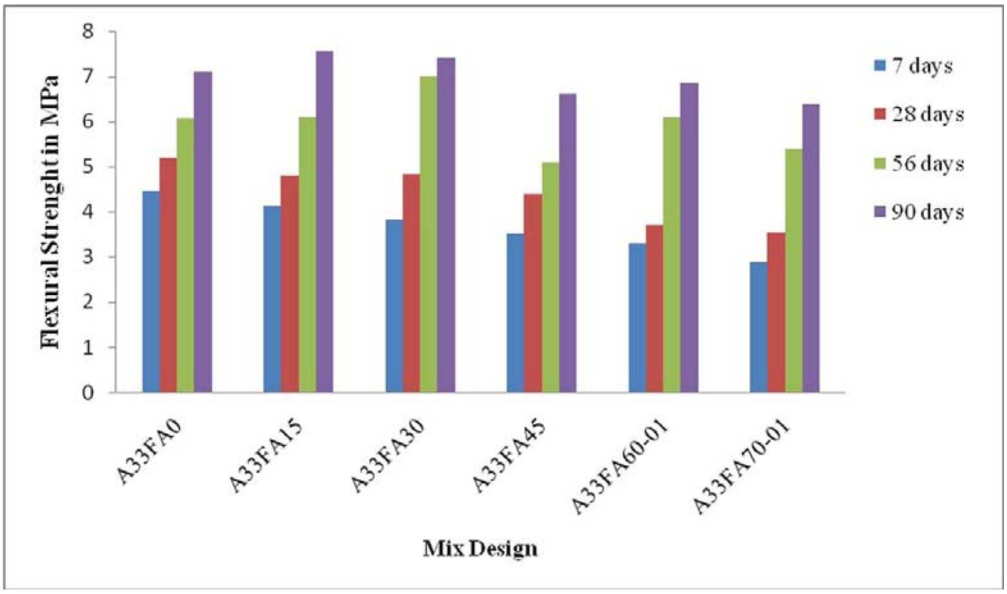

Fig.3: Flexural strength showing different age

5. CONCLUSION

From the above studied proportions and their results the following conclusions can be drawn:

1. The workability of High Strength Concrete improves with increase in fly ash content where the incorporation of FA produced an average slump loss reduction.

2. Addition of fly ash to concrete not only results in the increase of compressive strength but also resulted in the small reduction of drying shrinkage; Shrinkage of high strength- high volume fly ash concrete increases with increase in fly ash content.

3. The rate if increase of shrinkage with time is uniform for low fly ash content, whereas it generally increases after 28 days up to 56 days for high volume of fly ash.

4. The strength of concrete after a given curing period decreases with increase in fly ash content. However the increase in strength continues for a long period for concrete with high volume of fly ash. Hence it is likely that for target strength may be achieved after a long duration.

5. In general the effect of steel fiber addition had shown a remarkable reduction in the shrinkage in accelerated cementitious composites. Also, the fly ash substitution up to 60% had shown a slight improvement in compressive strength.

6. All the fly-ash concretes demonstrated larger increases in flexural strength from 28 days to 90, the split tensile strength of the concrete mixtures increased with age. The high-volume concrete gives a holistic solution to the problem of meeting the increasing demands for concrete in the future in a sustainable manner and at a reduced or no additional cost, and at the same time reducing the environmental impact of two industries that are vital to economic development namely the cement industry and the coal-fired power industry.

IOP Conf. Series: Materials Science and Engineering **225** (2017) 012247 doi:10.1088/1757-899X/225/1/012247

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IOP Conf. Series: Materials Science and Engineering **225** (2017) 012247 doi:10.1088/1757-899X/225/1/012247

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