Volume : 1 | Issue : 10 | October 2012 ISSN - 2250-1991

Research Paper Engineering

Comparative mechanical properties of different ternary blended concrete

*Deepa A Sinha

* Associate Professor, Structural Engineering Dept, BVM Engineering College, Vallabh Vidyanagar, Anand, Gujarat

ABSTRACT

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 blended allows the effect of one SCM to compensate for the inherent shortening of another. The main objective of this research was to investigate the properties of ternary blended concrete incorporating silica fume, metakaolin, and GGBS. The properties investigated include workability, compressive strength and. flexural strength . In this project, we have replaced cement by ternary blend of Fly ash, metakaolin, silicafume, GGBS up to 30% to determine the workability, compressive strength and flexural strength.

Keywords : Ternary blended concrete, fly ash, silica fume, ground granulated blast furnace slag, compressive strength, tensile strength, flexural strength

Introduction

Mineral admixtures have changed the concept of making durable and special concretes in last four decades. Use of ground granulated blast furnace slag, fly ash, silica fume and metakaolin have become a tradition for all high strength, high performance concretes.

During the past few decades, the potential of Portland cement in terms of its effective utility has been realised. As a result, the use of new admixtures has increased significantly within the concrete industry. However it was experienced, and hence realised, over a period of time, that it was not only the strength that is important, other attributes of concrete, such as durability,workability etc. were also vital performance parameters. This has led to the work, which was initially limited to high strength concrete (HSC), then extended to high performance concrete (HPC). HPC mix is designed with mineral and chemical admixtures along with other normal ingredients of concrete, having a low water -cementitious ratio.

Ternary blended cements based and ordinary portland cement (OPC) Slag Cement and pozzolanas have been the subject of investigation since 1950. Studies conducted in france resulted in the commercial production of ternary cements since 1953. And some parts of Australia, ternary and even quaternary cements have been intermitantly available since 1960. In Canada a ternary blended cement including a combination of Silica fume and fly ash is currently being produced by a cement company joliettec Quebec. A teranary blended Incorporating a single SCM to improve a concrete rheology or a specific durability property, however, 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 deicer salts. According to several reaserchers, ternary blends made of portland cement, silica fume and fly ash offer significant advantages over binary blends an even greater enhancement over straight portland cement. When combine in concrete silica fume and fly ash complement each other, the silica fume improving the early age performance of concrete. And fly ash continously improving the properties of hardened concrete as it matures.

RESEARCH SIGNIFICANCE

As ternary blends possesses a number of advantages it is essential that the fundamental behavior of ternary blended concrete is clearly understood.. Hence, the present research programme aimed at generating experimental data necessary for characterizing the behavior of ternary blended concrete .

Objective:

Main objective of this experimental investigation is to study the effect of ternary blends on the strength and workability and strength characteristics. 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).

EXPERIMENTAL PROGRAMME

The mix design was carried out for M30 grade concrete as per IS: 10262-2009 which yielded a proportion of 1:1.86: 2.41 with a w/c ratio of 0.45. The dosage of super plasticizer used was 0.78% (by weight of cement). Before mixing, 30% of cement was replaced by (FA + SF) or (FA+GGBFS) or (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. . 53 grade OPC was used for the experiments. Coarse aggregates with a maximum size of 12mm having a specific gravity of 2.74 and locally available sand with a specific gravity of 2.67 and falling in Zone-II [9] were used. To enhance workability a sulphonated naphthalene formaldehyde super plasticizer was used at a dosage of 0.78% by weight of cement which was kept constant for all mixtures.

The required amount of water was added to this dry mix and intimately mixed. The calculated quantity of super plasticizer was now added and mixed thoroughly.. 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 smooth and kept under wet gunny bags for 24 hours after which they were cured for 28 days and 90 days. After curing, they were tested for their respective strengths as per IS specifications. For assessing compressive strengths of ternary blends, standard cube specimens of 150 x 150 x 150 mm were cast. flexural strength standard beam of size 100 x 100 x 500 mm were cast.

Materials used:

- Cement: 53 Grade Ordinary Portland Cement (OPC), with specific gravity 3.15, initial setting time 120 minutes and final setting time 220 minutes, and 7 day compressive strength of 29N/mm2 and 28 day compressive strength of 54N/mm2, complying with IS: 12269 – 1987 was used.
- Fine aggregates: Locally available sand with specific gravity of 2.67, falling under the zone-II, complying with IS: 383 – 1970 was used.
- Coarse aggregates: Locally available coarse aggregates of 12mm and down size having a specific gravity of 2.74, complying with IS: 383 – 1970 was used.
- 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.
- Fly ash: Fly ash was obtained from Wanakbori thermal power plant. This was class F fly ash.
- Metakaolin: Metakaolin was obtained from 20 microns limited in Baroda, Gujarat.
- Silica fume: Silica fume was obtained from Elkem laboratories, Navi Mumbai.
- GGBFS: GGBFS was procured from Heidelberg Cement, Navi Mumbai.

EXPERIMENTAL RESULTS

Different test results such as workability, compressive strength and flexural strength are tabulated as shown:

1.1 Workability test results

Table 1 gives the workability test results of ternary blended steel fibre reinforced concrete as measured from slump test, compaction factor test and Vee Bee test and flow test. The variation in slump, compaction factor, Vee Bee time and % flow can be depicted in the form of graphs as shown in fig. 1,2,3 and 4

Table 1 Workability test results of ternary blended fibre reinforced concrete.

Different Percentage replacement of cement by ternary blend	Ternary blend with (FA+SF)				Ternary blend with (FA+GGBFS)				Ternary blend with (FA+MK)			
	Slump (mm)	Compacting factor (%)	Vee bee (sec)	Flow %	Slump (mm)	Compacting factor (%)	Vee bee (sec)	Flow %	Slump (mm)	Compacting factor (%)	Vee bee (sec)	Flow %
(0+0) Ref. Mix	70	0.82	8	42	70	0.82	8	42	70	0.82	8	42
(30+0)	80	0.88	5	41	80	0.88	5	41	80	0.88	5	41
(25+5)	76	0.82	6.1	45	78	0.85	8.2	40	78	0.84	7	44
(20+10)	68	0.8	9.6	41	71	0.82	8.8	40	72	0.81	9.5	40
(15+15)	62	0.78	11	37	66	0.8	9.5	38	63	0.78	11.2	39
(10+20)	55	0.72	12.8	36	62	0.75	9.8	36	57	0.76	12	36
(5+25)	47	0.71	15.6	35	59	0.74	10.1	35	51	0.74	14.4	36
(0+30)	43	0.7	17	33	55	0.72	10.2	31	47	0.72	15.3	38

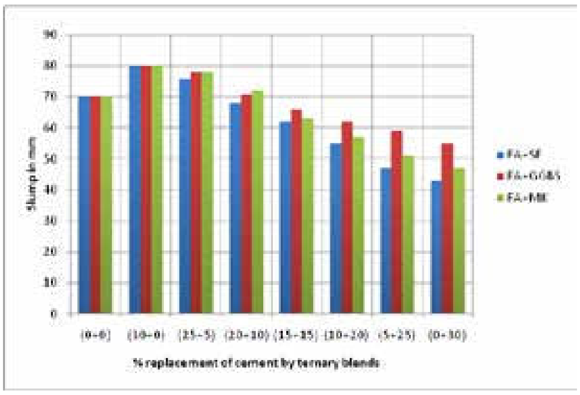

Figure 1 Variation of slump

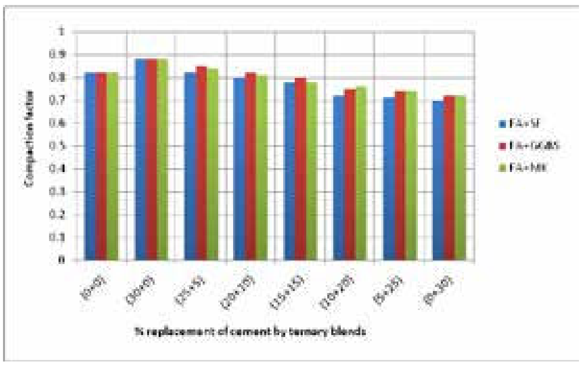

Figure 2 Variation of compaction factor

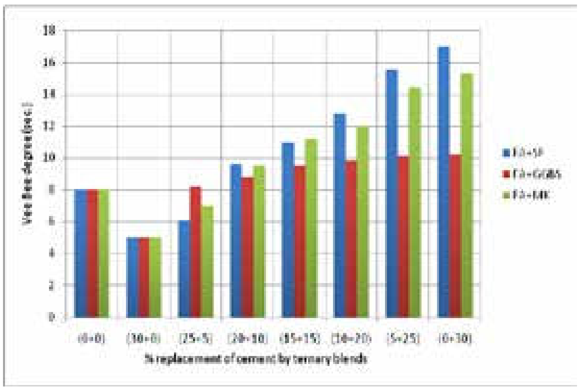

Figure 3 Variation of Vee Bee degree

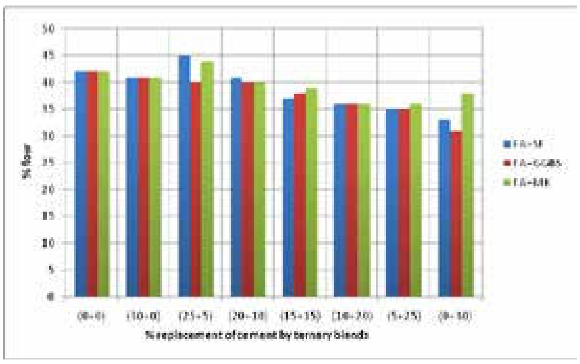

Figure 4 Variation of Flow Table

2 Compressive strength test results.
Overall results of 28 days compressive strength
Following table 2 gives the overall results of 28 days compressive strength of ternary blended concrete. Table also gives the percentage increase or decrease of compressive strength with respect to ref. mix. Variation in compressive strength can be depicted in the form of graph as shown in fig. 5

Following tables gives the compressive strength test results of different ternary blended concrete for 28 days curing.

Table 2 **Overall result of compressive strength for 28 days**

OVERALL RESULTS OF COMPRESSIVE STRENGTH AFTER 28 DAYS						
Percentage replacement of cement by ternary blends	Ternary blended SFRC with (FA + SF)		Ternary blended SFRC with (FA + GGBS)		Ternary blended SFRC with (FA + MK)	
	Compressive strength MPa	% increase or decrease of compressive strength w.r.t reference mix	Compressive Strength (Mpa)	% increase or decrease of compressive strength w.r.t reference mix	Compressive Strength (Mpa)	% increase or decrease of compressive strength w.r.t reference mix
(0+0)	40.45	-	40.45	-	40.45	-
(30+0)	34.53	-14.64	34.53	-14.64	34.53	-14.63
(25+5)	43.12	6.60	37.19	-8.06	38.38	-5.12
(20+10)	45.93	13.55	38.82	-4.03	43.12	6.60
(15+15)	48.45	19.78	41.19	1.83	53.19	31.50
(10+20)	49.19	21.61	44.16	9.17	48.60	20.15
(5+25)	40.45	0	38.53	-4.75	40.45	0
(0+30)	37.93	-6.23	30.67	-24.18	37.79	-6.58

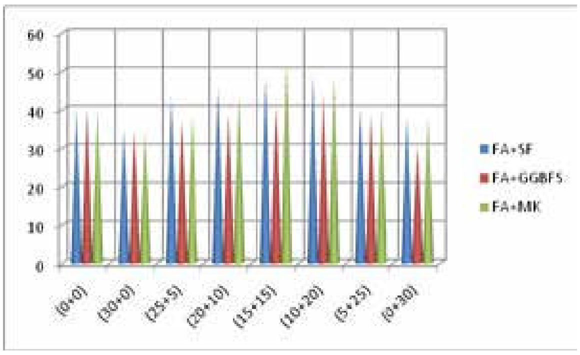

Figure 6 Variations of 28 days compressive strength

Overall results of 90 days compressive strength
Following table 3 gives the overall results of 90 days compressive strength of ternary blended concrete. Table also gives the percentage increase or decrease of compressive strength with respect to ref. mix. Variation in compressive strength can be depicted in the form of graph as shown in fig.6

Table 3Overall result of compressive strength for 90 days

OVERALL RESULTS OF COMPRESSIVE STRENGTH AFTER 90 DAYS						
Percentage replacement of cement by ternary blends	Ternary blended SFRC with (FA + SF)		Ternary blended SFRC with (FA + GGBS)		Ternary blended SFRC with (FA + MK)	
	Compressive strength (Mpa)	% increase or decrease of compressive strength w.r.t reference mix	Compressive strength (MPa)	% increase or decrease of compressive strength w.r.t reference mix	Compressive strength (MPa)	% increase or decrease of compressive strength w.r.t reference mix
(0+0)	52.3	-	52.3	-	52.3	-
(30+0)	53.64	2.56	53.64	2.56	53.64	2.56
(25+5)	55.12	5.39	54.53	4.26	54.38	3.98
(20+10)	59.12	13.04	55.12	5.39	55.27	5.68
(15+15)	60.75	16.16	56.16	7.38	57.93	10.76
(10+20)	62.97	20.40	61.04	16.71	56.15	7.36
(5+25)	57.04	9.06	54.08	3.40	53.93	3.12
(0+30)	54.38	3.98	53.79	2.85	53.79	2.85

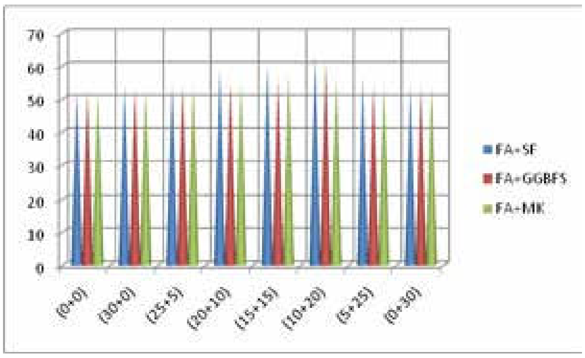

Figure 6. Variation of 90 days compressive strength

Overall results of 28 days flexural strength

Following table 4 gives the overall results of **28 days flexural** *strength of ternary blended SFRC. Table also gives the percentage increase or decrease of* **flexural** *strength with respect to ref. mix. Variation in* **flexural** *strength can be depicted in the form of graph as shown in fig.7*

***Table 4* Overall result of flexural strength for 28 days**

Percentage replacement of cement by ternary blend	Ternary blended SFRC with (FA + SF)		Ternary blended SFRC with (FA + GGBS)		Ternary blended SFRC with (FA + MK)	
	Flexural strength (MPa)	% increase or decrease of flexural strength w.r.t reference mix	Flexural strength (MPa)	% increase or decrease of flexural strength w.r.t reference mix	Flexural strength (MPa)	% increase or decrease offlexuralstrength w.r.t reference mix
(0+0) Ref. mix	4.32	-	4.32	-	4.32	-
(30+0)	4.91	13.66	4.91	13.66	4.91	13.66
(25+5)	5.54	28.24	5.18	19.91	5.24	21.30
(20+10)	5.97	25.93	5.48	26.85	5.44	25.93
(15+15)	6.34	38.19	5.74	32.87	6.27	45.14
(10+20)	6.54	51.39	5.91	36.81	5.83	34.95
(5+25)	6.4	48.15	5.06	17.13	5.68	31.48
(0+30)	6.01	39.12	4.90	13.43	5.05	16.90

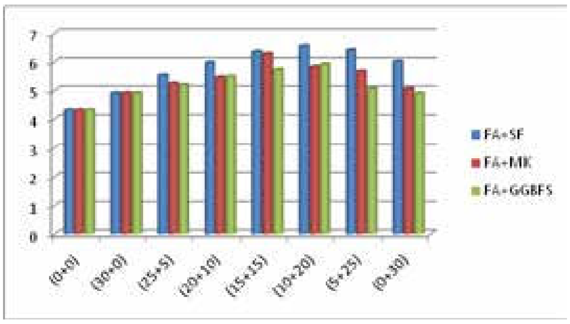

Figure 7 Variation of 28 days flexural strength

Overall results of 90 days flexural strength

Following table 5 gives the overall results of **90 days flexural** *strength of ternary blended SFRC. Table also gives the percentage increase or decrease of* **flexural** *strength with respect to ref. mix. Variation in* **flexural** *strength can be depicted in the form of graph as shown in fig.8*

***Table 5 Overall* result of flexural strength for 90 days for all blends**

Percentage replacement of cement by ternary blend	Ternary blended SFRC with (FA + SF)		Ternary blended SFRC with (FA + GGBS)		Ternary blended SFRC with (FA + MK)	
	Flexural strength (MPa)	% increase or decrease of flexural strength w.r.t reference mix	Flexural strength (MPa)	% increase or decrease of flexural strength w.r.t reference mix	Flexural strength (MPa)	% increase or decrease of flexural strength w.r.t reference mix
(0+0) ref. mix	5.85	-	5.85	-	5.85	-
(30+0)	6.01	2.74	6.01	2.74	6.01	2.74
(25+5)	6.44	10.09	6.40	9.40	6.42	9.74
(20+10)	6.83	16.75	6.61	12.99	6.71	14.70
(15+15)	7.20	23.08	6.82	16.58	7.12	21.71
(10+20)	7.70	31.62	7.08	21.03	6.81	16.41
(5+25)	6.53	11.62	6.87	17.44	6.51	11.28
(0+30)	6.32	8.03	6.55	11.97	5.89	0.68

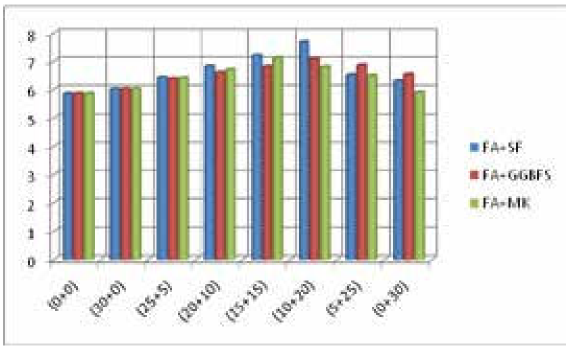

Figure 8 Variation of 90 days flexural strength

Observations and discussions-

- Pozzolanic material are easily available material and are very good supplementary cementitous material.Upto 30% replacement of cement with Fly-ash can give higher strength than normal concrete at 28 & 90 days.
- By Replacing cement with 15% fly-ash and 15% metakaolin gives the compressive strength 31.5% & 10.76% more than the reference mix for 28 days and 90 days respectively.
- By Replacing cement with 10% fly-ash and 20% silicafume gives the compressive strength 21.61% & 20.4% more than the reference mix for 28 days and 90 days respectively.
- By Replacing cement with 10% fly-ash and 20% GGBS gives the compressive strength 9.17% & 16.71% more than the reference mix for 28 and 90 days respectively .
- By using supplimentary cementitious materials we found that replacement of cement with Fly-ash gives higher strength than normal concrete at 28 days and 90 days.
- Replacement of cement with 15% fly-ash and 15% metakaolin gives the best results as compare to other mixes for compressive strength of 28 days.
- Under two point loading arrangement used for flexural strength testing, the failure occurs in middle third portion of the specimen. In case of TBC, the failure is sudden and through the aggregates
- By Replacing cement with 15% fly-ash and 15% metakaolin gives the flexural strength 45.14% & 21.71% more than the reference mix for 28 days and 90 days respectively.
- By Replacing cement with 10% fly-ash and 20% silicafume gives the flexural strength 51.39% & 31.62% more than the reference mix for 28 days and 90 days respectively.
- By Replacing cement with 10% fly-ash and 20% GGBS gives the flexural strength 36.81% & 21.03%more than the reference mix for 28 days and 90 days respectively.

Conclusion

- Out of all pozzolonic material Silicafume gives highest strength in flexure after 28 and 90 days.
- Silica fume gives highest compressive strength after 90 days.
- Metakaolin gives highest compressive strength after 28 days.

By using industrial waste materials we can make environment more sustainable.

REFERENCES

R.C.Joshi and T.S.Nagraj, “Generalization of flow behaviour of cementfly ash pastes”,Journal of Materials in Civil Engineering, Augest, 1990, pp.128-135 | Michel Chusid and Antony Reed, “Using metakaolin to improve appearance and performance of concrete”, Asian Journal of Civil Engineering (Building and Housing) Vol.10, 2009. | David Trejo and CekiHalmen, “Metakaolin concrete can be designed to achieve strength levels unattainable with conventional concrete containing only Portland cement or Portland cement and fly ash”, Developed by Committee E-701, Materials for Concrete Construction, ACI Education Bulletin E1,1999. | IS 456: 2000, “Indian standard code of practice for plain and reinforced concrete”, Bureau of Indian Standard, New Delhi. | 16. IS 10262: 2009, “Recommended guidelines for concrete mix design”, Bureau of Indian- Standard, New Delhi. | 17. IS 9103: 1999, “Indian standard concrete admixture specification”, Bureau of Indian Standard, New Delhi. | 18. IS 516: 1959, “Flexural strength of concrete”, Bureau of Indian Standard, New Delhi. |