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Residual characteristic properties of ternary blended steel fibre reinforced concrete subjected to sustained elevated temperature

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Abstract. To study the behavior of ternary blended steel fibre reinforced concrete when subjected to 800 Deg.C and 1000 Deg.C for 3 hours. It has been found that the ternary blended steel fibre reinforced concrete containing (FA+GGBFS) and (FA+MK) offer higher resistance to sustained elevated temperatures upto 800 Deg.C, where as the blend containing (FA+SF) does not offer any resistance at this temperature. The study reveals that the blend containing (FA+GGBFS) and (FA+MK) gives highest resistance at replacement levels of (10+20) and (15+15) respectively at sustained exposure to 800 Deg.C.

1. INTRODUCTION

Human safety in case of fire is one of the major considerations in the design of buildings. It is extremely necessary to have a complete knowledge about the behavior of all construction materials before using them in the structural elements. Concrete is a non-homogeneous material consisting of hardened cement paste and aggregates. With an increase in temperature, cracking is initiated due to thermal incompatibilities between the aggregates and the hardened cement paste. Developments in 1990s have seen a marked increase in the number of structures involving the first time heating of concrete. These include nuclear reactor pressure vessels, storage tanks for hot crude oil and hot water, coal gasification and liquefaction vessels, pavements subjected to jet engine blast, and in areas exposed to fire. The extensive use of concrete as a structural material in all the above mentioned structures and public utility buildings, multistory buildings, exposed to the elements of terrorism necessitated the need to study the behavior of concrete at high temperature and its durability for the required needs [1].

At high temperature pore pressure is built due to the vaporization of physically and chemically bound water which causes internal stresses [2]. It has been found that fibres enhance the tensile strength of concrete and help to withstand the pore pressure generated due to vaporization of water at elevated temperature. At elevated temperature decomposition of calcium hydroxide to calcium oxide occurs. If calcium oxide is wetted again or exposed to moist air, it rehydrates to calcium hydroxide accompanied by large expansion in volume which will disrupt concrete. This disadvantage can be minimized by reducing the calcium hydroxide content in the cement by addition of suitable pozzolanic materials. The maximum exposure temperature, exposure time, heating and cooling rates are also among the important factors [3].

Incorporating a single supplementary cementitous material (SCM) like fly ash (FA), silica fume (SF), metakaolin (MK), ground granulated blast furnace slag (GGBFS) to improve a concrete rheology or a specific durability property, may have associated limitations with its use (depending on the SCM), such as low early age strength, extended curing periods, increased admixture use, increased plastic shrinkage cracking, and freeze/thaw scaling in the presence of de-icer salts. The use of appropriately proportioned ternary blends allows the effects of one SCM to compensate for the inherent shortcomings of another. Such concretes have been found to exhibit excellent fresh and mechanical properties [4].

Research has been carried out to evaluate the performance at elevated temperatures on blended cement concretes containing supplementary cementitious materials (SCM) as partial replacement to ordinary Portland cement. These SCM include industrial by- products like fly ash [5, 6], silica fume [7], ground granulated blast furnace slag [8] and metakaolin [9] etc. The research indicated fire resistance of concrete is highly dependent on its constituent materials, particularly the pozzolanas. Experimental investigations also indicate the addition of silica fume highly densifies the pore structure of concrete, which can result in explosive spalling due to the buildup of pore pressure by steam. It is seen that the addition of fly ash or ground granulated blast furnace slag enhances the fire resistance of concrete. It is reported that the compressive strength of fly ash concrete retained higher strengths than the pure OPC concrete at higher temperature up to 650 °C. Research work has been carried out on three high strength concrete mixtures incorporating silica fume fly ash and ground granulated blast furnace slag independently subjecting to a maximum temperature of 900 °C and tested under load conditions. It is observed that ground granulated blast furnace slag concrete showed the best performance followed by fly ash and silica fume concretes. Similarly, research work has also been carried out to evaluate the performance of metakaolin concrete at elevated temperature up to 800 °C. The research findings have indicated that after an increase in compressive strength at 200 °C the metakaolin concrete suffered a more severe loss of compressive strength and permeability-related durability than the corresponding silica fume, fly ash and normal Ordinary Portland Cement (OPC) concretes at higher temperatures.

2. RESEARCH SIGNIFICANCE

As steel fibre reinforced concrete (SFRC) with ternary blends possesses a number of advantages it is essential that the fundamental behavior of SFRC with ternary blends under elevated temperatures is clearly understood. The performance characteristics of SFRC with ternary blends when exposed to elevated temperatures are important to reduce the risk of structural collapse in the event of fire. Hence, the present research programme aimed at generating experimental data necessary for characterizing the behavior of SFRC with ternary blends when exposed to elevated temperatures.

3. EXPERIMENTAL PROGRAMME

Main objective of this experimental investigation is to study the behavior of ternary blended steel fibre reinforced concrete when subjected to sustained elevated temperatures such as 800 °C and 1000 °C for 3 hours. 30% of cement is replaced by ternary blend combinations such as (FA+SF), (FA+GGBFS) and (FA+MK). The proportions of (FA+SF) or (FA+GGBFS) or (FA+MK) are (0+0), (30+0), (25+5), (20+10), (15+15), (10+20), (5+25) and (0+30). The residual strength characteristics such as compressive strength and tensile strength are studied. The mix design was carried out for M30 grade concrete as per IS: 10262-2009 [10] which yielded a proportion of 1:1.86: 2.41 with a w/c ratio of 0.45. The dosage of superplasticizer used was 0.78% (by weight of cement). The cement, sand and coarse aggregates were weighed according to the proportion of 1:1.86: 2.41 and dry mixed. Before mixing, 30% of cement was replaced by (FA+SF), (FA+GGBFS) and (FA+MK) according to the proportions such as (0+0), (30+0), (25+5), (20+10), (15+15), (10+20), (5+25) and (0+30) respectively. The required amount of water was added to this dry mix and intimately mixed. The calculated quantity of superplasticizer was now added and mixed thoroughly. After this, 1% steel fibres by volume was added to the mix and the entire concrete was agitated thoroughly to get a homogeneous mix. Then the mix was placed layer by layer in the moulds to cast the specimens. The specimens were prepared both by hand compaction as well by imparting vibrations through vibrating table. The specimens were finished

Table 1. Physical properties of fly ash.

Properties	Results	Requirement as per IS 3812-2003
Fineness, specific surface area (m^2/kg)	333	>320
Particles retained on 45 micron. IS sieve (Wet sieving) in %	3.5	<34
Lime reactivity, average compressive strength N/mm^2	4.58	>4.5
Compressive strength at 28 days in N/mm^2.	17.3	> 80% of the strength of corresponding plain cement mortar works

Table 2. Chemical properties of fly ash.

Properties	Results obtained	Req. as per IS 3812-2003
Silicon dioxide (SiO_2)+ Aluminum Oxide ($A1_2O_3$)+ Iron Oxide (Fe_2O_3) present by mass Min.	95.0	>70 Min.
Silicon dioxide (SiO_2), percent by mass Min.	62	>35 Min.
Total Sulphur as Sulphur trioxide (SO_3), percent by mass Max.	31	<3.0 Max.
Available Alkalis as sodium Oxide (Na_2O) in percent by mass Max.	NIL	>1.5 Max.
Loss on ignition, in percent by mass Max.	0.87	<5.0 Max.
Moisture content %	0.132	3.0 Max.

smooth and kept under wet gunny bags for 24 hours after which they were cured for 90 days and some of the samples were then tested for their 90 day strengths. After the curing remaining specimens were placed in the heating chamber, where in they were subjected to 800 °C or 1000 °C as the case may be for 3 hours. An electrical furnace consisting of 14 elements of Canthol wire giving electrical load of 14 KW was used for sustained elevated temperature test of concrete specimens. Furnace was cubical in shape of size 2 × 2 × 2 feet with a volume of 8 cubic feet, with temperature indicator, temperature sensor, and ampere rating. There is a knob to set the desired oven temperature.

The rate of temperature rise was 3 °C/minute. Specimens were maintained in the specified temperature for 3 hours. After 3 hours, all the specimens were removed and cooled to room temperature and then tested for their respective strengths as per IS [11, 12]. Percentage residual strength is calculated (% residual strength) = R_X X 100 / R_N, Where R_X is the strength at a particular temperature and R_N the strength at normal temperature.

3.1 Materials used

3.1.1 Cement: 53 grade ordinary portland cement (OPC), with specific gravity 3.15, initial setting time 120 minutes and final setting time 220 minutes, 7 day compressive strength of 29N/mm^2, 28 day compressive strength of 54N/mm^2, as per IS: 12269 – 1987 was used.

3.1.2 Fine aggregates: Locally available sand with specific gravity of 2.67, falling under the zone-II, complying with IS: 383 – 1970 was used.

3.1.3 Coarse aggregates: Locally available coarse aggregates of 12 mm and down size having a specific gravity of 2.74, complying with IS: 383 – 1970 was used.

3.1.4 Steel fibres: Steel fibers of 30 mm length and 0.7 mm thickness with corrugated shape which gave an aspect ratio of 42 were used. The steel fiber was added by 1% of volume fraction. Crimped steel fibres were used, since it helps in proper bonding.

Table 3. Physical and chemical properties of silica fume.

Sr No.	Particulars	Test results	Req. as per ASTM C-1240-03
Physical properties			
1	Particles retained on 45 micron Sieve (%)	0.4%	Max 10%
2	Bulk density kg/m^3	640	500 to 700
3	Specific gravity	2.2	2.2 to 2.4
4	Surface area (m^2/gm)	20	Min. 15
Chemical properties			
1	SiO_2	90.3%	Min 85%
2	Moisture content	0.6%	Max 3%
3	Loss of ignition @ 975 °C	2.1%	Max 6%
4	Carbon	0.8%	Max 2.5%

Table 4. Physical and chemical properties of GGBFS.

Characteristics	Test result	Requirements
Fineness m^2/kg	380	275(Min)
Soundness, Le-Chatelier Expansion(mm)	0	10(max)
Initial setting time (min)	210	Not less than IST of OPC
Insoluble residual (%)	0.11	1.5(max)
Magnesia content (%)	8.06	14(Max)
Sulphide content (%)	0.9	2.0 (Max)
Sulphite content (%)	0.28	2.5(Max)
Loss on ignition (%)	0.68	3.0 (Max)
Manganese content (%)	0.24	2.0(Max)
Chloride content (%)	0.001	0.10 (Max)
Moisture content (%)	0.01	1.0 (Max)
Glass content (%)	95.34	67(Min)
Compressive Strength after 7 days in N/mm^2	30.66	12 (Min)
Compressive Strength after 28 days in N/mm^2	48.6	32.5(Min)

3.1.5 Superplasticizer: Conplast SP 430, complying with IS: 9103 – 1979 was used, to impart workability. It was based on sulphonated naphthalene formaldehyde. Super plasticizer was used at the rate of 0.78% by weight of cement.

3.1.6 Pozzolanas: Properties of fly ash, silica fume, ground granulated blast furnace slag and metakaolin used in the experimentation are given in Tables 1 to 5.

4. EXPERIMENTAL RESULTS:

Tables 6, 7, 8 and 9 give the overall results of compressive and tensile strength of ternary blended steel fibre reinforced concrete at normal temperature and when subjected to 800 °C and 1000 °C. Tables also give the percentage increase or decrease of strength and residual strength.

5. OBSERVATIONS AND DISCUSSIONS

1. It was observed that at normal temperature after 90 days of curing the various ternary blended mixes gave better residual strength than the reference mix. It was observed that the reference mix had

Table 5. Physical properties of Metakaolin.

Physical properties	Results
Average particle size	1.5 μm
Residue 325 mesh,	0.5%
B.E.T. Surface area	15 m^2/gm
Pozzolanic reactivity	1050 mg
Specific gravity	2.5
Bulk density	300 ± 30 gm/lt
Brightness	80 ± 2
Physical form	Off-white power

compressive strength of 60.67 MPa, but the ternary blended mixes had healthy strength as follows: (FA+SF) combination with (10+20) gave 67.3 MPa, (FA+GGBFS) with (10+20) returned with 64.0 MPa and (FA+MK) with (15+15) returned with 64.6 MPa. Similar trend of observations are made in tensile strength of ternary blended steel fibre reinforced concrete with all the combination.

This may be attributed to the fact that the synergistic effect of the ternary blended combination can change the morphological structure of concrete by densifying the cement paste matrix and improving the interfacial zone. Also the replacement level of (10 + 20) with (FA+SF) and (FA + GGBFS) and replacement level of (15 + 15) with (FA+MK) probably have the higher pozzolanic reaction which can convert calcium hydroxide to calcium silicate hydrate gel. In addition, the physical effect of fine grains allows denser packing within the cement matrix and reduces the wall effect in the transition zone between the paste and aggregates thus returning higher strength for 90 days.

2. At 800 °C, it is observed from the experimental results that the ternary blended steel fibre reinforced concrete with the combination of (FA+SF) when subjected to a sustained elevated temperature of 800 °C for 3 hours shows a decreasing trend of compressive strength as silica fume content in it increases.

A similar trend was observed even with the tensile strength. At 800 °C the specimens with the combination of (FA+SF) have shown severe cracks. The residual strength is also observed to decrease as the silica fume content increases. This can be attributed to the fact that silica fume being very fine makes the concrete dense and brittle at 800 °C. Higher susceptibility of concrete with (FA+SF) combination to explosive spalling and cracking is due in parts to its lower permeability which limits the ability of water vapour to escape from the pores. This results in build up of pore pressure within the cement paste.

3. It is observed that the ternary blended steel fibre reinforced concrete with the combination of (FA+GGBFS) when subjected to sustained elevated temperature of 800 °C for 3 hours shows higher compressive strength at a cement replacement level of (10+20). Beyond this replacement, the compressive strength shows a decreasing trend. Similar observations were made with the tensile strength. Minor cracks were observed at 800 °C. But there was a color change from grey to whitish. The residual strength also shows peak of 31.48% at a replacement level of (10+20). This may be due to the fact of synergistic action of the combinations of (FA+GGBFS) at a cement replacement level of (10+20). Since ground granulated blast furnace slag has a rough textured surface, small pores are left within the concrete which can accommodate the vapour pressure due to rise in temperature and there by inducing resistance to concrete to sustain the temperature.

1. It is observed that the ternary blended steel fibre reinforced concrete with the combination of (FA+MK) when subjected to sustained elevated temperature of 800 °C for 3 hours shows higher compressive strength at a cement replacement level of (15+15). Beyond this replacement, the compressive strength shows a decreasing trend. Similar observations were made with the tensile strength. Minor surface cracks were observed at 800 °C. But there was a color change from gray to whitish. The residual strength also shows peak of 31.43% at a replacement level of (15+15).

Table 6. Overall results of compressive strength when subjected to 800 °C for 3 hours.

Percentage replacement of cement by ternary blends	SFRC with (FA+SF)					SFRC with (FA+GGBFS)					SFRC with (FA+MK)				
	Compressive strength of SFRC at normal temperature, after 90 day curing. (MPa)	Compressive strength of SFRC when subjected to 800 °C (MPa)	Percentage increase or decrease of compressive strength as compared to ref. mix	Percentage decrease of compressive strength when subjected to 800 °C	Residual strength (%)	Compressive strength of SFRC at normal temperature, after 90 day curing. (MPa)	Compressive strength of SFRC when subjected to 800 °C (MPa)	Percentage increase or decrease of compressive strength as compared to ref. mix	Percentage decrease of compressive strength when subjected to 800 °C	Residual strength (%)	Compressive strength of SFRC at normal temperature, after 90 day curing. (MPa)	Compressive strength of SFRC when subjected to 800 °C (MPa)	Percentage increase or decrease of compressive strength as compared to ref. mix	Percentage decrease of compressive strength when subjected to 800 °C	Residual strength (%)
(0+0) (Ref.)	60.67	18.07	-	70	29.78	60.67	18.07	-	70	29.79	60.67	18.07	-	70	29.78
(30 + 0)	61.33	18.22	1	70	29.71	61.33	18.22	1	70	29.71	61.33	18.22	1	70	29.71
(25 + 5)	64.37	17.04	-6	74	26.47	62.15	18.52	2	70	29.80	62.22	20.15	12	68	32.39
(20 + 10)	64.7	15.50	-14	76	23.96	63.04	18.67	3	70	29.61	63.85	20.24	12	68	31.70
(15 + 15)	66.22	14.96	-17	77	22.59	63.26	19.26	7	70	30.44	64.59	20.30	12	69	31.43
(10 + 20)	67.33	12.03	-33	82	17.87	64.00	20.15	11	69	31.48	62.96	15.32	-15	76	24.33
(5 + 25)	64.59	8.86	-51	86	13.72	62.07	17.78	-2	71	28.64	62.37	11.88	-34	81	19.05
(0 + 30)	64.15	5.33	-71	92	8.31	61.70	16.00	-11	74	25.93	60.74	6.22	-66	90	10.24

Table 7. Overall results of compressive strength when subjected to 1000 °C for 3 hours.

Percentage replacement of cement by ternary blends	SFRC with (FA+SF)					SFRC with (FA+GGBFS)					SFRC with (FA+MK)				
	Compressive strength of SFRC at normal temperature, after 90 day curing. (MPa)	Compressive strength of SFRC when subjected to 1000 °C (MPa)	Percentage increase or decrease of compressive strength as compared to ref. mix	Percentage decrease of compressive strength when subjected to 1000 °C	Residual strength (%)	Compressive strength of SFRC at normal temperature, after 90 day curing. (MPa)	Compressive strength of SFRC when subjected to 1000 °C (MPa)	Percentage increase or decrease of compressive strength as compared to ref. mix	Percentage decrease of compressive strength when subjected to 1000 °C	Residual strength (%)	Compressive strength of SFRC at normal temperature, after 90 day curing. (MPa)	Compressive strength of SFRC when subjected to 1000 °C (MPa)	Percentage increase or decrease of compressive strength as compared to ref. mix	Percentage decrease of compressive strength when subjected to 1000 °C	Residual strength (%)
(0+0) (Ref.)	60.67	0.00	-	100	0.00	60.67	0.00	-	100	0.00	60.67	0.00	-	100	0.00
(30+0)	61.33	0.00	0	100	0.00	61.33	0.00	0	100	0.00	61.33	0.00	0	100	0.00
(25+5)	64.37	0.00	0	100	0.00	62.15	2.22	0	96	3.58	62.22	0.00	0	100	0.00
(20+10)	64.7	0.00	0	100	0.00	63.04	3.11	0	95	4.94	63.85	0.00	0	100	0.00
(15+15)	66.22	0.00	0	100	0.00	63.26	4.30	0	93	6.79	64.59	0.00	0	100	0.00
(10+20)	67.33	0.00	0	100	0.00	64.00	4.89	0	92	7.64	62.96	0.00	0	100	0.00
(5+25)	64.59	0.00	0	100	0.00	62.07	4.52	0	93	7.28	62.37	0.00	0	100	0.00
(0+30)	64.15	0.00	0	100	0.00	61.70	3.26	0	95	5.28	60.74	0.00	0	100	0.00

Table 8. Overall results of tensile strength when subjected to sustained elevated temperature of 800 °C.

Percentage replacement of cement by ternary blends	SFRC with (FA+SF)					SFRC with (FA+GGBFS)					SFRC with (FA+MK)				
	Tensile strength of SFRC at normal temperature, after 90 day curing. (MPa)	Tensile strength of SFRC when subjected to 800 °C (MPa)	Percentage increase or decrease of tensile strength as compared to ref. mix	Percentage decrease of tensile strength when subjected to 800 °C	Residual strength (%)	Tensile strength of SFRC at normal temperature, after 90 day curing. (MPa)	Tensile strength of SFRC when subjected to 800 °C (MPa)	Percentage increase or decrease of tensile strength as compared to ref. mix	Percentage decrease of tensile strength when subjected to 800 °C	Residual strength (%)	Tensile strength of SFRC at normal temperature, after 90 day curing. (MPa)	Tensile strength of SFRC when subjected to 800 °C (MPa)	Percentage increase or decrease of tensile strength as compared to ref. mix	Percentage decrease of tensile strength when subjected to 800 °C	Residual strength (%)
(0+0) (Ref. mix)	6.19	1.95	-	68	31.56	6.19	1.95	-	68	31.56	6.19	1.95	-	68	31.56
(30+0)	6.27	1.99	2	68	31.74	6.27	1.99	2	68	31.74	6.27	1.99	2	68	31.75
(25+5)	6.54	1.90	-3	71	29.00	6.37	2.12	9	67	33.28	6.44	2.08	6	68	32.24
(20+10)	6.72	1.74	-11	74	25.89	6.47	2.31	18	64	35.70	6.74	2.17	11	68	32.20
(15+15)	6.94	1.70	-13	76	24.47	6.62	2.41	23	64	36.40	6.94	2.26	16	67	32.63
(10+20)	7.01	1.60	-18	77	22.82	6.89	2.45	26	64	35.61	6.79	2.12	9	69	31.27
(5+25)	6.59	1.56	-20	76	23.63	6.58	2.03	4	69	30.85	6.65	2.03	4	69	30.51
(0+30)	6.44	1.39	-29	78	21.58	6.30	1.79	-8	72	28.41	6.43	1.89	-3	71	29.35

Table 9. Overall results of tensile strength when subjected to sustained elevated temperature of 1000 °C.

Percentage replacement of cement by ternary blends	SFRC with (FA+SF)					SFRC with (FA+GGBFS)					SFRC with (FA+MK)				
	Tensile strength of SFRC at normal temperature, after 90 day curing. (MPa)	Tensile strength of SFRC when subjected to 1000 °C (MPa)	Percentage increase or decrease of tensile strength as compared to ref. mix	Percentage decrease of tensile strength when subjected to 1000 °C	Residual strength (%)	Tensile strength of SFRC at normal temperature, after 90 day curing. (MPa)	Tensile strength of SFRC when subjected to 1000 °C (MPa)	Percentage increase or decrease of tensile strength as compared to ref. mix	Percentage decrease of tensile strength when subjected to 1000 °C	Residual strength (%)	Tensile strength of SFRC at normal temperature, after 90 day curing. (MPa)	Tensile strength of SFRC when subjected to 1000 °C (MPa)	Percentage increase or decrease of tensile strength as compared to ref. mix	Percentage decrease of tensile strength when subjected to 1000 °C	Residual strength (%)
(0+0) (Ref.)	6.19	0.00		100	0.00	6.19	0.00		100	0.00	6.19	0.00		100	0.00
(30+0)	6.27	0.00	1	100	0.00	6.27	0.00	1	100	93.25	6.27	0.00	1	100	0.00
(25+5)	6.54	0.00	6	100	0.00	6.37	0.00	3	100	0.00	6.44	0.00	4	100	0.00
(20+10)	6.72	0.00	9	100	0.00	6.47	0.00	5	100	0.00	6.74	0.00	9	100	0.00
(15+15)	6.94	0.00	12	100	0.00	6.62	0.00	7	100	0.00	6.94	0.00	12	100	0.00
(10+20)	7.01	0.00	13	100	0.00	6.89	0.00	11	100	0.00	6.79	0.00	10	100	0.00
(5+25)	6.59	0.00	6	100	0.00	6.58	0.00	6	100	0.00	6.65	0.00	7	100	0.00
(0+30)	6.44	0.00	4	100	0.00	6.30	0.00	2	100	0.00	6.43	0.00	4	100	0.00

This may be due to the fact of synergistic action of the combinations of (FA + MK) at a cement replacement level of (15 + 15). Since metakaolin is a good pozzolanic material it can change the morphological structure of concrete thus improving the interfacial zone.

1. It is observed that the ternary blended steel fibre reinforced concrete with (FA+GGBFS) has shown more residual strength at sustained elevated temperature of 800 °C as compared to the combinations of (FA+SF) and (FA+MK). The order of preference can be given as (FA+GGBFS), (FA+MK) and finally (FA+SF).
2. It is observed that the ternary blended steel fibre reinforced concrete with the combinations (FA+SF) and (FA+MK) when subjected to 1000 °C have shown a crumbling effect and disintegration with severe cracks and spalling. Even these specimens could not be replaced from the oven to a safer place. The color was changed to total white. The specimens with the combination of (FA+GGBFS) have not crumbled much. Even though there were few serious cracks they could be tested on compression testing machine and have yielded minor compressive strength.

This may be due to the fact that GGBFS being more reactive in pozzolanic action have not allowed the serious cracks to appear.

6. CONCLUSIONS

All the ternary blended concrete mixes gave more strength than the binary blends and the reference mix both at normal temperature after 90 days of curing. The highest strength was observed as follows: (FA+SF) combination with (10 + 20), (FA + GGBFS) with (10 + 20) and (FA+MK) with (15+15) replacement levels at normal temperature after 90 days of curing. Ternary blended steel fibre reinforced concrete with the combination of (FA+SF) when subjected to sustained elevated temperature 800 °C shows poor performance. Ternary blended steel fibre reinforced concrete with the combination of (FA+GGBFS) when subjected to sustained elevated temperature of 800 °C shows better performance. Ternary blended steel fibre reinforced concrete with the combination of (FA+MK) when subjected to sustained elevated temperature of 800 °C shows better performance.

Ternary blended steel fibre reinforced concrete with the combination of (FA+GGBFS) shows higher resistance to sustained elevated temperature of 800 °C as compared to the combinations of (FA+MK) and (FA+SF). Ternary blended steel fibre reinforced concrete with the combination of (FA+GGBFS) can sustain to a little extent of sustained elevated temperature of 1000 °C where as the combination of (FA+SF) and (FA+MK) show very poor performance at 1000 °C.

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