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RESEARCH ARTICLE

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PERFORMANCE EVALUATION OF TERNARY BLENDED HYBRID FIBER REINFORCED CONCRETE

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ABSTRACT

Over the past several decades, extensive research work is in progress throughout the globe in concrete technology in finding alternative materials which can partially or fully replace ordinary Portland cement (OPC) and which can also meet the requirements of strength and durability aspects. Amongst the many alternative materials tried as partial cement replacement materials, the strength, workability and durability performance of industrial by products like flyash, blast furnace slag, silica fume, metakaolin, rice husk ash, etc., now termed as complimentary cementitious materials (CCM) are quite promising. Subsequently, these have led to the development of binary, ternary and tertiary blended concretes depending on the number of CCM and their combinations used as partial cement replacement materials.

In the present experimental investigation workability characteristics of fresh concrete as measured from slump test, compaction factor, Vee-Bee degree and flow table test are determined. And strength parameters such as compressive strength, tensile strength, flexural strength, shear strength and impact strength of hybrid fiber reinforced concrete with different ternary blends are found. Also near surface characteristics such as water absorption and sorptivity are determined.

Key words: Ternary blended concrete, hybrid fibers, fly ash, silica fume, matakaolin, ground granulated blast furnace slag (GGBFS), steel fibers, polypropylene fibers.

INTRODUCTION

Extensive research work for decades also is in progress throughout the globe in concrete technology in finding alternative materials which can partially or fully replace ordinary Portland cement (OPC) and which can also meet the requirements of strength and durability aspects. Amongst the many alternative materials tried as partial cement replacement materials, the strength, workability and durability performance of industrial by products like flyash, blast furnace slag, silica fume, metakaolin, rice husk ash, etc., now termed as complimentary cementitious materials (CCM) are quite promising. Subsequently, these have led to the development of binary, ternary and tertiary blended concretes depending on the number of CCM and their combinations used as partial cement replacement materials. The use of appropriately proportioned ternary blends allows the effect of one SCM to compensate for the inherent shortening of another.

Supplementary cementitious materials (SCMs) such as fly ash (FA) and slag are being increasingly used in cement and concrete due to environmental, economical, and concrete quality-related concerns. Concrete practice has shown that the performance of concrete containing SCMs, such as workability, entrained air stability, set time, and strength development, significantly varies with the sources or characteristics of the cementitious materials, SCM replacement levels, and weather conditions. Concrete containing SCMs often display slow hydration that is accompanied by slow setting and low early age strength. This effect is more pronounced as the level of SCM replacement is increased and when concrete is cured at a low temperature.

OBJECTIVE

The main objective of this experimental investigation is to study the performance evaluation of ternary blended hybrid fiber reinforced concrete. For the study, ternary blends such as(FA+SF), (FA+GGBFS) and (FA+MK) are chosen, in which 30% of cement is replaced by ternary blends in different proportions such as (30+0), (25+5),(20+10), (15+15), (10+20), (5+25) and (0+30). The workability characteristics are studied through slump, compaction factor, percentage flow and Vee Bee degree. The strength characteristics such as compressive strength, tensile strength, flexural strength and impact strength are studied. Along with this the near surface characteristics such as water absorption and sorptivity are studied. The work is carried out on fibre hybridization of (SF+PPF) on M30 grade of concrete.

MATERIAL USED

In this experimental study, Cement, sand, coarse aggregate, water, steel fibers and polypropylene fibers, flyash, silica fume, GGBFS and metakaolin are used.

Cement	**:** Ordinary Portland cement of 53 grade was used in this experiment conforming to I.S12269:1987
Coarse aggregates	**:** Locally available, maximum size 20 mm, specific gravity 2.60
Sand	**:** Locally available sand zone I with specific gravity 2.60, water absorption 1% conforming to I.S. – 383-1970.
Water	**:** Potable water was used for the experiment.
Chemical admixture	**:** Superplasticizer
Flyash	**:** Low calcium, class F dry fly ash from the silos of Raichur thermal power plant conforming to IS: 3812 (Part 1) – 2003 was used.
Silica fume	**:** It is supplied by Sai Durga Enterprises, Mariyappana playa , Rajajinagar, Bangalore.
Metakaolin	**:** It is supplied by Twenty Microns company Vadodhara. Metakaolin is obtained from the calcinations of kaolinitic clays at temperatures in the range of 700 - 800^{0}C.
GGBFS	**:** Low calcium, ground granulated blast furnace slag from the ACC cement plant, Kudithini, Hospet. Confirming to IS: 3812 (Part 1) – 2003 was used.
Steel fibers	**:** Crimped (L=35mm, thickness=1mm)
Polypropylene fibers	**:** 12mm lengths were used.

EXPEIMENTAL RESULTS

WORKABILITY TEST RESULTS

Following tables give the slump test, compaction factor test, Vee-Bee test and flow table test results for different combination of ternary blended hybrid fiber reinforced concrete. The variations in the workability are depicted in the form of graphs.

Table 1: Slump test results for different percentage replacement of cement by various blends of pozzolonas

Percentage replacement of cement by pozzolonas	Slump values in mm for cement replacement by		
	(FA+SF)	(FA+MK)	(FA+GGBFS)
(30%+0%) Ref. mix	63	63	63
(25%+5%)	65	68	65.7
(20%+10%)	67	71	69
(15%+15%)	70	73.5	72.3
(10%+20%)	73	75	74
(5%+25%)	74	76.3	71
(0%+30%)	72	77.5	69.4

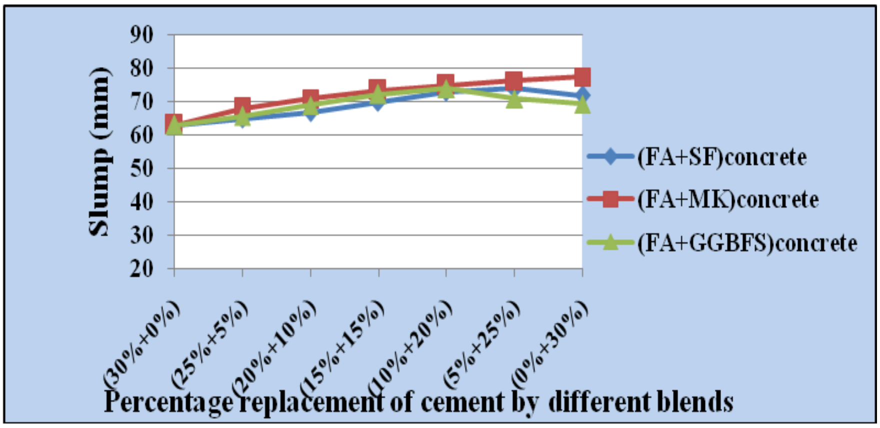

Fig. 1 Variation of slump

Table 2 Compaction factor test results for different percentage replacement of cement by various blends of pozzolonas

Percentage replacement of cement by pozzolonas	Compaction factor for cement replacement by		
	(FA+SF)	(FA+MK)	(FA+GGBFS)
(30%+0%)Ref. mix	0.923	0.923	0.923
(25%+5%)	0.942	0.955	0.949
(20%+10%)	0.958	0.963	0.956
(15%+15%)	0.962	0.971	0.971
(10%+20%)	0.974	0.983	0.981
(5%+25%)	0.981	0.996	0.973

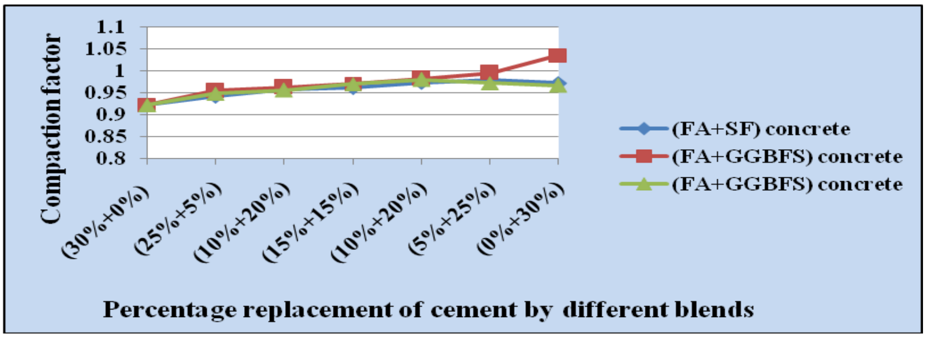

Fig. 2 Variation of compaction factor values

Table 3 Vee Bee consistometer test results for different percentage replacement of cement by various blends of pozzolonas

Percentage replacement of cement by pozzolonas	Vee Bee degree for cement replacement by		
	(FA+SF)	(FA+MK)	(FA+GGBFS)
(30%+0%) Ref. mix	110	110	110
(25%+5%)	101	104	102
(20%+10%)	98	99	98
(15%+15%)	85	87	87
(10%+20%)	79	81	80
(5%+25%)	74	74	85
(0%+30%)	81	69	92

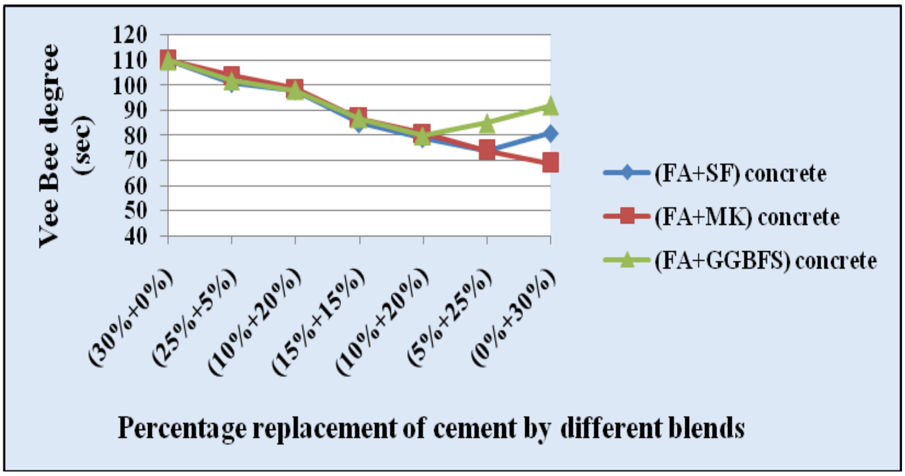

Fig. 3 Variation of Vee Bee degree

Table 4 Flow table test results for different percentage replacement of cement by various blends of pozzolonas

Percentage replacement of cement by pozzolonas	Flow table test results for cement replacement by		
	(FA+SF)	(FA+MK)	(FA+GGBFS)
(30%+0%) Ref. mix	38.64	38.64	38.64
(25%+5%)	36.25	37.87	36.67
(20%+10%)	34.67	35.30	35.18
(15%+15%)	32.67	32.85	32.70
(10%+20%)	29.70	30.09	30.02
(5%+25%)	26.65	28.37	31.85
(0%+30%)	30.8	37.28	33.03

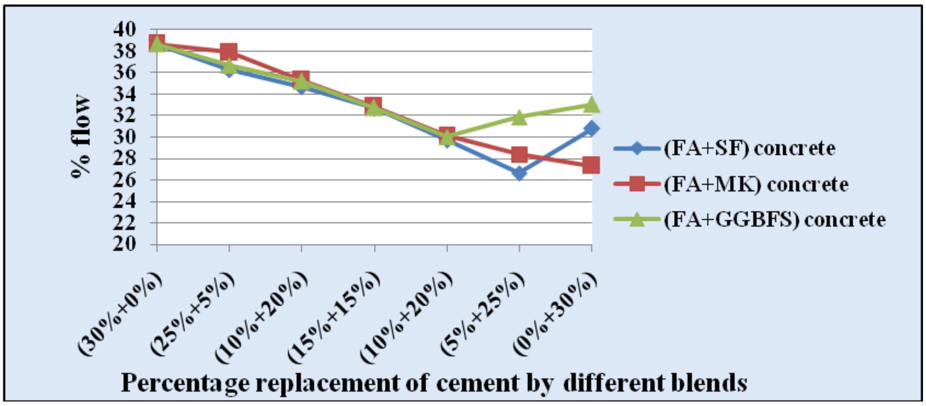

Fig. 4 Variation of percentage flow

NEAR SURFACE CHARACTERISTIC TEST RESULTS

Following tables give the water absorption test results and sorptivity test results for different combination of ternary blended hybrid fiber reinforced concrete. The variations in water absorption and sorptivity values are depicted in the form of graphs.

***Table 5 Water absorption test results**

Percentage replacement of cement by pozzolonas	Percentage water absorption test results for cement replacement by		
	(FA+SF)	(FA+MK)	(FA+GGBFS)
(30%+0%)Ref. mix	0.94	0.94	0.94
(25%+5%)	0.87	0.90	0.88
(20%+10%)	0.81	0.82	0.84
(15%+15%)	0.76	0.79	0.75
(10%+20%)	0.69	0.75	0.69
(5%+25%)	0.61	0.71	0.76
(0%+30%)	0.79	0.64	0.87

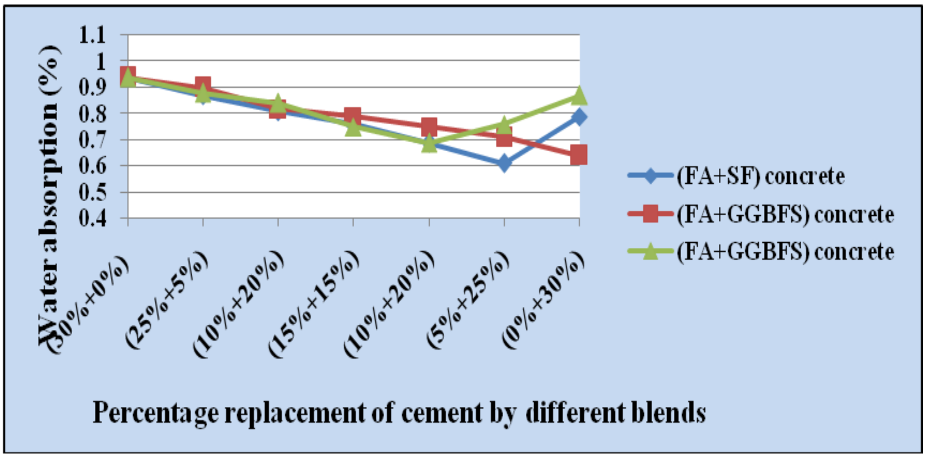

Fig. 5 Variation of water absorption values

Table 6 Sorptivity test results

Percentage replacement of cement by pozzolonas	Sorptivity values for cement replacement by (mm/min$^{0.5}$)		
	(FA+SF)	(FA+MK)	(FA+GGBFS)
(30%+0%) Ref. mix	5.1	5.1	5.1
(25%+5%)	4.8	5.02	5.03
(20%+10%)	4.6	4.9	4.98
(15%+15%)	4.5	4.8	4.85
(10%+20%)	4.3	4.74	4.83
(5%+25%)	4.25	4.67	5.2
(0%+30%)	4.35	4.5	5.65

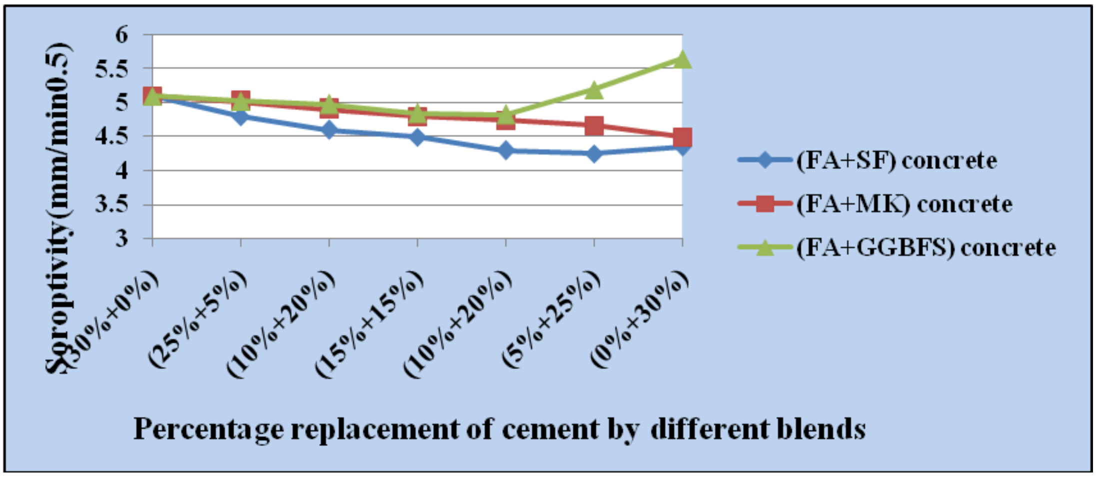

Fig. 6 Variation of sorptivity values

STRENGTH TEST RESULTS

Following tables give the overall results of compressive strength, tensile strength, flexural strength, shear strength and impact strength of ternary blended fiber reinforced concrete. Also it gives the percentage increase or decrease of strength with respect to reference mix. The variation of strength is depicted in the form of graph.

Table 7 Overall results of compressive strength

Percentage replacement of cement by pozzolona	Compressive strength of concrete by replacing cement by (FA+SF) (MPa)	Percentage increase or decrease of compressive strength with respect to reference mix	Compressive strength of concrete by replacing cement by (FA+MK) (MPa)	Percentage increase or decrease of compressive strength with respect to reference mix	Compressive strength of concrete by replacing cement by (FA+GGBFS) (MPa)	Percentage increase or decrease of compressive strength with respect to reference mix
(30% + 0%) Ref. mix	31.11	-	31.11	-	31.11	-
(25 % + 5%)	32.44	+4	34.04	+9	32.44	+4
(20 % + 10%)	32.88	+6	35.40	+13	33.34	+7
(15 % + 15%)	34.51	+11	37.18	+19	35.10	+12
(10% + 20%)	35.40	+14	38.22	+22	36.73	+18
(5% + 25%)	36.44	+17	39.70	+27	36.14	+16
(0%+30%)	34.66	+11	40.73	+30	35.25	+13

Table 8 Overall results of tensile strength

Percentage replacement of cement by pozzolona	Tensile strength of concrete by replacing cement by (FA+SF) (MPa)	Percentage increase or decrease of tensile strength with respect to reference mix	Tensile strength of concrete by replacing cement by (FA+MK) (MPa)	Percentage increase or decrease of tensile strength with respect to reference mix	Tensile strength of concrete by replacing cement by (FA+GGBFS) (MPa)	Percentage increase or decrease of tensile strength with respect to reference mix
(30% + 0%) Ref. mix	1.65	-	1.65	-	1.65	-
(25 % + 5%)	1.74	+6	1.83	+10	1.79	+8
(20 % + 10%)	1.83	+10	1.93	+16	1.88	+13
(15 % + 15%)	1.93	+16	2.16	+30	2.07	+25
(10% + 20%)	2.02	+22	2.21	+33	2.16	+30
(5% + 25%)	2.16	+30	2.31	+40	2.02	+22
(0%+30%)	2.02	+22	2.40	+45	1.93	+16

Table 9 Overall results of flexural strength

Percentage replacement of cement by pozzolona	Flexural strength of concrete by replacing cement by (FA+SF) (MPa)	Percentage increase or decrease of flexural strength with respect to reference mix	Flexural strength of concrete by replacing cement by (FA+MK) (MPa)	Percentage increase or decrease of flexural strength with respect to reference mix	Flexural strength of concrete by replacing cement by (FA+GGBFS) (MPa)	Percentage increase or decrease of flexural strength with respect to reference mix
(30% + 0%) Ref. mix	2.77	-	2.77	-	2.77	-
(25 % + 5%)	2.89	+4	2.92	+5	2.90	+4
(20 % + 10%)	2.97	+7	3.02	+9	2.98	+7
(15 % + 15%)	3.04	+9	3.09	+11	3.04	+9
(10% + 20%)	3.08	+11	3.14	+13	3.08	+11
(5% + 25%)	3.17	+14	3.16	+14	3.05	+10
(0%+30%)	3.05	+8	3.37	+21	2.97	+7

Table 10 Overall results of shear strength

Percentage replacement of cement by pozzolona	Shear strength of concrete by replacing cement by (FA+SF) (MPa)	Percentage increase or decrease of shear strength with respect to reference mix	Shear strength of concrete by replacing cement by (FA+MK) (MPa)	Percentage increase or decrease of shear strength with respect to reference mix	Shear strength of concrete by replacing cement by (FA+GGBFS) (MPa)	Percentage increase or decrease of shear strength with respect to reference mix
(30% + 0%) Ref. mix	5.17	0	5.17	-	5.17	-
(25 % + 5%)	5.36	+3	5.92	+14	5.73	+10
(20 % + 10%)	5.92	+14	6.47	+25	6.47	+25
(15 % + 15%)	6.84	+32	7.34	+41	6.84	+32
(10% + 20%)	7.39	+42	7.55	+46	7.58	+46
(5% + 25%)	8.5	+64	8.50	+64	7.19	+39
(0%+30%)	7.25	+40	8.69	+68	5.55	+7

Table 11 Overall results of impact strength for initial crack

Percentage replacement of cement by pozzolona	Impact strength of concrete by replacing cement by (FA+SF) (N-m)	Percentage increase or decrease of impact strength with respect to reference mix	Impact strength of concrete by replacing cement by (FA+MK) (N-m)	Percentage increase or decrease of impact strength with respect to reference mix	Impact strength of concrete by replacing cement by (FA+GGBFS) (N-m)	Percentage increase or decrease of impact strength with respect to reference mix
(30% + 0%) Ref. mix	610.09	-	610.09	-	610.09	-
(25 % + 5%)	870.38	+42	918.56	+50	904.8	+48
(20 % + 10%)	1000.83	+63	1055.66	+73	1021.39	+64
(15 % + 15%)	1035.10	+69	1062.53	+74	1110.49	+76
(10% + 20%)	1055.67	+73	1117.36	+83	1110.49	+80
(5% + 25%)	1110.52	+65	1192.76	+95	1041.96	+64
(0%+30%)	959.69	+57	1227.04	+101	877.42	+42

Table 12 Overall results of impact strength for final failure

Percentage replacement of cement by pozzolona	Impact strength of concrete by replacing cement by (FA+SF) (N-m)	Percentage increase or decrease of impact strength with respect to reference mix	Impact strength of concrete by replacing cement by (FA+MK) (N-m)	Percentage increase or decrease of impact strength with respect to reference mix	Impact strength of concrete by replacing cement by (FA+GGBFS) (N-m)	Percentag e increase or decrease of impact strength with respect to reference mix
(30% + 0%) Ref. mix	651.22	-	651.22	-	651.22	-
(25 % + 5%)	925.42	+42	973.41	+49	966.58	+48
(20 % + 10%)	1048.83	+61	1103.65	+69	1069.32	+64
(15 % + 15%)	1089.94	+67	1117.36	+71	1151.30	+76
(10% + 20%)	1096.67	+68	1165.32	+78	1172.20	+80
(5% + 25%)	1158.49	+77	1240.75	+90	1069.37	+64
(0%+30%)	993.97	+52	1275.02	+95	925.42	+42

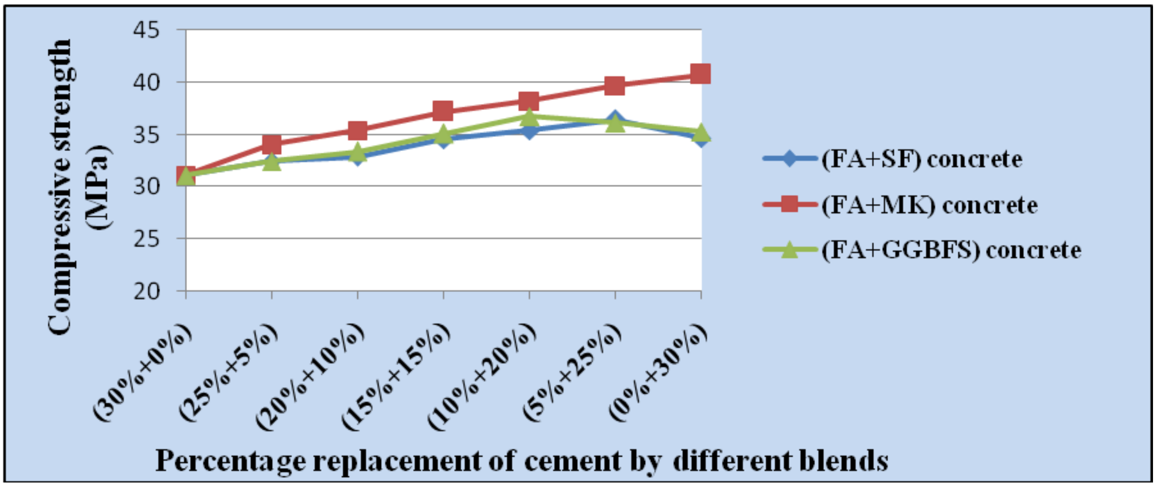

Fig. 7 Variation of compressive strength

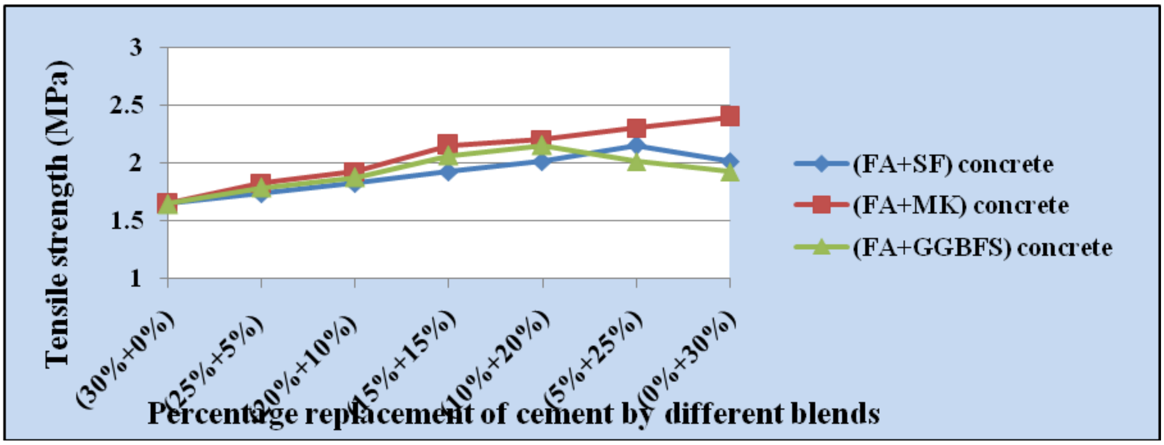

Fig. 8 Variation of tensile strength

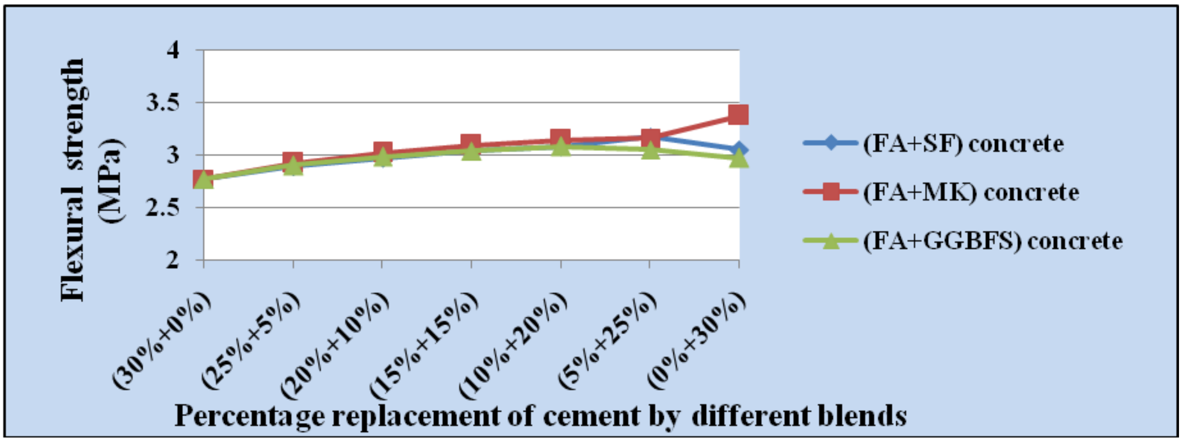

Fig. 9 Variation of flexural strength

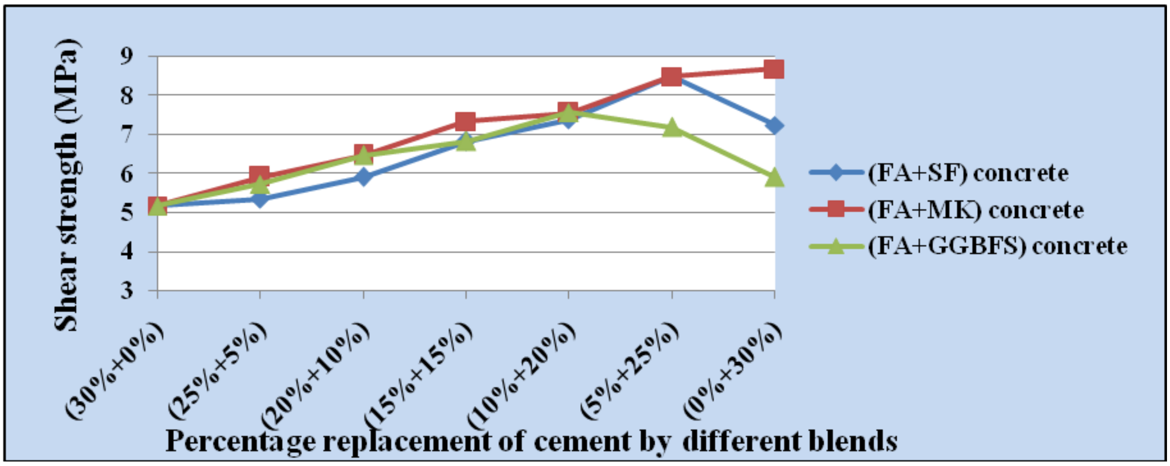

Fig.10 Variation of shear strength

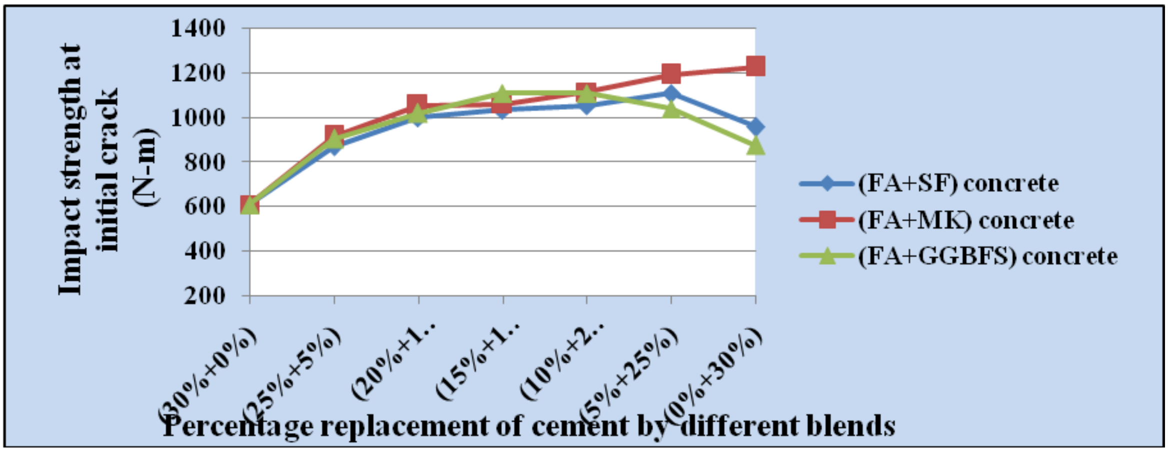

Fig. 11 Variation of impact strength for initial crack

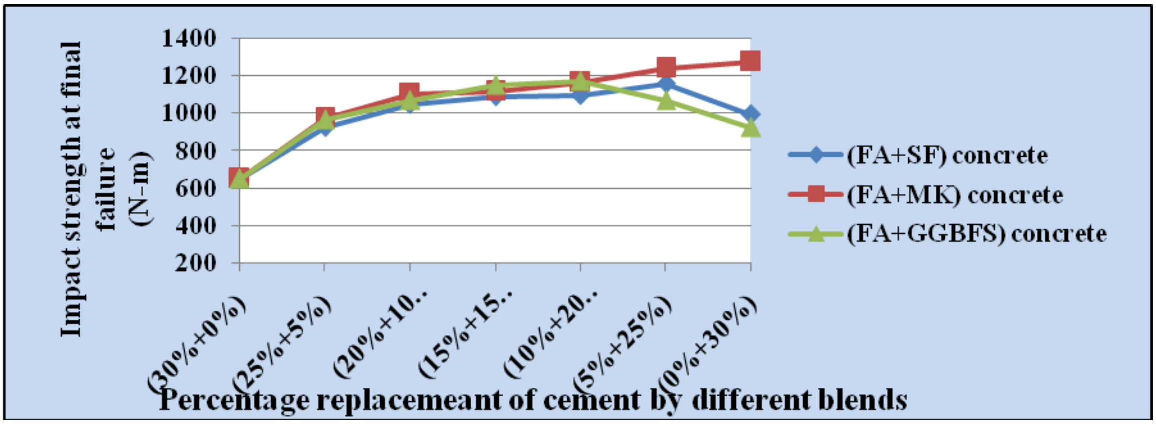

Fig.12 Variation of impact strength for final failure

CONCLUSIONS

The following conclusions may be drawn based on the observation made in the performance evaluation of ternary blended hybrid fiber reinforced concrete.

- The workability of ternary blended hybrid fiber reinforced concrete is high for (FA+SF) at a cement replacement level of (5%+25%). Similarly workability of ternary blended hybrid fiber reinforced concrete is high for (FA+MK) and (FA+GGBFS) at a cement replacement level of (0%+30%) and (10%+20%) respectively.

- The water absorption and sorptivity values of ternary blended hybrid fiber reinforced concrete is high for (FA+SF) at a cement replacement level of (5%+25%). Similarly water absorption and sorptivity values of ternary blended hybrid fiber reinforced concrete is low for (FA+MK) and (FA+GGBFS) at a cement replacement level of (0%+30%) and (10%+20%) respectively.
- The compressive strength of ternary blended hybrid fiber reinforced concrete is high for (FA+SF) at a cement replacement level of (5%+25%). Similarly compressive strength of ternary blended hybrid fiber reinforced concrete is high for (FA+MK) and (FA+GGBFS) at a cement replacement level of (0%+30%) and (10%+20%) respectively.
- The tensile strength of ternary blended hybrid fiber reinforced concrete is high for (FA+SF) at a cement replacement level of (5%+25%). Similarly tensile strength of ternary blended hybrid fiber reinforced concrete is higher for (FA+MK) and (FA+GGBFS) at a cement replacement level of (0%+30%) and (10%+20%) respectively.
- The flexural strength of ternary blended hybrid fiber reinforced concrete is high for (FA+SF) at a cement replacement level of (5%+25%). Similarly flexural strength of ternary blended hybrid fiber reinforced concrete is higher for (FA+MK) and (FA+GGBFS) at a cement replacement level of (0%+30%) and (10%+20%) respectively.
- The shear strength of ternary blended hybrid fiber reinforced concrete is high for (FA+SF) at a cement replacement level of (5%+25%). Similarly shear strength of ternary blended hybrid fiber reinforced concrete is higher for (FA+MK) and (FA+GGBFS) at a cement replacement level of (0%+30%) and (10%+20%) respectively.
- The impact strength of ternary blended hybrid fiber reinforced concrete is high for (FA+SF) at a cement replacement level of (5%+25%). Similarly impact strength of ternary blended hybrid fiber reinforced concrete is higher for (FA+MK) and (FA+GGBFS) at a cement replacement level of (0%+30%) and (10%+20%) respectively.

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