Mineralogical Study on High Volume Silica Fume Concrete At Elevated Temperatures By XRD Analysis

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Abstract*-Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. mechanical and mineralogical properties of high volume silica fume concrete exposed to elevated temperature from 200°C to 800°C at an interval of 200°C for 24hr duration is investigated and compared with conventional concrete. The mechanical properties studied are residual compressive strength, weight loss, color change. Mineralogical study is carried out by using X-Ray Diffraction test. M40 grade concrete is designed and cement is replaced with silica fume percentage replacements of 10, 15 and 20 % by weight of cement with a water binder ratio of 0.40.*

I. INTRODUCTION

Concrete is the most versatile construction material due to its high compressive strength and mouldability. It is most widely used material and it is estimated that the second highest consumed material in the world. As the consumption of concrete increases day by day, the use of cement also increases tremendously. The increasing scarcity of raw materials and an urgent need to protect the environment against pollution has accentuated the significance of developing new building materials.

X-ray diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions. X-ray diffraction is most widely used for the identification of unknown crystalline materials (e.g. metals, minerals, inorganic compounds). XRD measures the intensities of a reflected X-Ray beam from a small area. Atomic-level spacing within the crystal lattice of the specimen can be obtained by the results. This helps us in understanding details of the crystal structure for the substance. XRD helps in identifying different phases with identical compositions with finer details of the crystal structure, such as the state of atomic “order”. In addition, strain analysis and determination of the degree of crystallization can also be assessed.

II. REVIEW OF LITERATURE

AbidNadeem et al.[1]carried out to evaluate the performance of HighPerformance Concrete (HPC) made with Silica Fume (SF) and Metakaolin (MK) at elevated temperatures. They examined on partial replacement of cement with SF from 10% to 40%, temperatures from 27oC to 800oC and two types of cooling methods (in air and water). They determined compressive strength, durability and mass loss by using chloride permeability, water absorptivity tests and quantitative analysis of the SEM image test. Test results showed degradation in the mechanical and durability properties of HPC at elevated temperatures.

N. Vishwanath et al.[2]investigated on the Silica fume composite concreteunder sustained elevated temperature. Tested the capable contribution of Silica Fume concrete (SFC) in maintaining or improving the property of hardened concrete in compression under sustained temperature. With replacement levels of 35%, 40% & 45% by mass of cement, 4 mixes were cast. After curing they were exposed to temperatures 200oC and 300oC sustained for period of 5 hours. Compressive strength, tensile strength and X-ray diffraction tests are conducted and compared with each other samples at different temperatures.

Shane Donatello et al.[3]presented a report on The physical and chemicalchanges in a very high volume Silica fume cement paste (SF-4) and CEM II/A-M Portland composite-cement (MS) following exposure to temperatures up to 1000oC. The liquid to solid ratios were 0.36 and 0.32 for the SF-4 and MS pastes respectively. Pastes were mixed manually for 3 min and cast into 1×1×6 cm stainless steel moulds. Then samples are placed in curing chamber then exposed to 200, 400, 600, 800 or 1000oC for a period of 1 hr. After testing flexural strength some fragments of each sample batch were ground to a fine powder and analyzed by X-ray diffraction.

HarunTanyildizi et al.[4]studied on the effect of high temperature oncompressive and splitting tensile strength of lightweight concrete containing Silica fume. They investigated experimentally and statistically. The mixes incorporating 0%, 10%, 20% and 30% Silica fume are prepared. 100×100×100mm cubes are casted and heated at temperatures of 200oC, 400oC and 800oC, respectively. Compressive strength and splitting tensile strength of light weight concrete was tested by using analysis of variance (ANOVA) method.

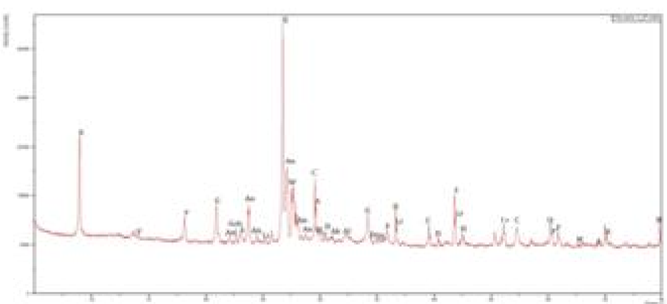
Omer Arioz et al.[5]studied on Effects of elevated temperatures onproperties of concrete. Various concrete mixtures prepared by OPC, crushed limestone, river gravel, test samples subjected to elevated temperature from 200oC to 1200oC. After exposure, weight losses are determined and then compressive strength was conducted.

George Mathew et al.[6]studied on Influence of Silica Fume in LaterizedConcrete Exposed to Elevated Temperatures. Cement is replaced with mineral admixtures (fly ash and GGBFS) at an increment of 5%, starting from 10% and going to 35%. Compressive strength, split tensile Strength and modulus of elasticity are performed on all types of Silica Fume specimens that are 28 days cured and exposed at 200oC, 400oC, and 600oC.

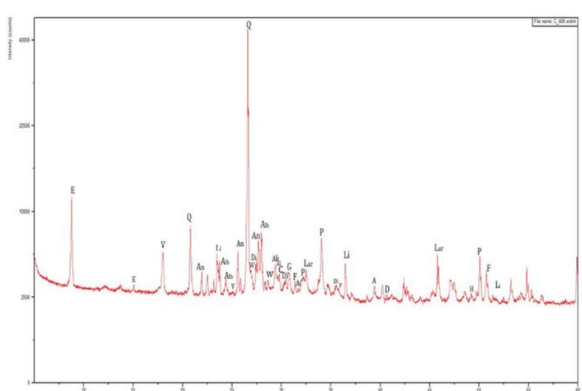
X-RAY DIFFRACTION

X-Ray Diffraction test was conducted at NISHKA LABS in uppal, hyderbad., the specimens were fine powdered to do XRD. Totally 6 samples are tested, 3 from C100 mix and another 3 from C85S15 mix at 27oC, 400oC, 800oC

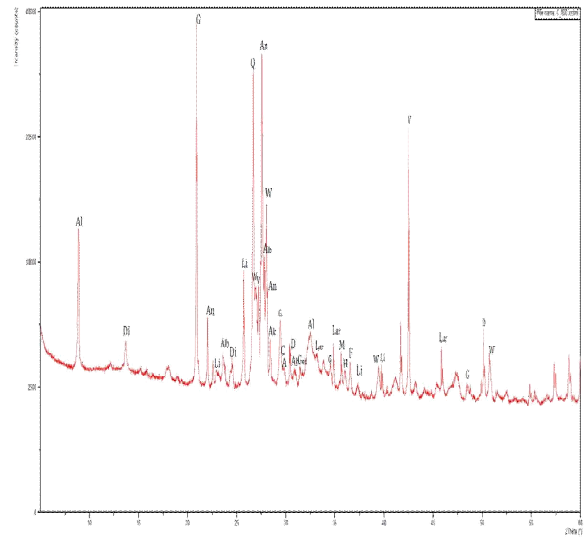
X-Ray Diffraction Test results are shown below:



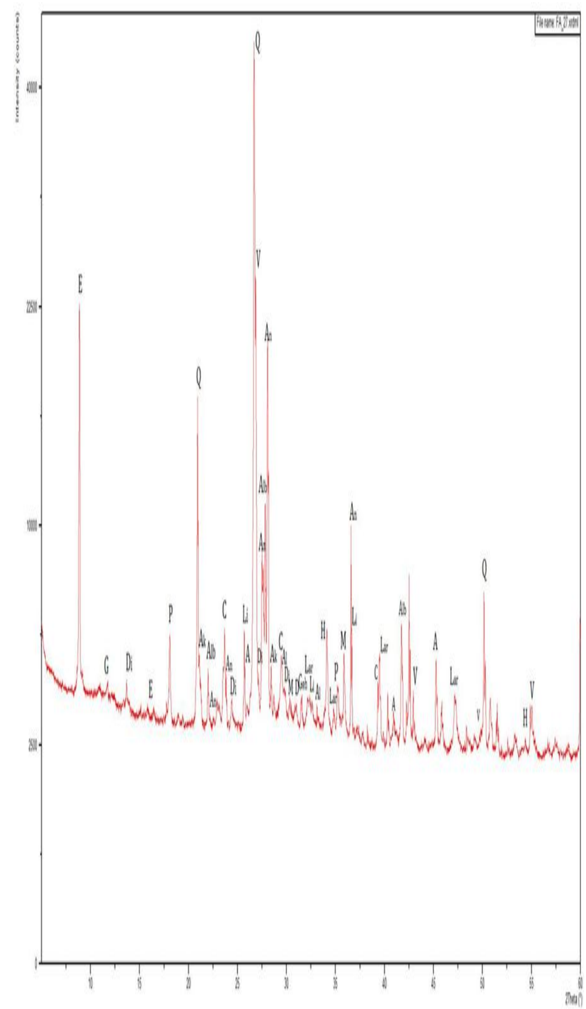
XRD data (phase peak labels) for C100 mix at 27oC.



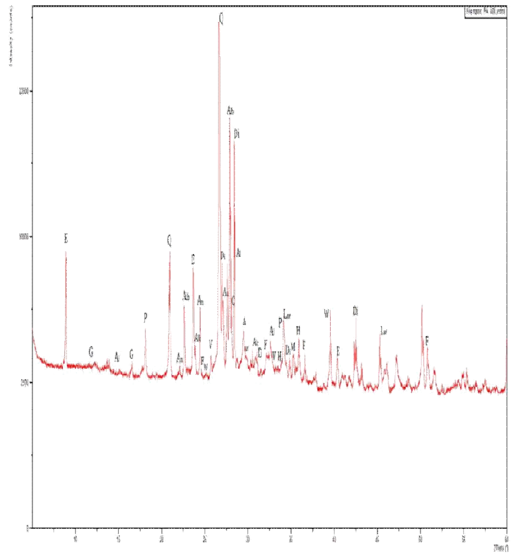
XRD data (phase peak labels) for C100 mix at 400oC



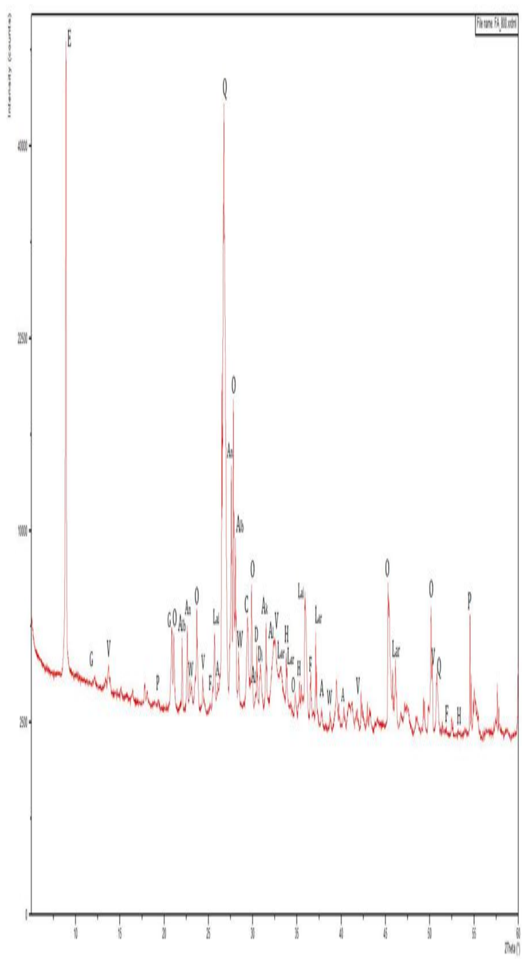
XRD data (phase peak labels) for C100 mix at 800oC.



XRD data (phase peak labels) for C85S15 mix at 27oC.



XRD data (phase peak labels) for C85S15 mix at 400oC.



XRD data (phase peak labels) for C85S15 mix at 800oC.

Quantity of different phases those are present in C100 mix and C85S15 mix at different temperatures analysed by XRD Test are shown in below table.

Quantity of different phases those are present in C100 mixand C85S15 mix at different temperatures analysed by XRD

PHASE NAME	**CONTENT %**					
	C100			**SF15**		
	27^{o}C	**400^o C**	**800^o C**	**27^o C**	**400^o C**	**800^o C**
QUARTZ	29.7	34	22.2	23.5	36.4	12.9
PORTLANDITE	2	3		2	2	1
ALITE	2	5	7.1	2	5.1	4
BELITE						
ALBITE	6.9	9	9.1	14.3	12.1	10.9
ETTRINGITE	2	7		1	5.1	2
ANHYDRITE	2	2	2		1	1
ANORTHITE	11.9	19	19.2	22.4	24.2	24.8
AKERMANITE	1	1	2	1	1	2
CALCITE	1		3	2		2
DIOPSIDE	3	6	1	2	12.1	2
FAYALITE	1	2	2		2	1
LAIHUNITE		4	4	2		2
GEHLENITE	6.9		1	1		
HEMATITE	1		1	1		
VATERITE			2	5.1		3
WOLLASTONITE	11.9	4	7.1			9.9
DOLOMITE		1	1	2		
MAGHEMITE	11.9					
GYPSUM	3		3			2

III. RESULTS AND DISCUSSIONS

Depending on results discussions are prepared. The main aim of testing is to know thebehaviour of high volume Silica fume concrete at elevated temperatures and study of mineralogical change in it. So that a result of normal (C100) concrete is compared with results of high volume Silica fume (C90S10, C85S15and C80S20) concrete mixes.

Effect of phase composition on residual compressive strength by XRD.

Silica fume mixes show higher compressive strength than normal concrete mix at 27°C this increase in strength due to micro filler effect coupled with pozzolanic reaction with calcium hydroxide (CH). The normal concrete mix show higher residual compressive strength at 200°C due to the drop in calcium hydroxide (CH) and unhydrated (UH) area fraction which is beneficial for the micro structure. And also due to the quantity increment of strength giving phases like quartz, ettringite (before hydration), diopside and etc,. Fly ash mixes show increased compressive strength at 400°C. This increase in strength may partially be due to the additional hydration of the unhydrated cement grains resulting from stream effect under the condition of internal autoclaving or due to evaporation of free water sample.

COLOUR CHANGES

Mineralogical reason

Silica fume mix samples exhibited a shifting colour from grey to red-orange between 600°C to 800°C, which was associated with the possible formation of Fe-silicates/hematite. This can be directly linked to Fe present in the majority fly ash component of the Silica fume cement.

No such drastic colour change was observed in the normal concrete. Slightly yellowing at above 800°C is likely to be due to sulphur formation from sulphides in any blast furnace slag present.

C100 mix at 800°C

C100 mix at 600°C

CRACKS

Cracks occurred at elevated temperature due to the internal pressure of evaporable moisture. Cracks are visually observed at 600°C to 800°C. There is no visible effect on the surface of the specimen heated upto 400°C. The concrete started to crack when the temperature increased to 600°C. But the effect was not significant at this temperature level. The cracks become very pronounced at 800°C.

Mineralogical reason

Cracks occurred at elevated temperature due to hydration of chemical compositions. For example the formation of ettringite after hydration over the silica, it compresses the other minerals and forms cracks. Appreciable coarsening of pores are appeared due to heating at high elevated temperatures at 600°C and 800°C.

Specimens exposed between 600°C to 800°C

5.6 XRD RESULT

The presence of a quartz peak at 27° 2Ɵ is a result of MS cement having been blended with minor quantities of unspecified pozzolanic additions. After treatment at 400°C, the only notable change in crystalline phases was the disappearance of ettringite signals. However, after treatment at 800°C, portlandite peaks disappeared, calcite peaks were greatly reduced and the formation of a dominant broad set of peaks due to poorly ordered crystals diffracting between 30° and 34° 2Ɵ appeared. Diffraction in this particular region corresponds well to alite and belite as well as non-hydraulic phases such as akermanite, gehlenite and etc,.

IV.CONCLUSIONS

In Silica fume mixed samples formation of Fe-silicates/hematite exhibited a change in color from grey to red-orange between 600°C to 800°C.

Weight loss was much more in normal concrete mix compared to Silica fume concrete mixes. Cracks were observed in all mixes between 600°C to 800°C.

Better cost economy due to lower material cost and highly favorable lifecycle cost.

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