BEHAVIOUR OF TERNARY CONCRETE WITH FLYASH AND GROUND GRANULATED BLAST FURNACE SLAG

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ABSTRACT. Industrial wastes containing cementitious properties such as Flyash, Ground granulated blast furnace slag, Silica fume, Metakaolin, Rice husk ash etc has been tried as an alternative to partially replace cement in concrete. The performance of such cementitious materials in terms of strength, workability and durability parameters have been quite promising. Subsequently, these have led to the development of binary, ternary and tertiary blended concretes depending on the number of Supplementary Cementitious Materials (SCM) and their combinations used as partial cement replacement materials. The SCM used in Ternary Blended Concrete, to some extent, has remained successful in meeting these objectives. Ternary concrete mixtures include three different cementitious materials. 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.
This evaluates the performance of concrete containing supplementary cementitious materials (SCM) like FlyAsh and Ground Granulated Blast Furnace Slag (GGBS) with respect to fresh and hardened concrete of Ternary mixes.

Keywords: Supplementary cementitious materials, Ternary Blended Concrete, Fly ash.

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INTRODUCTION

Construction industry has been facing challenges with regards to sustainability, disposal of industrial waste material, reduction in use of raw materials and energy requirement in cement manufacturing, reducing the carbon emission and rendering the environment cleaner, reduction in cement consumption in concrete, making durable concrete thus increasing the service life of construction etc. Extensive research work in concrete technology for 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 still continues. Industrial wastes containing cementitious properties such as Flyash, Ground granulated blast furnace slag, Silica fume, Metakaolin, Rice husk ash etc has been tried as an alternative to partially replace cement in Concrete. The performance of such cementitious materials in terms of strength, workability and durability parameters have been quite promising. Subsequently, these have led to the development of binary, ternary and tertiary blended concretes depending on the number of Supplementary Cementitious Materials and their combinations used as partial cement replacement materials. The SCM used in Ternary Blended Concrete, to some extent, has remained successful in meeting these objectives.

TERNARY BLENDED CONCRETE

Ternary concrete mix includes three different cementitious materials. This paper focusses on the combination of Cement, flyash, and slag as the three cementitious materials. 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.

EXPERIMENTAL PLAN

This experimental investigation is aimed at evaluating the performance of concrete containing supplementary cementitious materials (SCM) like FlyAsh and Ground Granulated Blast Furnace Slag (GGBS). FlyAsh and GGBS are the cementitious materials that can be used in the production of long-lasting concrete composites.

Materials

- Cement – The OPC 53 grade cement confirming to IS 269:2015 with specific gravity of 3.15, fineness of 300 m^2/kg, and standard consistency of 28.5% was used.
- Flyash – Grade-I Flyash used in the study confirmed to IS 3812(Part1):2013. Sp. Gravity – 2.1 ; fineness – 389 m^2/kg
- Ground Granulated Blast Furnace Slag – GGBS confirmed to IS 12089:1987
- Coarse aggregate – Crushed angular granite metal of 20mm (sp. Gravity 2.67; Fineness Modulus 7.09) and 10mm (specific gravity 2.66: Fineness Modulus 6.09) was used.
- Fine Aggregates – River sand having the specific gravity of 2.60 and fineness modulus 2.84 was used. The fine aggregates used in the study confirmed to IS 383:2016.
- Admixture – Superplasticiser SikaPlast 3001 NS,255kg with specific gravity of 1.09 was used as water reducing admixture.

Concrete

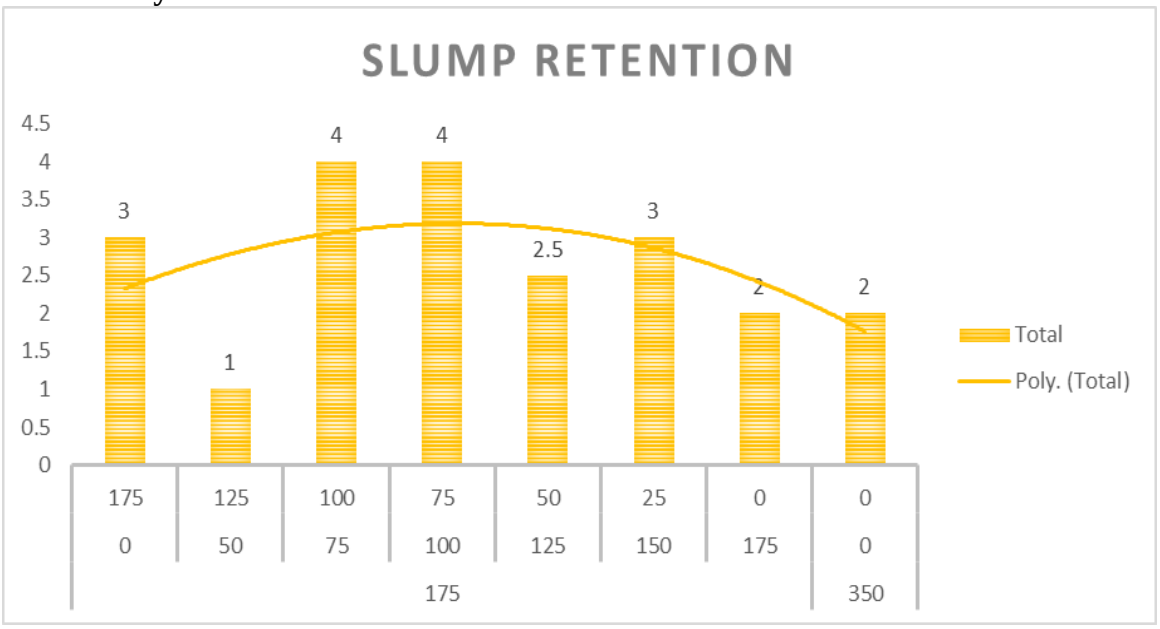
1. Concrete mixes of M25 grade was prepared with different combinations of OPC, Flyash, and GGBS. The Water Binder ratio was maintained at 0.457 (Water-160kg, Binder-350kg).

MIX	CEMENT (kg)	FLYASH (kg)	SLAG (kg)	SAND (kg)	20mm (kg)	10mm (kg)	WATER (kg)	ADMIX -TURE (kg)	WORKAB -ILITY (mm)
M25	175	175	0	757	666	443	160	2.1	120
M25	350	0	0	802	677	450	160	2.1	100
M25	175	150	25	760	669	444	160	2.1	120
M25	175	125	50	763	671	446	160	2.1	110
M25	175	100	75	778	662	440	160	2.1	120
M25	175	75	100	781	665	441	160	2.1	140
M25	175	0	175	790	672	446	160	2.1	120
M25	175	50	125	784	667	443	160	2.1	100

2. The slump retention, final setting time, compressive strength values, and growth rate of compressive strength of these mixes were measured for 3, 7, 28, and 60 days.
3. The compressive strength of ternary blended concrete (TBC) is compared with the Ordinary Portland Cement concrete and binary concrete.
4. Aggregates (Fine, Coarse-10 mm, and Coarse-20 mm), Water, Admixture were kept almost same for all the different trial mixes.
5. Admixture dosage was 2.1% by weight of Cement & Cementitious particles.

RESULTS & DISCUSSIONS

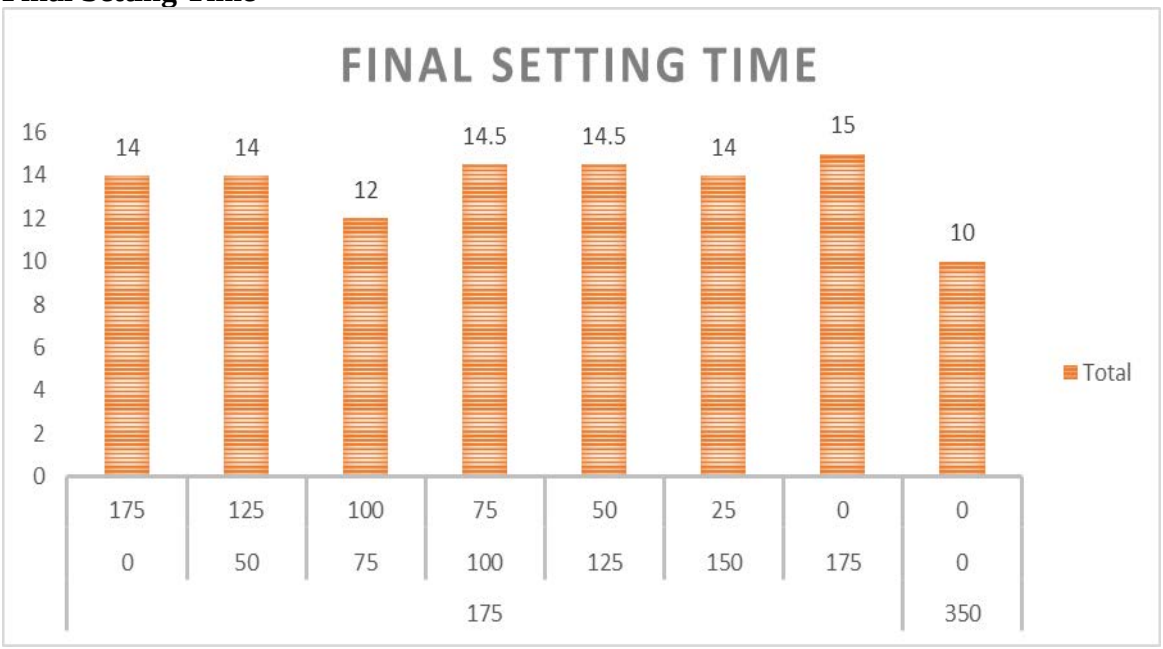
Workability



CEMENT (KG)	FLYASH (KG)	SLAG	FLYASH %	SLAG %	RETENTION HRS.
175	175	0	50	0	2
175	150	25	43	7	3
175	125	50	36	14	2.5
175	100	75	29	21	4
175	75	100	21	29	4
175	50	125	14	36	1
175	0	175	0	50	3
350	0	0	0	0	2

The Slump retention time is the least for the Portland Cement Concrete. The Supplementary Cementitious Materials (SCM) contribute to the slump retention of ternary and binary concrete.

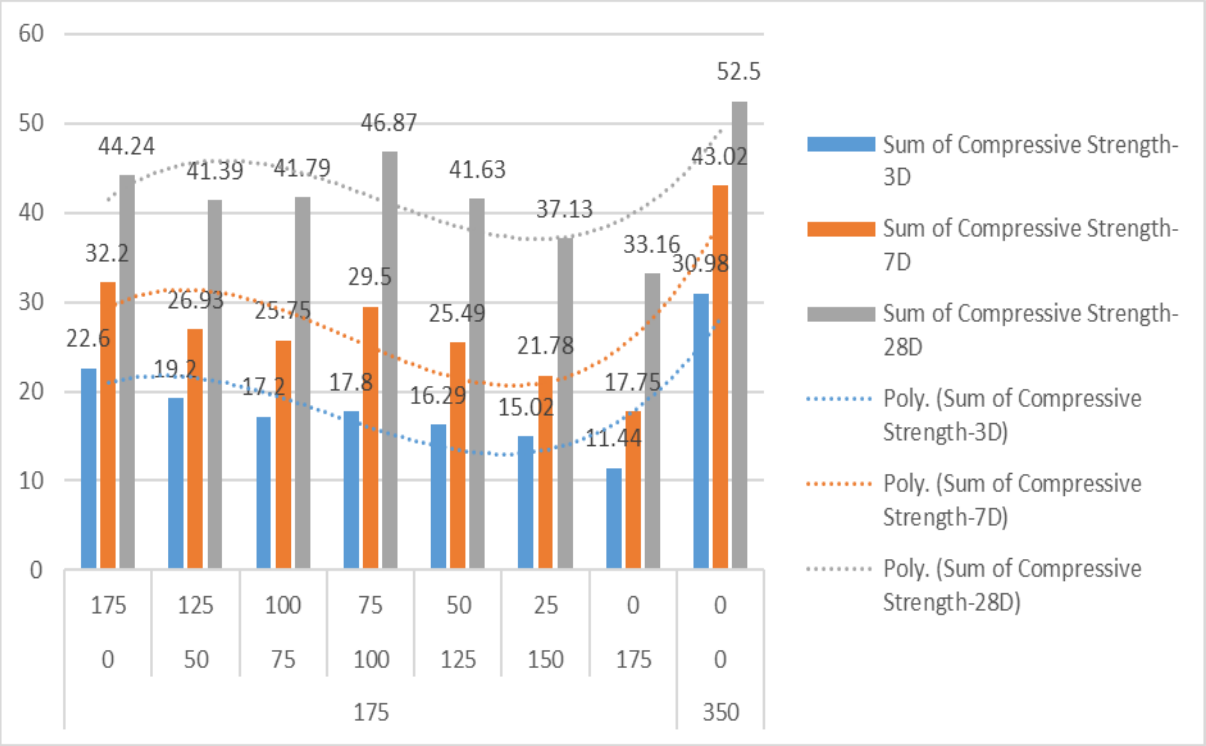
Final Setting Time



CEMENT (KG)	FLYASH (KG)	SLAG (KG)	FINAL SETTING TIME, HRS.
175	175	0	15
175	150	25	14
175	125	50	14.5
175	100	75	14.5
175	75	100	12
175	50	125	14
175	0	175	14
350	0	0	10

The Portland Cement Concrete has the least/fastest Final Setting Time. Amongst the Ternary blended Concrete, the Final Setting Time of mix (21% FA + 29% GGBS) is the least.

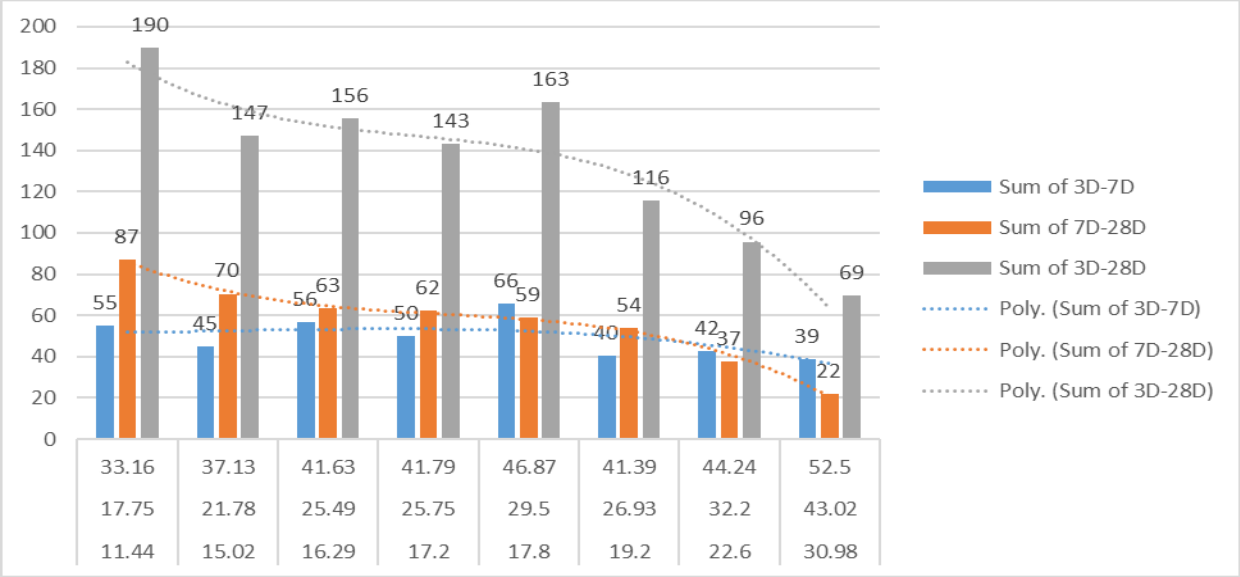
Compressive Strength



CEMENT (KG)	FLYASH (KG)	SLAG (KG)	COMPRESSIVE STRENGTH-3D	COMPRESSIVE STRENGTH-7D	COMPRESSIVE STRENGTH-28D
175	175	0	11.44	17.75	33.16
175	150	25	15.02	21.78	37.13
175	125	50	16.29	25.49	41.63
175	100	75	17.8	29.5	46.87
175	75	100	17.2	25.75	41.79
175	50	125	19.2	26.93	41.39
175	0	175	22.6	32.2	44.24
350	0	0	30.98	43.02	52.5

At 3 days, 7 days, and 28 days, the Compressive Strength of Ordinary Portland Cement Concrete is considerably higher than the Ternary Blended Concrete. As the percentage of FlyAsh goes on decreasing, and the percentage of GGBS goes increasing, the compressive strength of the Ternary Blended Concrete goes on increasing. This holds good for compressive strength of the Ternary Blended Concrete at 3 days, 7 days, and 28 days.

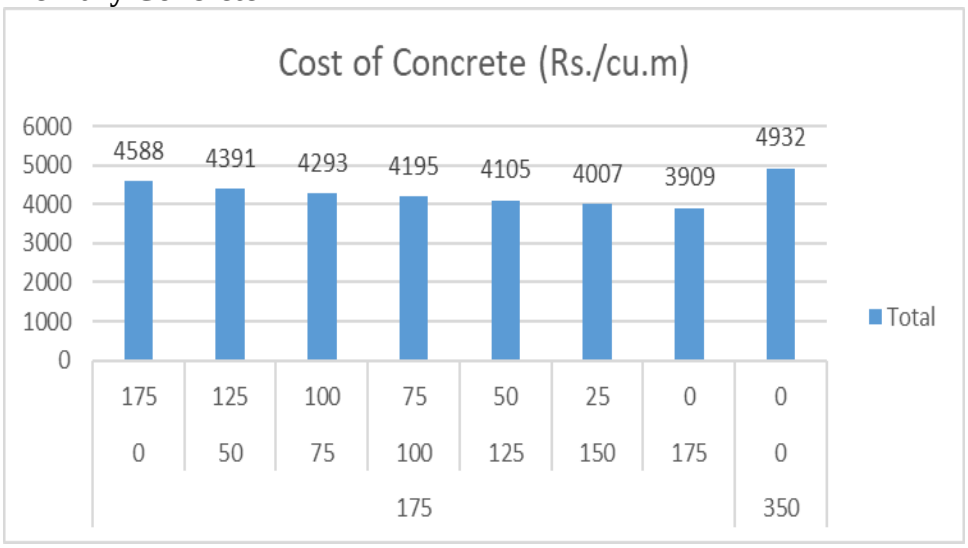
Rate of development of Compressive Strength



CEMENT (KG)	FLYASH (KG)	SLAG (KG)	% STRENGTH DEVELOPED (3D-7D)	% STRENGTH DEVELOPED (7D-28D)	% STRENGTH DEVELOPED (3D-28D)
175	175	0	55	87	190
175	150	25	45	70	147
175	125	50	56	63	156
175	100	75	66	59	163
175	75	100	50	62	143
175	50	125	40	54	116
175	0	175	42	37	96
350	0	0	39	22	69

The rate of development of compressive strength in the TBCs is higher as compared to the Ordinary Portland Cement Concrete. This holds good for all the cases viz., strength development during the period : 3 days to 7 days , 7 days to 28 days, and 3 days to 28 days.

Cost of Ternary Concrete Mix



CEMENT (KG)	FLYASH (KG)	SLAG (KG)	MIX COST (RS/CU.M)
175	175	0	3909
350	0	0	4932
175	150	25	4007
175	125	50	4105
175	100	75	4195
175	75	100	4293
175	0	175	4588
175	50	125	4391

As the quantity of flyash goes on increasing the cost of concrete goes on decreasing.
The cost of concrete with OPC is considerably higher than that with cement replaced with cementitious particles.

CONCLUSIONS

It was observed that Ternary Blended Concrete (TBC) mixes exhibited superior qualities like slump retention, enhanced workability, whereas their compressive strength values were found to be less than that of the conventional concrete mixes. The compressive strength of Portland Cement Concrete was higher than the TBC while tested at 3 days, 7 days, and 28 days. It was also observed that the rate of development of compressive strength of Ternary Blended Concrete (TBC) was higher than the Portland Cement Concrete.

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