FLY ASH COMPOSITE CONCRETE UNDER SUSTAINED ELEVATED TEMPERATURE

K.N.Vishwanath,
Dept. of Civil Engg.,
Dayananda Sagar College of Engineering
Bengalore-560 078: INDIA.

Dr. N Suresh
Dept. of Civil Engg.,
National Institute of Engineering
Mysore-570 008: INDIA

Abstarct

The role of fly ash on the behavior of hardened concrete with partial replacement of cement with fly ash in compression under sustained elevated temperatures is reported here. The capable contribution of fly ash concrete (FAC) in maintaining or improving the property of hardened concrete in compression under sustained temperature was tested. With replacement levels of 35%, 40% & 45% by mass of cement, 4 mixes were cast. After curing they were exposed to temperatures 200^{0}C and 300^{0}C sustained for period of 5 hours. The specimens were allowed to cool to room temperature and then tested under compression. The results of X-ray diffraction tests done, show that elevated temperatures in this range favour CSH formation and the consumption of CH in the presence of fly ash. Based on the compressive strength, it could be concluded that blending with fly ash is a viable technique to sustain concrete at elevated temperatures.

Introduction

It is quite common that many concrete structures like Chimney in manufacturing plants, reactive chambers in Nuclear thermal power plants are subjected to high temperature for considerable duration. The structure may fail prematurely due to degradation of physical & chemical properties caused by sustained temperature. The surface layer spall, exposing the reinforcements in the structure which tend to get twisted and overall stability of the structure is disturbed.

Research carried out have has established that a partial substitution of industrial waste and a mineral admixture such as flyash in concrete mixes would help to over come the problem of workability, Durability and achieving higher strength[1]. In India very few studies have been reported on the use of flyash as a replacement for cement when concrete is used to resist higher temperature. The structural property of Concrete that has been studied most widely as a function of heat exposure is Compressive strength [2]

The reactive silica present in the fly ash combines with free calcium Hydroxide liberated during Hydration process[3] (which otherwise would have leached out increasing the porosity of the matrix), to form additional C-S-H gel. This C-S-H gel increases denseness of the matrix and improves the pore structure there by increasing the strength & durability. The paper reports on the performance of FAC mix having different replacement levels of cement with low calcium Flyash when exposed to different temperature & varied duration of exposure. The property to take compressive load is compared with reference mix prepared without fly ash but subjected to the same type of exposure conditions.

Though for Concrete exposed for normal conditions ACI Committee 211.G recommends 25% as the limit to the replacement[3,4] to obtain maximum efficiency, for any given strength. The objective of the study was to determine the maximum Cement Replacement Level (CRL) by fly ash in concrete mixes, exposed to high & sustained temperatures without negatively affecting the strength.

Scope

With 60 cubes for each parameter like, percentage of replacement, temperature and duration of exposure a total of 360 cubes were cast. The water to cement ratio and quantity of aggregate were maintained same through the experiment for all mixes. The cast specimen cubes were exposed to temperature for a duration and then tested for compressive load. The resistance of FAC for temperature was investigated.

Material and method

43 grade cement confirming to IS: 12269 was used in the study. Crushed aggregate of sp.gr. 2.65, having water absorption 1.8%: Locally available river sand falling under Zone II, having Sp. gr. 2.71 with water absorption 0.68% was used. Fly ash was sourced from Mettur Thermal Power Plant in Tamilnadu.

Mix proportion was carried out as per IS 10262-2010. Fly ash was added as a replacement by mass of cement obtained from the proportion.

A concrete mix of 30 MPa at the age of 28 days is proportioned. This concrete is used through out the investigation. Cubes of 150 mm were cast, both for reference mix without fly ash, and for mix replacing conventional Portland cement with 35%, 40%, and 45% by fly ash. The cubes were cured for 28, 56,& 90 days. At the end of curing they were air dried for surface moisture by visual inspection. All these concrete mixtures were exposed to heating, for durations of 2, 3, 4 & 5 hours at temperature level of 200^{o}C and 300^{o}C respectively. On completion of heating, the cubes were brought to room temperature and then tested for compressive strength

TEST RESULTS & DISCUSSION

Mixture proportion in table 1, The physical and chemical properties of fly ash used is given in table 2, compressive strength development in table 3, 4, 5 & 6. For the purpose of discussion **Specimen with 35%, 40% & 45% replacement of cement with flyash is termed as specimen A, B & C respectively.**

When exposed to 200^{o}C:

After 28 days of curing, there is steady increase in the strength by CC specimen as the duration of exposure increases and is the highest among all other Cement replacement specimen and has attained 60 MPa after 56 days curing for 4 hr exposure. Up to 56 days curing B & C specimen have enhanced their strength taking ability & then there is no increase but maintains the achieved strength of 49 MPa further upto 90 days.

When exposed to 300^{o}C:

After 28 days curing B & C specimen have the same strength that was achieved at 3 hours exposure.Reference concrete is gaining strength linearly, specimen B has the highest. Even at 56 days reference concrete has shown a marginal increase in strength from 42 to 63 MPa between 3 to 4 hours exposure where asspecimen B maintains the same strength as acquired earlier. Controlled concrete is the strongest at 90 days taking almost 68 MPa, followed by specimen C at 62 MPa.

At 28 days the difference in variation of strength is very marginal between 2 and 5 hours of exposure period. But in between, Specimen A and C show lot of variations and specimen C is constant throughout. Thus with a moderate content of Fly ash the strength do not vary for any amount of exposure. This would be due to the optimal blend of fly ash with cement resulting in continuous hydration process (Fig 3.1A, B &C). As seen from the Fig 3.1A, B & C for 2-4 hours of exposure both for 200°C & 300°C temperature the strength of A & B specimen remains almost the same at 45 MPa. But for 5 hr exposure, specimen A replacement has more strength at 300°C than at 200°C. At 300°C, C replaced specimen has more strength than when exposed to 200°C for 5 hr duration.

Specimen A has failed in taking the achieved load from 2 to 5 hours of exposure .But specimen B and C have shown an improvement in retaining the achieved strength from 2 to 5 hours of exposure. This is due to the fact that higher fly ash content having additional alumina leads to formation of more cementitious material filling the pores and thus density increases and naturally the result of higher compressive strength (Fig .3.2 A, B &C). At 90 days as seen in Fig .3.2 A, B & C specimen B has strength of 39 MPa & 58 MPa for 200°C & 300°C temperature. At the age of 90 days specimen B has the same strength of 38 MPa when heated to 200°C. But the same when heated to 300°C strength increase from 47 MPa to 58 MPa between 2-5 hours of exposure. Specimen A gain strength all of a sudden beyond Target mean strength by 28 days as seen in Fig 3.3A, later on as the curing prolongs the compressive strength reduces drastically. Due to lesser Fly ash content pores are empty in the cubes at the beginning and as the curing period extends the voids are filled with more of cementitious material occupies the space, hence the specimen takes higher load. This leads to normal hydration process and gradual increase in the strength gain. In 3.3B &C for 4 and 5 hours duration specimen B is showing a consistent increment in the strength gain with a marginal variation. Specimen C though is taking a higher load at 56 days it is failing to take the same load after extended curing period. Thus higher Fly ash content may not be a necessity to get higher compressive strength under sustained elevated temperature.

As an additional check to understand the structural behaviour of fly ash composite concrete Tensile strength test was conducted with cylindrical specimen[5]. Fig 4.6 represents the behaviour of specimen A, B & C in relation to controlled specimen D. As the duration of exposure increases specimen D shows the reduction in tensile strength very marginally. But interestingly, specimen A & B with a moderate fly ash shows a steady increase in their tensile strength taking capacity. The additional cementitious material formed due to secondary hydration reaction could be adding on to the higher bond strength in the matrix. As a result a higher tensile capacity for flyash composite concrete.The same is due to extended hydration reaction .Controlled Specimen D is deteriorating and is weak in taking tensile strength.

Sample XRD Graph has been included. As seen in the Graph 6.1A from 0 to 20 ^{o} 2 Theta position the amount of hump is more than what is in graph 6.1B. Indicating Cao & Quartz are still in amorphous sate and thus incomplete hydration. But in graph 6.1B the amount of hump has drastically come down at 20 ^{o} 2 Theta position telling that Cao & Quartz are now in crystalline state completing most of the hydration reaction

Conclusions:

1. The early age strength of fly ash concrete is in line with that of controlled concrete elements. For a moderate temperature rise of 200°C fly ash concrete as well as controlled concrete elements have similar target mean strength at the end of 5 hours exposure.
2. For extended curing periods of 56 and 90 days elements with higher fly ash content show marginal improvement in their final strength. This is mainly due to the spherical shape of fly ash particles compared to the morphology of cement alone.
3. 35% fly ash replacement has a tendency to alter its capacity to take the compressive loading over the duration of exposure 40% and 45% replacement elements sustain the achieved target load with marginal increment for a extended curing period. At 28 days elements with 40% replacement cement will sustain the achieved compressive strength for extended exposure duration.
4. In relation to the controlled concrete elements not subjected for temperature fly ash composite elements exposed to temperature have higher residual strengths
5. The study indicate that blending of FA with cement as a partial replacement leads to improved properties in achieving the strength as well as having requisite residual strength even after subjecting them for prolonged exposure for different temperature ranges.
6. It is also evident from the XRD analysis graph, where in the amount of humps has reduced (one specimen sample graph) which indicates the amount of amorphous material available for hydration is almost nil. (Fig 6.1 A & B).

Table 1: Mix proportion details :

Water	Cement	Fine Agg.	Coarse Agg.
186	450Kg	598.64Kg	1099.17Kg
0.4	1.0	1.287	2.364

Table 2 A: Physical properties of fly ash used:

SI.No	Test Conducted	Obtained Results
1.	Specific Gravity	2.0
2.	Fineness, specific surface area in m2/kg determined by Blaine's Air	298
3.	Soundness, by Autoclave expansion or contraction in %, maximum	0.035
4.	Particle retained on 45µm IS sieve (wet sieving) in %, maximum	38.5

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Table 2 B: Chemical Properties of fly ash Used

SI. No.	Tests Conducted	Obtained Results %
1.	(SiO_2) plus (Al_2O_3) plus (Fe_2O_3), % by	90.90
2.	(SiO_2), % by mass, (Min.)	58.2
3.	(MgO) % by mass, (Min.)	0.98
4.	Total Sulphur as SO_3, % by mass,(Max.)	0.15
5.	LOI, %by mass,Max.	0.50

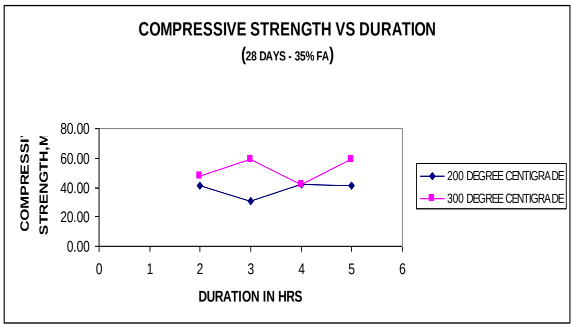

Fig 3.1A: Compressive Strength Vs Duration 28 days – 35% FA

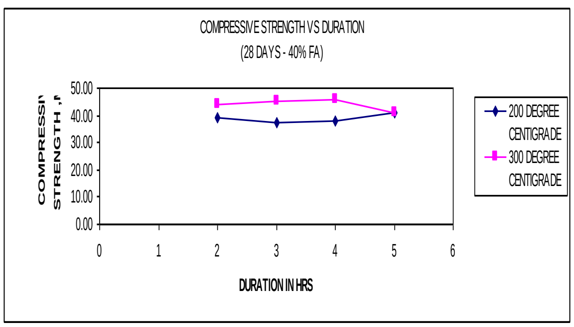

Fig 3.1B: Compressive Strength Vs Duration 28 days – 40%FA

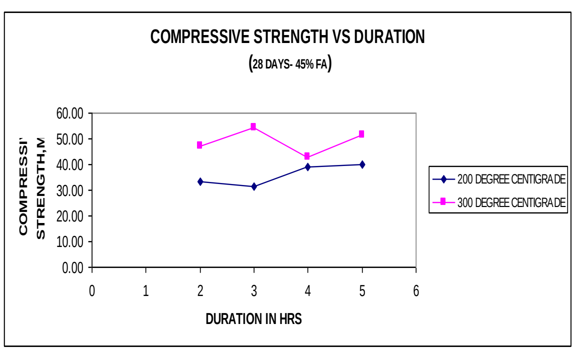

Fig 3.1C: Compressive Strength VS Duration (28 days – 45% FA)

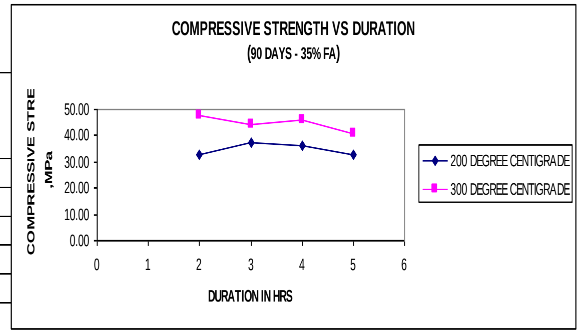

Fig 3.2A: Compressive Strength VS Duration(90 days – 35% FA)

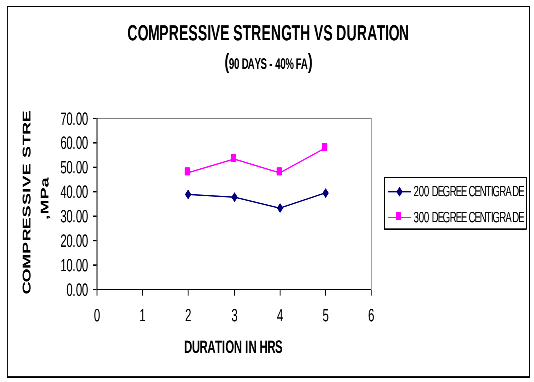

Fig 3.2B: Compressive Strength VS Duration -90 days – 40% FA

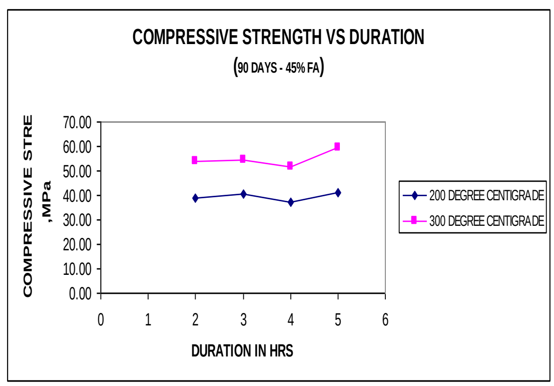

Fig 3.2 C: Compressive Strength VS Duration-90 days– 45% FA

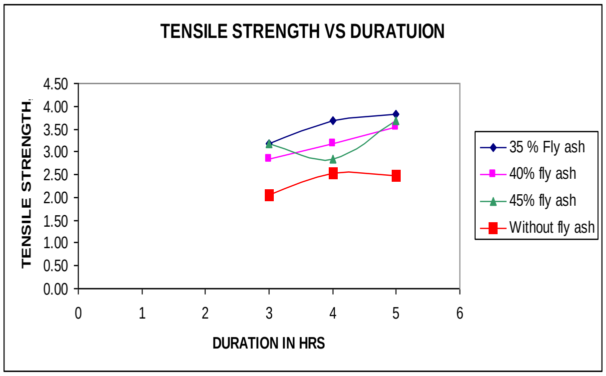

Fig 4: Tensile Strength at 28 days for 300°C exposure

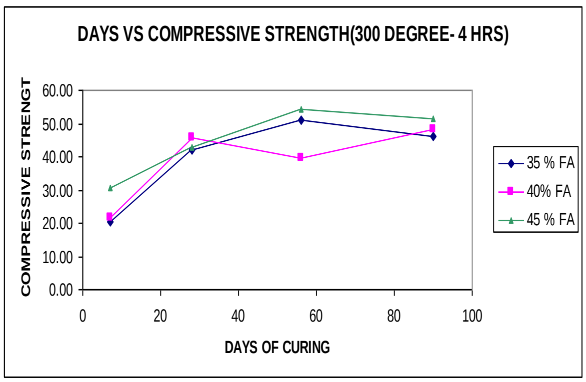

Fig 3.3A: Days VS Compressive Strength-300°C–3 hrs duration

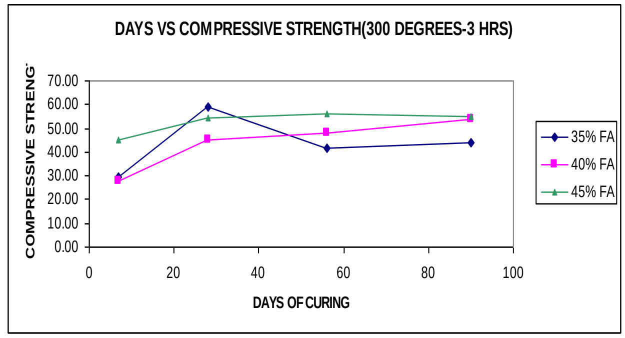

Fig 3.3B: Days VS Compressive Strength- 300°C–4 hrs duration

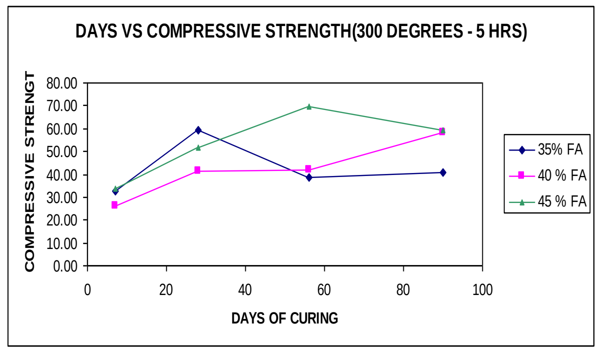

Fig 3.3 C: Days VS Compressive Strength-300°C –5 hrs duration

Table 3 A : 28 days, 200°C & 300°C (duration wise) strength for 35%, 40%, 45% FA

MEAN VALUES				
AGE -28 DAYS				
TEMPERATURE EXPOSED	**DURATION OF EXPOSURE**	**STRENGTH WITH 35%**	**STRENGTH WITH 40 %**	**STRENGTH WITH 45%**
200	2	40.89	38.89	33.11
	3	30.44	37.44	31.33
	4	42.22	38.00	38.89
	5	40.89	40.89	40.00
300	2	47.33	44.22	47.33
	3	58.89	45.11	54.44
	4	42.22	45.78	42.67
	5	59.11	41.11	51.56

Table 3 B : 90 days, 200°C & 300°C (duration wise) strength for 35% ,40%, 45% FA

MEAN VALUES				
AGE -90 DAYS				
TEMPERATURE EXPOSED	**DURATION OF EXPOSURE**	**STRENGTH WITH 35%**	**STRENGTH WITH 40 %**	**STRENGTH WITH 45%**
200	2	32.89	39.11	39.11
	3	37.22	37.89	40.44
	4	36.22	33.33	37.00
	5	32.67	39.33	40.89
300	2	47.56	47.56	54.00
	3	44.22	53.56	54.67
	4	46.00	48.00	51.56
	5	40.89	58.00	59.33

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TENSILE STRENGTH

TABLE 4: 28 days, 300°C-Tensile strength for 35% ,40%, 245% FA & Without Fly ash

TENSILE STRENGTH ,MPa 300 DEGREES – AT 28 DAYS				
DURATION OF EXPOSURE	STRENGTH WITH 35 % FLY ASH	STRENGTH WITH 40% FLY ASH	STRENGTH WITH 45 % FLY ASH	STRENGTH WITH OUT FLY ASH
3	3.19	2.83	3.19	2.05
4	3.68	3.19	2.83	2.54
5	3.82	3.54	3.68	2.48

XRD Graph:

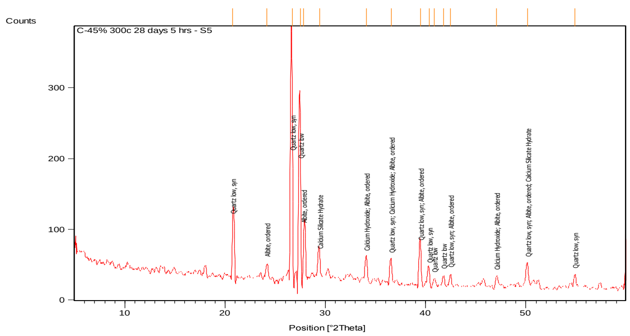

Figure 6.1A: XRD Pattern of specimen 45 % replacement 300 °C/ 28 days curing /5 hours

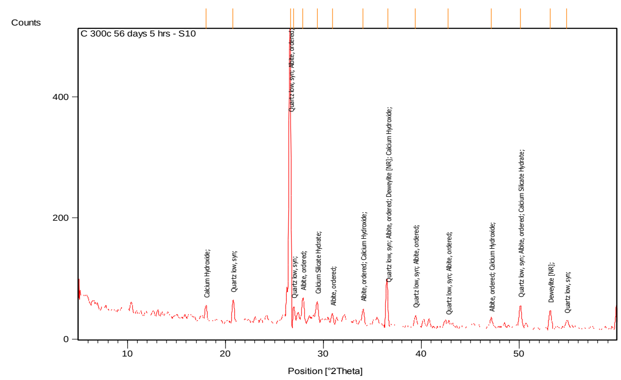

Figure 6.1B: XRD Pattern of specimen 45 % replacement, 300°C/ 56 days curing /5 hrs

1. Dr. M.Lakshmipathy, & N.Suresh: "Performance of Concrete at Elevated temperature". *Proceedings-ACC2000* B.I.E.T Jhansi.
2. Potha Raju M. and Janaki Rao A., "Effect of Temperature on Residual Compressive Strength of Flya ash Concrete", *Indian Concrete Journal* May 2001. p 347-352
3. Goplakrishna, S. Rajamane, N.P. .Neelamegan, M. .Peter, J.A. Dattatreya J.K : "Effect of partial replacement of cement with flyash on strength & durability of HPC"., *Indian Concrete Journal* May 2001. p 335-341
4. Joshi R.C Lohtia R.P: "Fly ash in Concrete: Production, Properties & uses" *Garden & Branch Science Publishers Ne*therlands.1999 P 269
5. Bureau of Indian standards, IS: 5816-1970. ' Methods of test for Splitting Tensile Strength of Concrete Cylinder"