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Behavior of Ternary Blend of Portland Cement at Elevated Temperatures

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Abstract*: *The present work is performed for detailed analysis of the sub-systems for the prescribed condition. Its purpose is to provide information to engineers of use of ternary blend of Portland cement in construction of concrete structures. By replacing SUGAECANE BAGASSE ASH with cement was found to boost some properties of the paste, mortar and concrete including compressive strength and water tightness in certain to replace percentages and fineness. Different percentages of SUGARCANE BAGASSE ASH (0%, 5%, 10%, 15%, 20%, 25%, and 30%) and SILICA FUME 10% constantly maintained throughout the mixes for casting of ternary concrete. Concrete specimens are subjected to 7 and 28days curing and later on they are kept in different elevated temperatures. After that specimens are cooled by two different methods such as Air cooling and Water cooling. And then the specimens are allowed for testing. The test results cover the weight loss and development of compressive strength of OPCconcrete and ternary blended mix concrete with different percentages of sugarcanebagasse ash & silica fume and at curing period of 7 and 28 days and its residual compressive strength at elevated temperatures up to 700°C. These target temperatures were 200°C, 300°C, 500°C and 700°C under one hours heating exposure. The test results reveal that ternary blend of Portland cement is attractive for obtaining high strength, low permeability and maintaining workability when compared to ordinary Portland cement.

KEYWORDS : Elevated temperatures, air cooling, water cooling, sugarcane bagasse ash, silica fume.

I. INTRODUCTION

In construction materials concrete is the most broadly used material, It is a composite material composed of aggregate bonded together with fluid cement which hardens over time.

For the acceptable limits of uniformity, workability, and strength of the end product the composition and quantity of each constituent of concrete should be controlled as they influences the characteristics of the concrete.

A. Sugarcane Bagasse Ash

The by-product obtained from sugar industries after controlled burnt to generate power for requirement of different activities in the factory is called as bagasse. Material obtained by the burning of leaves, as a waste is called as bagasse ash, which is replaced by cement because of its potential pozzolonic property[3].

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B. Silica Fume

Silica fume is made in electric discharge chamber as a by-product of the silicon contained elemental element's or alloys. Silica fume looks similar to Portland cement or some fly ashes because of its gray coloured powder. It is used as a supplementary cementations material.

C. Super Plasticizer

Superplasticizers, are used to reduce the high vary of water amount, chemical-admixtures are used for well-dispersed particle suspension wherever it is needed.

D. Effect of elevated temparatures on concrete:

Behavior of concrete at hot temperature depends on exposure conditions (i.e., temperature-moisture-load-time regime). Curing influences the degree of hydration. Concrete at elevated temperature is sensitive to the temperature level, heating rate, thermal cycling, and temperature duration (as long as chemical and physical transformations occur)[1].

II. TESTS PERFORMED

A. Test on Fresh Concrete

Strength, durability, appearance of the finished product and as well as cost of labour is being affected by the physical parameters of concrete. Easily placed and compacted homogeneous concrete (i.e. without bleeding and segregation), then it is termed as workable.

Workability methods: By the following methods workability of concrete is determined:

1. Slump cone
2. Compacting factor
3. Vee – bee test

In this project to determine the workability the slump cone test and compaction factor test is conducted.

B. Test on Hardened Concrete

Compressive strength:

Compressive testing machine is used to test the cube specimens for determining compressive strength for 28 days. At least three specimens belonging to different batches should be allowed for testing for each selected age. Just before the 4 to 5 hours of test performed specimens should be removed from water. After placing the specimen in the machine gradual load is applied continuously at the rate of 140 kg/cm^2 per minute till specimen fails.

Load at the failure divided by area of specimen gives compressive strength of concrete.

III. RESULTS AND DISCUSSIONS

Behavior of concrete containing sugarcane bagasse ash & silica fume at elevated temperature of Air cooling and water cooling:

Weight loss of Air cooling and Water cooling cubes after exposure to elevated temperatures:

The variation of weight loss of OPC and Ternary concrete as a function of treatment at elevated temperatures and cooled by air and water cooling at different replacements are represented in table.

Table 3.1: summary of weight loss in ternary concrete at elevated temperatures and cooled with air cooling

	A-series (0%)	B-series (5%)	C-series (10%)	D-series (15%)	E-series (20%)	F-series (25%)	G-series (30%)
200	0.112	0.135	0.146	0.132	0.134	0.132	0.227
300	0.187	0.219	0.273	0.264	0.272	0.338	0.288
500	0.404	0.427	0.546	0.443	0.546	0.55	0.567
700	0.539	0.552	0.595	0.564	0.578	0.566	0.6

Graph 3.1: AC (temp. Vs weight loss)

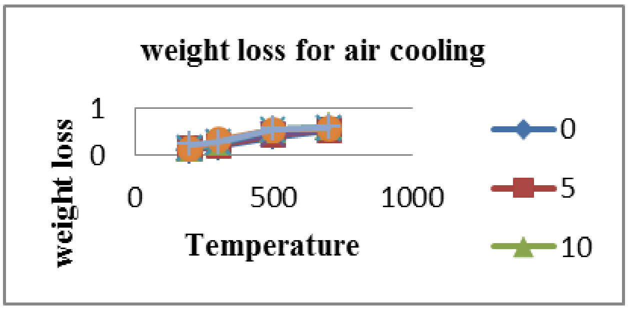
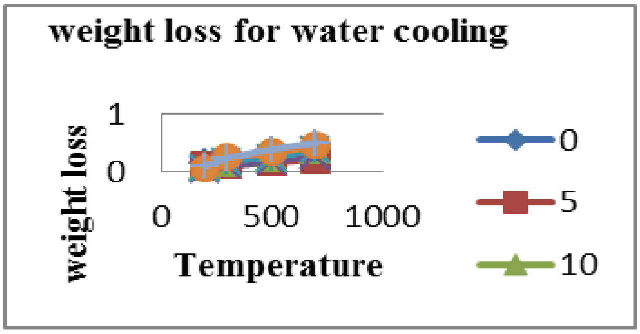


Table 3.2: summary of weight loss in ternary concrete at elevated temperatures and cooled with water cooling.

	A-series (0%)	B-series (5%)	C-series (10%)	D-series (15%)	E-series (20%)	F-series (25%)	G-series (30%)
200	0.148	0.103	0.077	0.012	0.06	0.05	0.089
300	0.111	0.107	0.152	0.101	0.175	0.249	0.234
500	0.163	0.158	0.219	0.175	0.239	0.339	0.374
700	0.249	0.201	0.376	0.245	0.383	0.454	0.496

Graph 3.2: WC (temp. Vs weight loss)



Observations for weight loss of ternary concrete:

1. From the above graph 3.1 & 3.2 we observed that the weight loss of the specimen increases as the exposure temperature increases.
2. Graphs 3.1 & 3.2 shows that for case of 15% replacement of OPC with SCBA and SF, drop in weights is observed. And for the next levels of replacement there is further increase in weight loss.
3. It seems that for the case of 15% replacement of OPC with SCBA and SF, the densification of concrete must be better and hence chances for the discharge of moisture could be lesser compared to others.

Compressive strength:

The variation of compressive strength of Ternary concrete as a function of treatment temperature up to 700°C and cooled with Air and Water cooling is represented in the tables. Also, the residual compressive strength of concrete at different elevated temperatures at 7, 28 days is graphically represented in graphs.

Table 3.3: Air cooling 7Days compressive strength test

	A-series (0%)	B-series (5%)	C-series (10%)	D-series (15%)	E-series (20%)	F-series (25%)	G-series (30%)
27	20.59	23.55	21.97	24.59	17.03	16.14	4.14
200	23.7	26.52	25.19	28.59	20.59	17.33	6.33
300	21.77	25.62	23.1	26.81	19.7	16.59	5.62
500	26.22	29.62	28.14	31.11	24.44	21.92	7.1
700	16.15	18.81	16.73	20.74	15.11	11.1	4.29

Table 3.4: Air cooling 7Days Residual compressive strength test results

	A-series (0%)	B-series (5%)	C-series (10%)	D-series (15%)	E-series (20%)	F-series (25%)	G-series (30%)
27	100	100	100	100	100	100	100
200	115.10	112.60	114.66	116.27	120.90	107.37	152.90
300	105.73	108.79	105.14	109.03	115.68	102.79	135.75
500	127.34	125.77	128.08	126.51	143.51	135.81	171.50
700	78.44	79.87	76.15	84.34	88.73	68.77	103.62

Graph 3.3: Temp. Vs R.C.S (AC-7 Days)

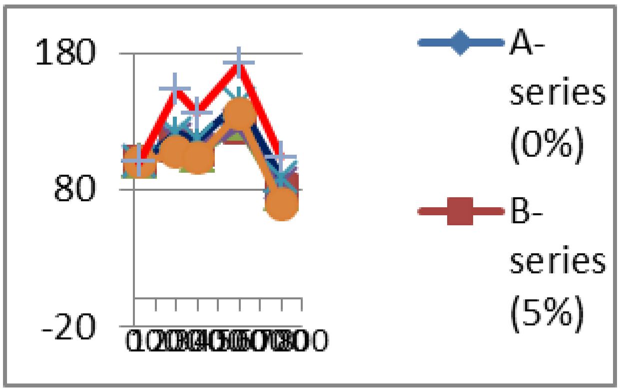


Table 3.5: Air cooling 28Days Compressive strength test results

	A-series (0%)	B-series (5%)	C-series (10%)	D-series (15%)	E-series (20%)	F-series (25%)	G-series (30%)
27	30.66	33.03	32	34.07	29.03	21.33	14.2
200	33.18	35.11	34.37	36.44	32.44	21.92	16.14
300	31.85	34.66	33.62	35.55	31.25	21.77	15.55
500	34.66	36.14	35.4	37.77	33.62	23.4	17.03
700	23.25	26.21	25.1	27.4	23.11	17.62	10.96

Table 3.6: Air cooling 28Days Residual Compressive strength test results

	A-series (0%)	B-series (5%)	C-series (10%)	D-series (15%)	E-series (20%)	F-series (25%)	G-series (30%)
27	100	100	100	100	100	100	100
200	108.22	106.30	107.41	106.96	111.75	102.77	113.50
300	103.88	104.93	105.06	104.34	107.65	102.06	109.35
500	113.05	109.42	110.63	110.86	115.81	109.70	119.76
700	75.83	79.35	78.44	80.42	79.61	82.61	77.07

Graph 3.4: Temp. Vs R.C.S (AC-28 Days)

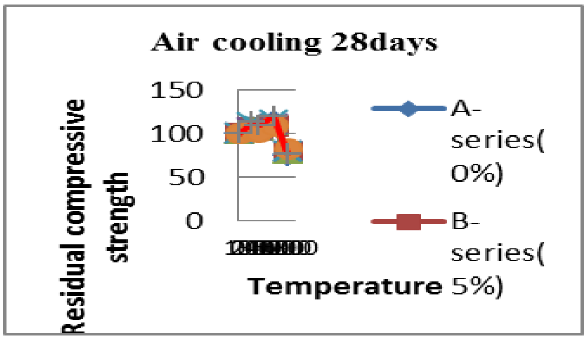


Table 3.7: Water cooling 7Days Compressive strength test results

	A-series (0%)	B-series (5%)	C-series (10%)	D-series (15%)	E-series (20%)	F-series (25%)	G-series (30%)
27	20.59	23.55	22.96	24.59	17.03	16.14	5.18
200	22.07	24.14	23.25	26.51	19.99	17.63	6.81
300	19.1	22.67	20.1	23.11	16.88	10.67	4.14
500	18.37	21.48	19.36	22.22	14.67	9.93	3.85
700	13.63	14.96	14.66	17.03	12.14	6.51	3.26

Table 3.8: Water cooling 7Days Residual Compressive strength test results

	A-series (0%)	B-series (5%)	C-series (10%)	D-series (15%)	E-series (20%)	F-series (25%)	G-series (30%)
27	100	100	100	100	100	100	100
200	107.19	102.51	101.26	107.81	117.38	109.23	131.47
300	92.76	96.26	87.54	93.98	99.12	66.11	79.92
500	89.22	91.21	84.32	90.36	86.14	61.52	74.32
700	66.20	63.52	63.85	69.26	71.29	40.33	62.93

Graph 3.5: Temp. Vs R.C.S (WC-7 Days)

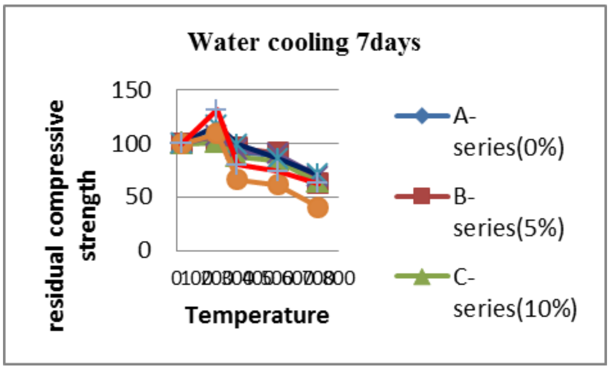


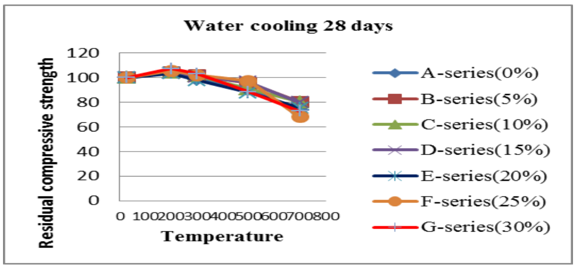
Table 3.9: Water cooling 28Days Compressive strength test results

	A-series (0%)	B-series (5%)	C-series (10%)	D-series (15%)	E-series (20%)	F-series (25%)	G-series (30%)
200	32	34.51	33.33	35.41	30.07	22.51	15.25
300	30.22	33.62	32.44	34.07	28.44	21.77	14.66
500	28.14	31.55	29.03	32.88	25.48	20.73	12.59
700	22.51	26.51	25.62	27.25	21.92	14.51	10.37

Table 3.10: Water cooling 28Days Residual Compressive strength test results

	A-series (0%)	B-series (5%)	C-series (10%)	D-series (15%)	E-series (20%)	F-series (25%)	G-series (30%)
27	100	100	100	100	100	100	100
200	104.37	104.48	104.16	103.93	103.58	105.53	107.24
300	98.56	101.79	101.38	100.88	97.97	102.06	103.09
500	91.78	95.52	90.72	96.51	87.77	97.19	88.54
700	73.42	80.26	80.06	79.98	75.51	68.03	72.93

Graph 3.6: Temp. Vs R.C.S (WC-28 Days)



Observations for Residual compressive strength of ternary concrete:

- From the graphs 3.5 & 3.6 it is observed that the strength is decreased with increase of temperature when subjected to immediate water cooling for all the cases of ternary blended concrete.
- From the graphs 3.3 & 3.4 it shows that the phenomenal strength is decreased at 300^{o}c and regained strength at 500^{o}c when subjected to air cooling for all the cases of ternary blended concrete.
- It is noticed that 15% SCBA & 10% SF exhibited better performance compared to other percentage replaced ternary concrete when subjected to elevated temperatures with Air cooling.
- From the graphs 3.5 & 3.6 it is identified that at 200°c the ternary blended concrete performed well when subjected to elevated temperatures with sudden cooling.
- From the graphs 3.3 & 3.4 at air cooling it is seen that the compression strength is higher at 500°c at all replacements levels of ternary blended concrete.
- This increase in strength in Sugar cane bagasse ash concrete is due to presence of high Silica in Sugar cane bagasse ash. Silica in Sugar cane bagasse ash react with residual CH after the formation of C-S-H gel, and increase the amount of C-S-H gel and results in increase the strength.
- It is observed that at all percentage replacements the ternary concrete of SCBA & SF indicates poor endurance properties at 700^{0}C this is due to complete detoriation of C-S-H gel after temperature is exceeding 500^{0}C.
- Due to the fine particles present in the Sugarcane bagasse ash, they react with the residual chemical and also fill the pores that formed while hydration of cement thus increases the strength.

IV. CONCLUSION

1. From the present study, it is noticed that 15% SCBA & SF ternary concrete replacement of OPC has shown better performance at all temperatures.
2. Increase in strength and decrease in setting time has been observed in addition of Silica fume
3. Rate of loss in strength is highly reliant on the type of cooling regimes. The loss of compressive strength is minimum under air cooling as the heat gradient is gradual, whereas the loss is maximum under sudden cooling due to sudden thermal shock.
4. SCBA inclusion reduces the $Ca\ (OH)_2$ content which is responsible for reduction in cracks and hence rises in compressive strength in concrete.
5. For air cooling the maximum compression strength is gained at 500^{0}C at all replacement levels of ternary concrete.
6. For Water cooling the maximum compression strength is gained at 200^0 C at all replacement levels of ternary concrete.
7. Ultimately, it is concluded that use of ternary blend of Portland cement at elevated temperatures can be designed for high strength, low permeability, sulphate resistant and elimination of thermal cracks.

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