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MICROSTRUCTURAL ANALYSIS OF STEEL FIBER TERNARY BLENDED HIGH STRENGTH CONCRETE SUBJECTED TO SUSTAINED ELEVATED TEMPERATURE

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ABSRACT

This paper deals with the analysis of microstructural properties of ternary blended high strength concrete subjected to sustained elevated temperature. The objective of this paper is to study the residual strength of various steel fiber reinforced ternary blended (ALCCOFINE,METAKAOLINE,SILICA FUME) high strength concrete with optimum percentage of steel fibers when subjected to sustained elevated temperatures like 200°C,400°C,600°C,800°C and 1000°C,To find the near surface characteristics such as water absorption and soroptivity.To study the microstructural properties of ternary blended steel fibre reinforced high strength concrete subjected to sustained elevated temperatures through

1. **Scanning Electron Microscopy (SEM)**
2. **X-ray Diffraction (XRD)**.
3. **Energy Dispersive Spectroscopy**

KEY-WORDS: microstructural properties, ternary blend, compressive strength, soroptivity, water absorption, steel fiber, SEM, XRD, EDS

1) INTRODUCTION

- The term of '**microstructure**' is used to describe the appearance of the material on the nanometer-centimeter length scale. The objective of the microstructural analysis is to support the findings shown in the mechanical testing analysis. It is important to notice that the performed microstructural analysis were qualitative with the objective to give additional information that can explain the results obtained in the other executed tests, The purpose of **SUSTAIN ELEVATED TEMPRATURE** Understanding performance characteristics of HSC when exposed to high temperature is an important first step in reducing the likelihood of structural collapse in the event of fire, which is the long term goal of project and To develop experimental data necessary for accurate characterization of behavior of HSC when subjected to fire, including the explosive spalling failure mechanism, These data can also be used for the validation of predictive models, which can account for the developed pore vapor pressure and the moisture transport in HSC, and the sudden spalling mechanism of HSC when subjected to fire.

2) LITERATURE REVIEW

(1)Balakrishnaiah.D, Dr.Srinivasa Rao.p, Adinarayana.D, studied Residual Compressive Strength of Ternary Blended Concrete at Elevated Temperatures they conclude that A gradual reduction in compressive strength was found with increase in temperature from 200oC to 600oC for exposure duration of 4 hours, The Ternary Blended Concrete has shown improved resistance for higher temperature for lower water/binder ratios(2) Dr. MOHD. HAMRAJ studied experimental study on binary blended high strength steel fiber reinforced concrete using alcoofine as mineral admixture and they conclude that 15% cement replacement with ***Alccofine*** gave optimum strength and workability for Binary Blended Concrete. Hence Binary Blended Concrete consisted of 85% OPC and 15% of Alccofine, The workability of SFRC mixes is improved with the partial replacement of cement with Alccofine (3)A Review of Microstructure Properties of Porous Concrete Pavement Incorporating Nano Silica and they conclude that From the review on the SEM observation, the texture of the cement paste containing nano silica was denser and compact,The XRD analyses show that by incorporating nano silica in cement paste, the intensity line of C-S-H higher than control cement paste.(4) **Chi-Sun Poon** et al (2003) carried out an experimental investigation to evaluate the performance of metakaolin (MK) concrete at elevated temperatures up to 800°C. Eight normal and high strength concrete (HSC) mixes incorporating 0%, 5%, 10% and 20% MK were prepared. The residual compressive strength, chloride-ion penetration, porosity and average pore sizes were measured and compared with silica fume (SF), fly ash (FA) and pure ordinary Portland cement (OPC) concretes. It was found that after an increase in compressive strength at 200°C, the MK concrete suffered a more severe loss of compressive strength and permeability related durability than the corresponding SF, FA and OPC concretes at higher temperatures. Explosive spalling was observed in both normal and high strength MK concretes and the frequency increased with higher MK contents.

3) MATERIALS AND METHODS

3.1) Material

Locally available 53 grade of Ordinary Portland Cement (Ultra Tech Brand) confirming to IS: 12269 was chosen for investigations. The cement was used in composition with fly ash and silica fume or alcoofine or metakaoline, supplasticizer Master Glenium sky 8860 (Fosroc Chemical India Ltd), river sand (Specific gravity of Fine Aggregate = 2.53) in accordance with IS 2386- 1963 standard specifications and coarse aggregate (machine crushed angular granite metal of 20mm) with specific gravity, bulk density and fineness modules of coarse aggregate are found to be 2.70, 1560 kg/cu m and 7.1 respectively. Locally available potable water was used for mixing and curing.

3.2) Mix proportions

Content for FA+ US

Mix Proportion(FA+SF)	OPC+1% steel(0+0)	OPC+1% steel(10+0)	OPC+1% steel(10+6.5)	OPC+1% steel(10+9.75)	OPC+1% steel(10+13)	OPC+1% steel(10+16.75)

Content for FA+ SF

Mix Proportion(FA+SF)	OPC+1% steel(0+0)	OPC+1% steel(10+0)	OPC+1% steel(10+5)	OPC+1% steel(10+7.5)	OPC+1% steel(10+10)	OPC+1% steel(10+12.5)

Content for FA+ MK

Mix Proportion(FA+MK)	OPC+1% steel(0+0)	OPC+1% steel(10+0)	OPC+1% steel(10+5.68)	OPC+1% steel(10+8.52)	OPC+1% steel(10+11.5)	OPC+1% steel(10+14.2)

3.3) Casting of specimens

A total of 126, concrete cubes were cast using steel moulds of size 150mm x 150mm x 150mm

3.4) Testing

The specimens of ternary blended concrete, after 28 days of curing, were exposed to200°C,400°C,600°C,800°C and 1000°C for a duration of 4 hours in furnace and allowed to cool to room temperature. The tests were conducted using 2000 kN compression testing machine as per standard procedure for compressive strength. The average strength of three samples was taken per batch. After the specimens subjected to elevated temperature soroptivity test was coundcted and after that SEM and XRD analysis should be taken.

3.5) **METHODOLOGY**

Find loose and dry rodded dry bulk density of 20mm aggregate in 30 liter cylinder ,Find loose and dry rodded bulk density of 10 mm aggregate in 15 liter cylinder, Find loose and dry rodded bulk density of sand in 3 liter cylinder, In 30 liter cylinder put 20mm and 10mm in different proportions of (65%,35%),(64%, 36%), (66%, 34%), (50%, 50%), (70%, 30%), (30%, 70%), (40%, 60%),(60%, 40%), etc. and we find the maximum density rate was founded that,(65%, 35%) combination of 20mm and 10mm maximum bulk density which is a combination ,Sand was again add in the cylinder with C.A.:F.A. proportion of (65%, 35%),(64%, 36%), (66%, 44%), (70%, 30%), (60%, 40%), and (40%, 60%), etc. and we find the maximum density rate was founded that, (65%, 35%)maximum bulk density, Add weighted amount of cement slurry keeping on the vibrating table and find the maximum cement that can be found in the aggregate.

4) RESULTS AND DISCUSSION

4.1) Soroptivity test

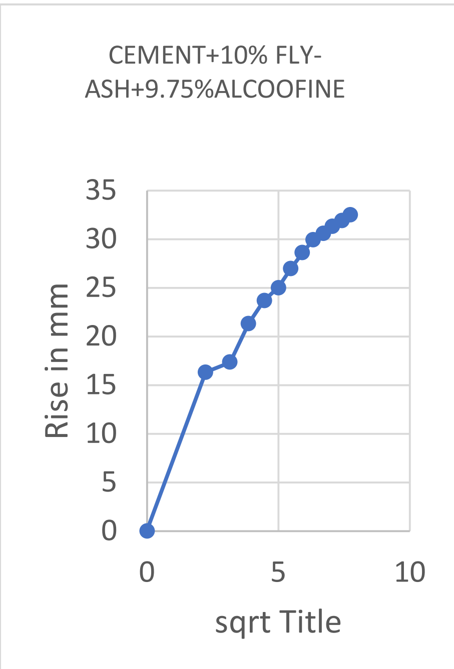
The cubical samples of size 150 x 150 x 150 mm were placed in a recipient in contact with level of water capable to submerge them about 5 mm for 1 hour.

Criteria for Soroptivity

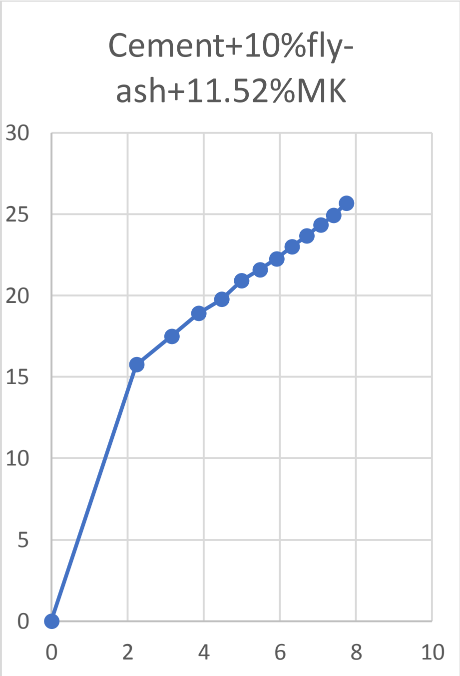
Acceptance Criteria		Soroptivity mm/min$^{0.5}$
Laboratory concrete		<6
As-built Structures	Full acceptance	<9
	Conditional acceptance	9 to 12
	Remedial measures	12 to 15
	Rejection	>15

As per soroptivity criteria following results

should be taken.



Sq.time	Rise in mm	soroptivity
0	0	0
2.236068	16.3	7.304489
3.162278	17.3	5.481281
3.872983	21.3	5.508243
4.472136	23.7	5.299481
5	25.0	5
5.477226	27.0	4.923417
5.91608	28.6	4.834282
6.324555	29.9	4.727605
6.708204	30.6	4.55661
7.071068	31.3	4.426488
7.416198	31.9	4.2969
7.7459	32.5	4.191429
	avg	5.04



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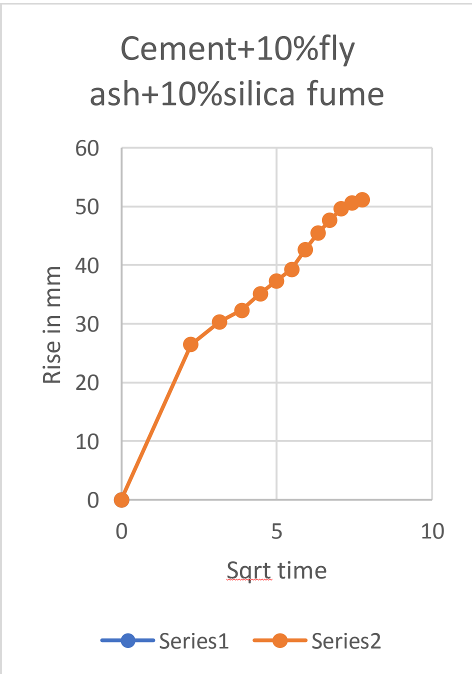

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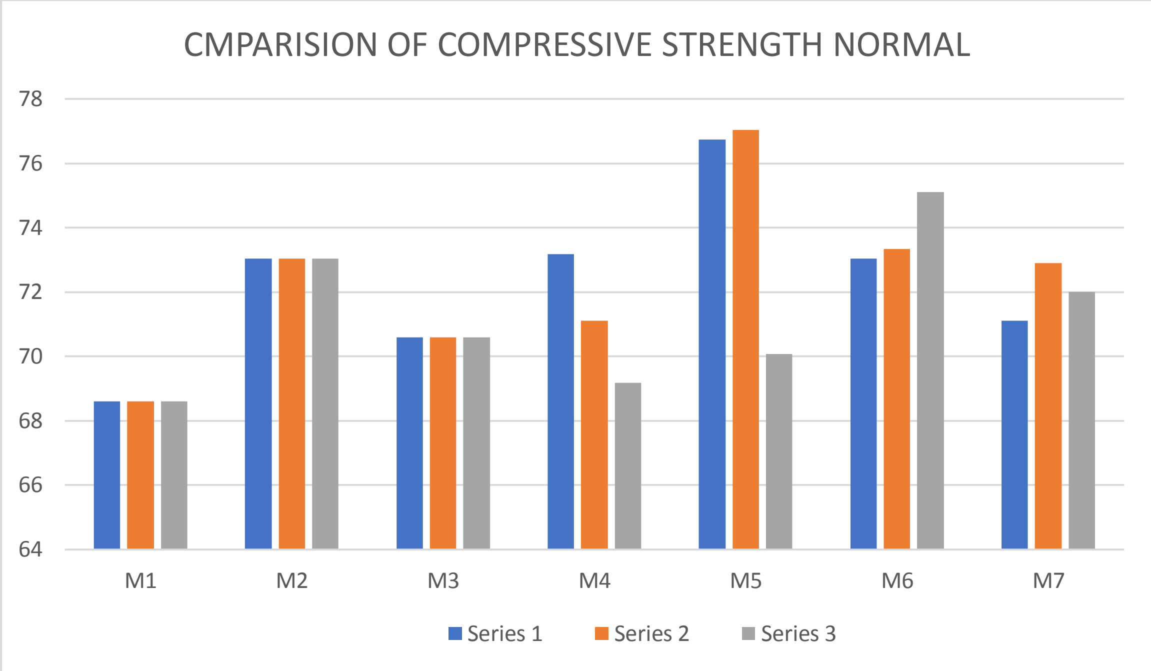
7.416198	31.9	4.2969
7.7459	32.5	4.191429
	avg	5.04

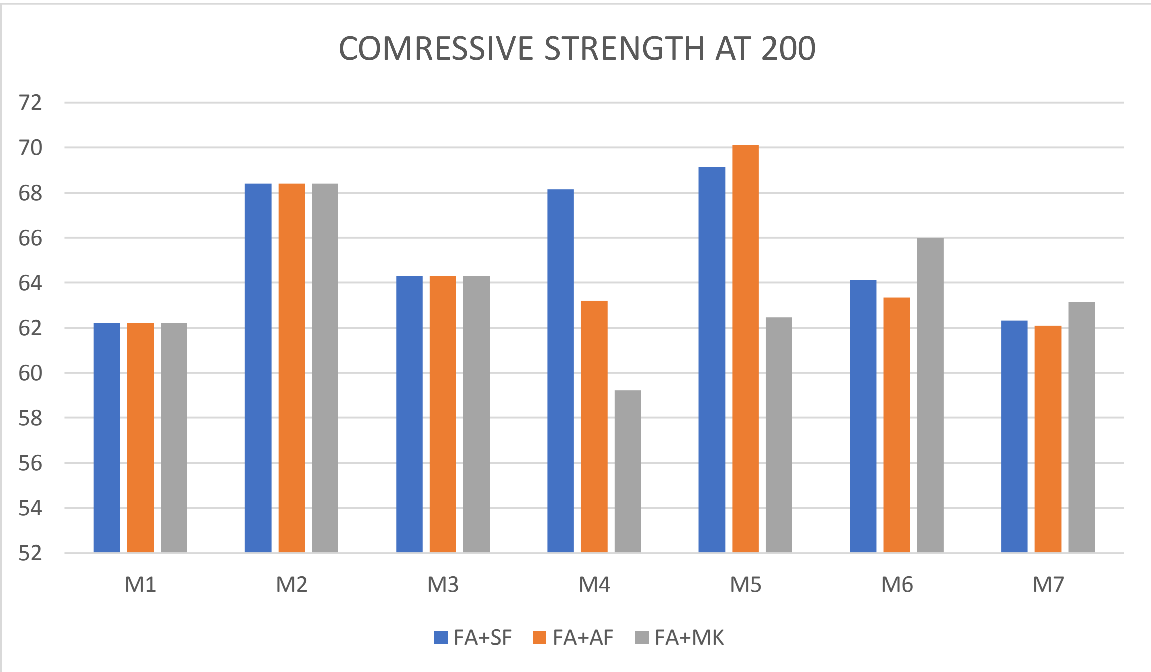
4.2) Compressive strength

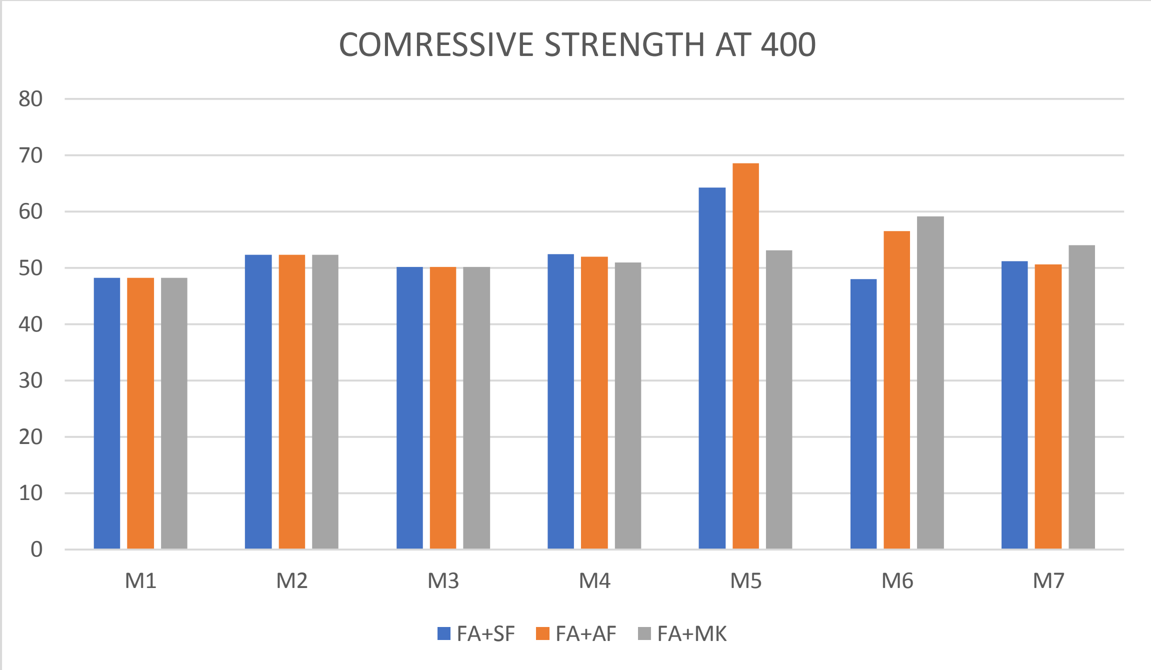
After 28 days curing following strength should be taken at elevated temperature,

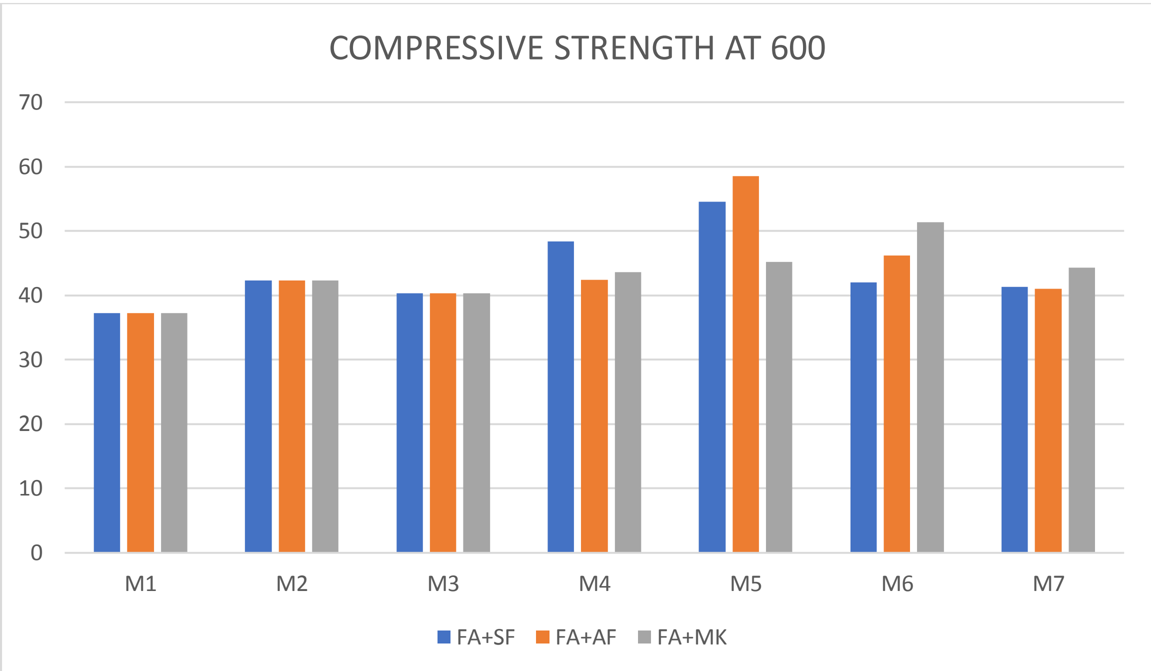
Percentage replacement of cement by ternary blends	Subjected to 600°C			Subjected to 800°C			Subjected to 1000°C		
	(FA+SF)	(FA+AF)	(FA+MK)	(FA+SF)	(FA+AF)	(FA+MK)	(FA+SF)	(FA+AF)	(FA+MK)
	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)
Ref. Mix.	37.25	37.25	37.25	21.11	21.11	21.11	0	0	0
Opc+1%steel	42.31	42.31	42.31	34.32	34.32	34.32	0	0	0
Opc+1%steel(10+0)	40.32	40.32	40.32	30.5	30.5	30.5	0	0	0
Opc+1%steel (10+5)	48.36	42.36	43.58	31.25	25.36	26.39	0	0	0
Opc+1%steel (10+7.5)	54.54	58.47	45.21	37.77	39.46	29.65	1.35	2.31	0
Opc+1%steel (10+10)	42	46.14	51.36	26.98	30.25	32.25	0	0	1.11
Opc+1%steel (10+12.5)	41.25	40.98	44.25	24.25	23.21	25.63	0	0	0

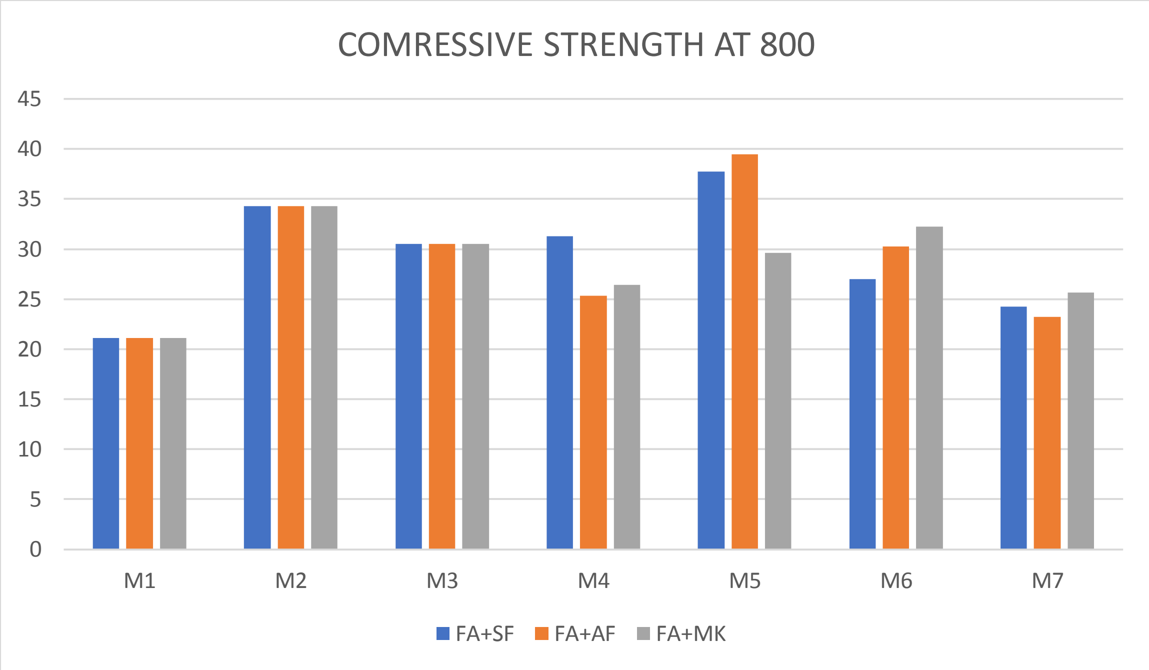
Percentage replacement of cement by ternary blends	Subjected to NORMAL TEMP.			Subjected to 200°C			Subjected to 400°C		
	(FA+SF)	(FA+AF)	(FA+MK)	(FA+SF)	(FA+AF)	(FA+MK)	(FA+SF)	(FA+AF	(FA+MK)
	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)	Comp. strength (MPa)
Ref. Mix.	68.59	68.59	68.59	62.22	62.22	62.22	48.25	48.25	48.25
Opc+1%steel	73.04	73.04	73.04	68.4	68.4	68.4	52.34	52.34	52.34
Opc+1%steel(10+0)	70.59	70.59	70.59	64.3	64.3	64.3	50.21	50.21	50.21
Opc+1%steel (10+5)	73.18	71.11	69.18	68.14	63.2	59.23	52.44	52.01	51
Opc+1%steel (10+7.5)	76.74	77.03	70.07	69.14	70.1	62.47	64.21	68.54	53.14
Opc+1%steel (10+10)	73.03	73.33	75.11	64.12	63.34	66	48	56.47	59.17
Opc+1%steel (10+12.5)	71.11	72.89	72	62.31	62.1	63.14	51.23	50.56	54.01


CMPARISION OF COMPRESSIVE STRENGTH NORMAL
78
76
74
72
70
68
66
64
M1
M2
M3
M4
M5
M6
M7
Series 1
Series 2
Series 3


COMRESSIVE STRENGTH AT 200
72
70
68
66
64
62
60
58
56
54
52
M1
M2
M3
M4
M5
M6
M7
FA+SF
FA+AF
FA+MK


COMRESSIVE STRENGTH AT 400
80
70
60
50
40
30
20
10
0
M1
M2
M3
M4
M5
M6
M7
FA+SF
FA+AF
FA+MK


COMPRESSIVE STRENGTH AT 600
70
60
50
40
30
20
10
0
M1
M2
M3
M4
M5
M6
M7
FA+SF
FA+AF
FA+MK

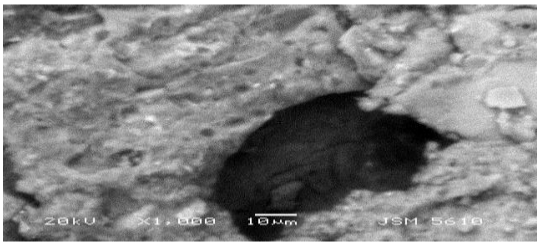


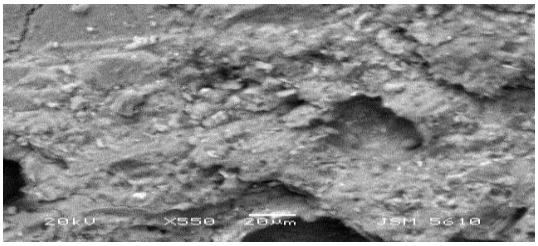
4.3) SEM AND EDS ANALYSIS

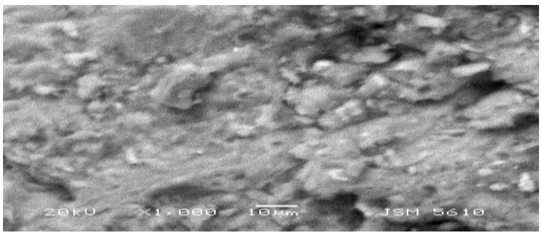
The SEM has unique capacities for analyzing surfaces. It is analogous to the reflected light althrough different radiation source to produce required illumination.

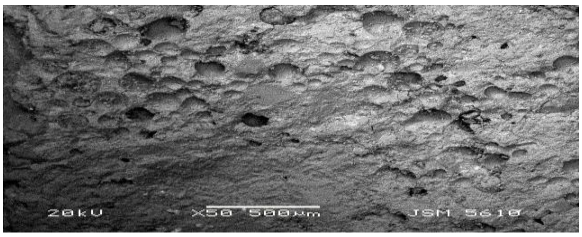
SEM ANALYSIS AT NORMAL TEMPRATURE;

SAMPLE 1; CEMENT+10% FLY-ASH+9.75 %ALCOOFINE



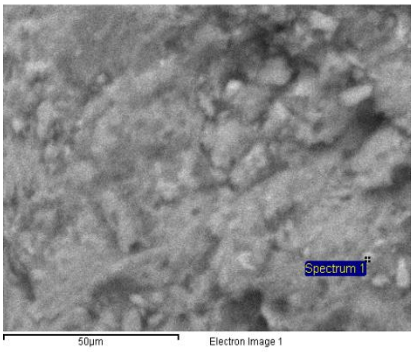


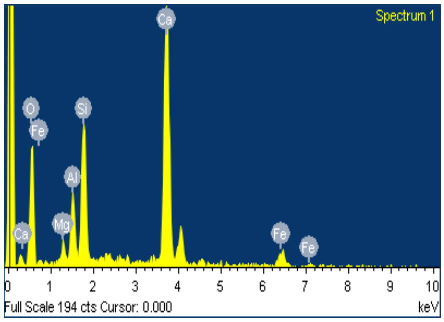




SEM Analysis show that,in figure 1 blank space is porocity, in figure 2 rounded particals are FLY-ASH, Triangular particals are alcoofine &all partical embedded in cementile matrix, in figure 3 & 4 dense and uniform distribution of variables.

EDS Analysis for sample 1;

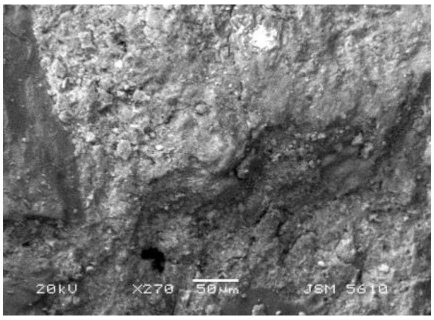


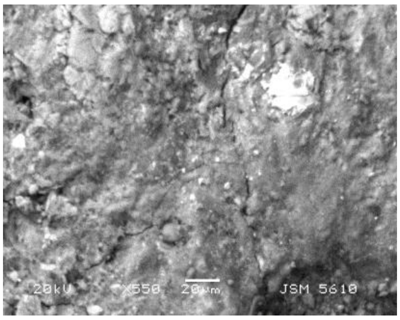


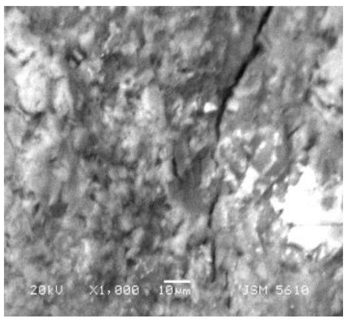
Element	Weight%	Atomic%
O K	53.81	71.75
Mg K	1.59	1.39
AI K	4.61	3.64
SI K	10.84	8.23
Ca K	25.53	13.59
Fe K	3.63	1.39
TOTAL	100	

EDS Analysis say that Cementing behaviour at localized area. It is a lined based flyash partical ,completely surrounded by cementile face.

SAMPLE 2; CEMENT+10% FLY-ASH+11.5%METAKAOLINE



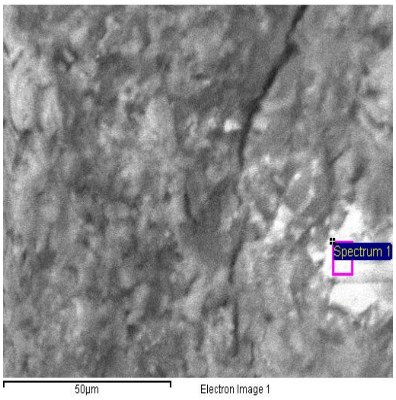


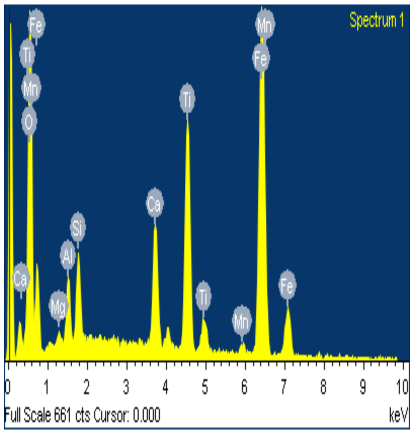


a) b) c)

for SAMPLE 2 SEM analysis say that, IN figure a) internal crack are found.IN figure b) titanium are shown, IN figure c) manganese & iron are presence in cementile matrix.

EDS Analysis for sample 2



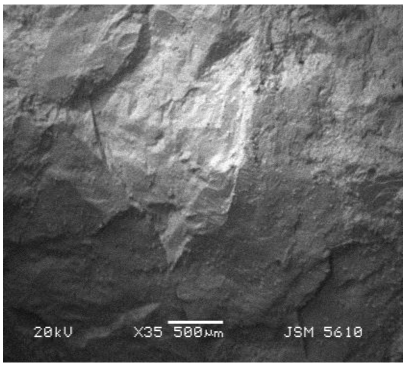


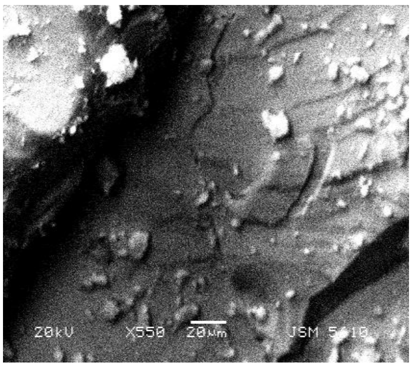
Element	Weight%	Atomic%
O K	41.89	68.29
Mg K	0.56	0.60
AI K	2.39	2.31
SI K	2.82	2.62
Ca K	4.33	2.82
Ti K	11.99	6.53
Mn K	0.80	0.38
Fe K	35.21	16.44
TOTAL	100	

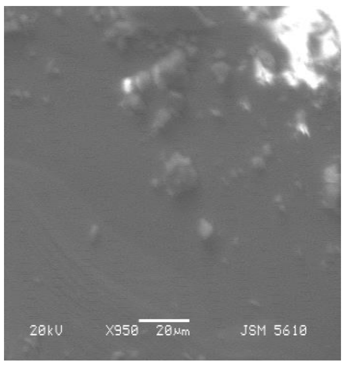
EDS analysis say that, IN figure a) internal crack are found.IN figure b) titanium are shown, IN figure c) manganese & iron are presence in cementile matrix.

SAMPLE 3; CEMENT+10% FLY-ASH+SILICFUME

SEM ANALYSIS

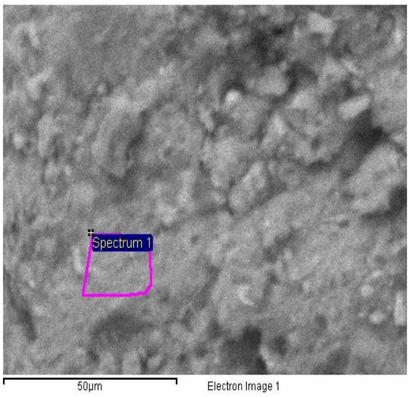


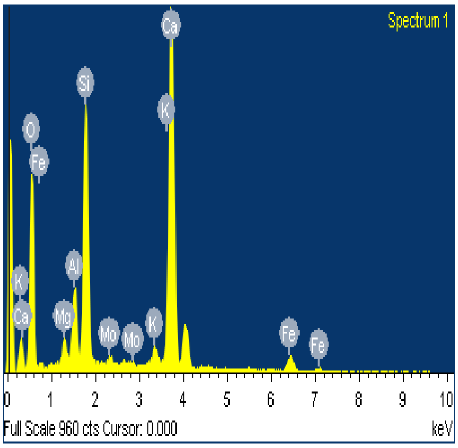




A) B) C)

EDS Analysis of sample 3



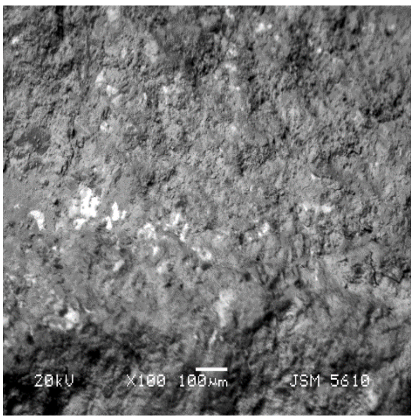


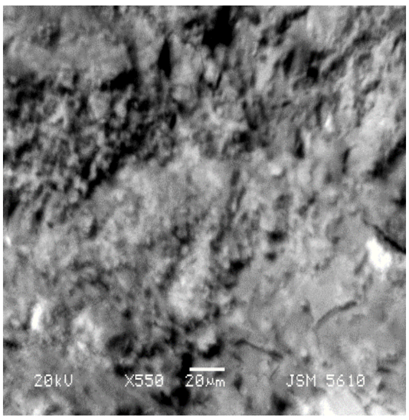
Element	Weight%	Atomic%
O K	56.64	74.09
Mg K	1.35	1.16
Al K	3.28	2.54
Si K	11.73	8.74
K K	0.99	0.53
Ca K	22.65	11.83
Fe K	2.37	0.89
Mo L	0.99	0.22
TOTAL	100	

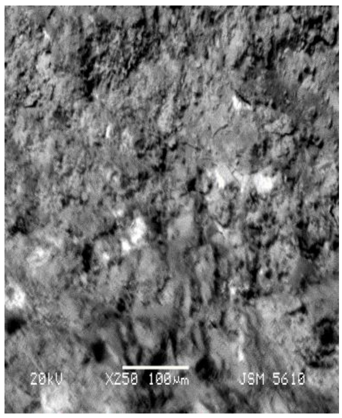
EDS analysis say that homogeneous and dense matrix are shown, change in the cementing behaviour, excess silica in the form of SF is retard the cementing behaviour of cement.

SEM ANALYSIS AT ELEVATED TEMPERATURE

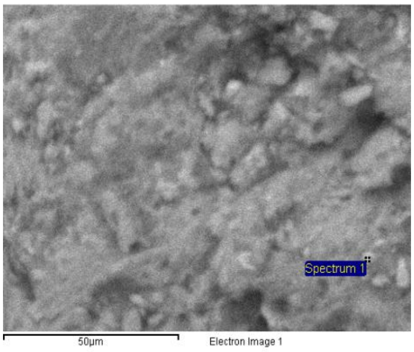
SAMPLE 1; CEMENT+10% FLY-ASH+ 9.75% ALCOOFINE

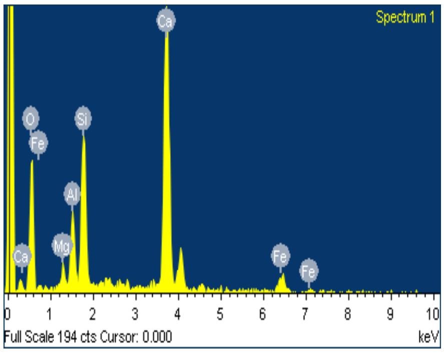






EDS ANALYSIS





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Ca K	25.53	13.59
Fe K	3.63	1.39
TOTAL	100	

SEM AND EDS analysis say that surface of the specimen uniformly varying smooth , internal cracks are found, face of the specimen is burn, internal portion of the specimen melt but it is shown that the specimen have good bindig layer so that it give better strength than other samples.

5) CONCLUSION

The following conclusions can be drawn from the present study:

1. It is observed that the **compressive strength** of ternary blended steel fiber reinforced concrete shows higher compressive strength at **(10% + 7.5%)** replacement with **(FA + SF)** combination.
2. Thus it can be concluded that the compressive strength of ternary blended concrete shows higher compressive strength at a replacement level of **(10+9.75)** with **(FA+AF)** combination.
3. It is observed that the compressive strength of ternary blended steel fiber reinforced concrete shows higher compressive strength at **(10+11.52)** replacement with **(FA+MK)** combination.
4. It is observed that in soroptivity test **(FA+9.75%AF),(FA+11.52%MK)** and **(FA+7.5% SF**) give best results**.**
5. SEM Analysis say that **(FA+9.75%AF)** have all partical embedded in cementile matrix and it have dense and uniform distribution of variables.
6. EDS Analysis say that **(FA+9.75%AF)** Cementing behaviour at localized area. It is a lined based flyash partical ,completely surrounded by cementile face.

7. SEM and EDS Analysis at elevated temperature say that **(FA+9.75%AF)** gives the best strength at elevated temperature, it have good binding strength.

6) SCOPE OF STUDIES

1. This study helps to know the behavior of specialized concrete at sustained elevated temperatures which can be used in industrial chimneys, cooling towers, gasification and liquification tanks and vessels which are subjected to high temperature in the field of metallurgical, chemical, power, glass and cement industries.

2. These specialized concretes would also be used extensively to meet the demand towards the new thrust of atomic power generation to resist the effects of artificially induced high temperatures such as might be encountered near furnaces or in atomic reactors, in pavements subjected to jet engine blast and in areas exposed to fire.

3. Also more importantly this study will also help to make structures and buildings more durable and sustaining in case of accidental fires or against acts of terrorism and war.

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