

# Experimental Investigation of Ternary Blended Hooked Fiber Reinforced Concrete

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**Abstract:** Cement industry may be one amongst the key sources of environmental pollution so the reduction of cement demand should be improved. Ground granulated blast furnace slag (GGBS), silica fumes (SF), fly ash (FA) and metakaolin are the by-products of industries and it ought to be reused to scale back the waste pollution. Thus, this study investigated the employment of Ground granulated blast furnace slag and fly ash as a cement replacement in ternary homogenized cements on mechanical properties. In this paper study the effect of using Supplementary Cementitious Materials (SCMs) in hooked fiber reinforced concrete. SCMs introduced in two different forms such as binary and ternary blends. In this paper, various properties of blended hooked fiber reinforced concrete (TBHFR) are done. These properties are compared to Conventional Hooked Fiber Reinforced Concrete (CHFRC). Here found the optimum percentage of fly ash and GGBS and also found the maximum strength of concrete by the addition of GGBS with the optimum percentage of fly ash and vice versa. Also found the best combination of fly ash and GGBS. In this project 1% weight of fraction of hooked fiber are incorporated in concrete with constant dosage of 0.8% of plasticizer by the weight of binder. Here compressive strength, flexural strength and split tensile strength calculated.

**Keywords:** Supplementary cementitious material, ternary blends, binary blends, metakaolin, GGBS and hooked fiber

## 1. Introduction

Concrete is a composite material which made up of filler and binder. The binder (cement paste) "glues" the filler together to form a solid material. The constituents used for the binder are cement and water, while the filler can be fine and coarse aggregate. Cement industry may be one amongst the key sources of environmental pollution so the reduction of cement demand should be improved. Ground granulated blast furnace slag (GGBS) and Fly ash (FA) are the by-products of industries and it ought to be reused to scale back the waste pollution. Main pollution of cement productions include; cement dirt, air pollution, water pollution, solid waste pollution, sound pollution, ground vibration and resources depletion attributable to staple extraction. Moreover, carbon dioxide emission from burning method of cement business is that the main reason behind global warming. Therefore, the reduction of cement demand must be discussed to improve environmental pollution from cement industry.

Now, blended cement with pozzolanic materials such as fly ash (FA), granulated blast furnace slag (GGBS), silica fume (SF), Metakaolin and other natural pozzolona materials is widely used in cement and concrete construction by replacing part of cement. Ground granulated blast furnace slag (GGBS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Fly ash is used as the blending agent to achieve durable concrete. Two different types of fly ash are there based on amount of calcium presents. One is class C fly ash which highly in calcium content another is class F fly ash its calcium content varies from 0 to 8 %. Ternary blended cement mixes with 40% GGBS and 10% Fly ash produced strengths higher to that of the control mix. This research work investigated the compressive strength, flexural strength and split tensile

strength of ternary blended cement concrete containing Ground granulated blast furnace slag and Fly ash. The successful utilization of GGBS and FA in ternary combination with OPC for making concrete would further add value to these wastes and reduce the volume of OPC currently required for civil engineering and building works

## 2. Literature Survey

[1] Deepa A Sinha, (2012)

The mix design was carried out for M<sub>30</sub> 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. 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. So in this paper the performance of the flexural toughness for various steel fibre reinforced ternary blended concrete are found.

[2] Rama Mohan Rao P, Sai Kumar M, (2015)

In this experimental work cement is replaced by GGBS by 40%, 50%, 60%, 70% with respect to 5%, 7.5%, 10% of SF. Optimum mix is found from the total 12 mixes. Compressive strength of ternary blended concrete is higher than the regular concrete. Steel fibers are added at 0.5%, 1.0%, 1.5%, and 2.0%  $v_f$  to the optimum mix. Compressive strength test, flexural strength test, split tensile strength test, young's modulus test are conducted for the four mixes. Ternary blended cement mortar containing 7.5% SF and 50% GGBS by weight contribute in giving compressive strength higher than the regular concrete.

[3] Mohd Muthahar Hussain and Mohd Obaidullah, (2013)

Exact analysis of shear strength in reinforced concrete beam is quite complex. Maximum Strength is obtained when 10% Metakaolin and 30% fly ash by weight of cement.

Reinforced beams must be designed for shear as well as bending. Maximum shear occur near supports. Shear failure is actually a diagonal tension failure that is brittle in nature.

**[4]Kaur G, Kaushik S K and Singh S P,(2012)**

The effect of binary and ternary blends of fly ash (FA), silica fume (SF) and metakaolin (MK), on the fatigue performance of steel fibre reinforced concrete (SFRC) has been investigated. Corrugated rectangular steel fibres at a constant volume fraction of 1.0% have been incorporated in all mix combinations as the reinforcing material. The fatigue equations of SFRCs with and without these cement additions are suggested through the method of the regressive analysis.

**[5] Obada Kayali (2001)**

Here Proposed that effects of replacing large proportion of Portland cement with either fly ash, ground granulated blast furnace slag or metakaolin in high strength concrete. The effects on strength and durability against chloride penetration were reported. He concluded that increase the fly ash content strength was reduced but durability property was improved up to 50% of cement replacement beyond this concrete may likely become vulnerable to chloride ion penetration and thus increased susceptibility to chloride initiated corrosion may occur.

**[6]Purva P. Awari, Ramesh Pujar and Shreeshail B Heggond,(2015)**

In the present experimental investigation a mix design high strength concrete of M60 & M80 is tried using triple blending technique with ternary blend of condensed silica fume and metakaolin as partial replacement by weight of cement at various blended percentages ranging between 5% – 15% with steel fibers having aspect ratio of 50. The various proportions of steel fibers are added at 0.5%, 0.75%, 1.0%, 1.25% and 1.5% as total fiber percentages. Specimens with total fiber content of 1.5% showed better strength in all proportions and blend proportion of 10% condensed silica fume and 5% metakaolin showed maximum strength in compression, tension and flexural.

### 3. Objective of the Work

The objectives is to found the optimum percentage of Fly Ash and GGBS by the replacement of cement and found the strength of concrete by the addition of GGBS with the optimum percentage of Fly Ash and vice versa. And to found the best combination of fly ash and GGBS.

### 4. Methodology

The methodology of the work consist of

- 1) Selection of grade of concrete; M30.
- 2) Mix design of M30 grade concrete.
- 3) Collection of material and testing of materials
- 4) Casting of the specimens and testing of specimens.
- 5) Study the results and documentation.

### 5. Material Test and Chemical Composition

Ordinary Portland cement of 43 grade was used in this work the material testing results are given in Table 1.

**Table 1: Material Testing Results**

Property	Ordinary Portland Cement	GGBS	Fly ash
Specific Gravity	3.2	2.94	2.64
Fineness	3%	1%	1%
Standard Consistency	33%	31%	37%

In this study , M<sub>30</sub> grade of concrete was used for entire study. Here cement was replaced by fly ash and GGBS at different percentages and find out the optimum value of fly ash and GGBS. Fly ash was used to replace the part of cement at 5%,10% ,15%,20% , 25% and GGBS was 10%, 20%, 30%, 40% ,50% respectively . The hooked fiber was added 1% of entire weight of the concrete. Here 20% of fly ash and 40% of GGBS provide the maximum strength. After that 10 to 30% of GGBS and 5 to 20% of fly ash is added to the optimum percentage of fly ash and GGBS then found out maximum strength of concrete. Concrete mixes were mixed and cast into (150×150×150)mm cubes, (500×100×100)mm prisms, (150×300)mm cylinders. The mix proportions of different mixes are summarized in Table 2.

The properties of hooked fiber is given below.

SL No	Property	Value
1.	Material	Low carbon drawn wire
2.	Length of single fiber	30mm
3.	Diameter of single fiber	0.60mm
4.	Aspect ratio	50
5.	Type of fiber	Hooked

**Table 2: Mix proportion of different mixes (kg/m<sup>3</sup>)**

Mixes	Materials					
	OPC	GGBS	Fly ash	FA	CA	Water
CM	438.13	0	0	695.3	1106.9	197.2
F <sub>1</sub>	416.22	0	21.9	695.3	1106.9	197.2
F <sub>2</sub>	394.32	0	43.8	695.3	1106.9	197.2
F <sub>3</sub>	372.41	0	65.72	695.3	1106.9	197.2
F <sub>4</sub>	350.5	0	87.63	695.3	1106.9	197.2
F <sub>5</sub>	328.6	0	109.5	695.3	1106.9	197.2
G <sub>1</sub>	394.32	43.81	0	695.3	1106.9	197.2
G <sub>2</sub>	350.5	87.63	0	695.3	1106.9	197.2
G <sub>3</sub>	306.69	131.4	0	695.3	1106.9	197.2
G <sub>4</sub>	262.87	175.5	0	695.3	1106.9	197.2
G <sub>5</sub>	219.1	219.1	0	695.3	1106.9	197.2
F <sub>21</sub>	315.45	35.05	87.63	695.3	1106.9	197.2
F <sub>22</sub>	280.4	70.1	87.63	695.3	1106.9	197.2
F <sub>23</sub>	245.35	105.2	87.63	695.3	1106.9	197.2
G <sub>41</sub>	249.47	175.5	13.14	695.3	1106.9	197.2
G <sub>42</sub>	236.32	175.5	26.29	695.3	1106.9	197.2
G <sub>43</sub>	223.18	175.5	39.43	695.3	1106.9	197.2

### 6. Mix Design

**Table 3: M<sub>30</sub> Mix Proportioning**

Cement (Kg/m <sup>3</sup> )	438
Fine aggregate (Kg/m <sup>3</sup> )	695
Coarse aggregate (Kg/m <sup>3</sup> )	1107
Water (li/m <sup>3</sup> )	197
Water cement ratio	0.45
Mix ratio 1 : 1.59 : 2.52 : 0.45	

## 7. Experimental Investigation

### A. Experimental Program

The cubes are to be tested to find the compressive strength, the cylinders are to be tested to find split tensile strength and prism are to be tested to find flexural strength of specimen after 7 and 28 days. In each trial, the strength of concrete is noted. Finally the results are to be tabulated and graphically plotted.

### B. Test Conducted

**Compression strength test:** Compression strength test was conducted for different mixes for 7 days and 28 days using compression test machine and the results were tabulated accordingly.

**Flexural strength test:** Flexural strength test was conducted on prisms of dimensions 100mm x 100mm x 500mm for 28 days using flexural test machine and the results were tabulated.

**Split tensile test:** Split tensile test was conducted on cylinders of dimensions 150mm x 300mm for 28 days using compression test machine and the results were tabulated

**Young's modulus test:** Young's modulus test was conducted on cylinders of dimensions 150mm x 300mm for 28 days using compression test machine and the results were tabulated.

## 8. Results and Discussions

The results of this work is obtained mainly through conducting various laboratory tests and analysis. The results obtained are as follows.

**Table 4: Results of Fly ash replacement**

Mixes	Compressive Strength (N/mm <sup>2</sup> )		Split Tensile Strength (N/mm <sup>2</sup> )	Modulus of Elasticity (GPa)	Flexural Strength (N/mm <sup>2</sup> )	Breaking load (KN)
	7 <sup>th</sup> day	28 <sup>th</sup> day				
CM	20.74	38.5	3.42	36.2	4.34	22
F <sub>1</sub> (5% FA)	21.88	38.94	3.44	36.32	4.46	22.90
F <sub>2</sub> (10% FA)	22.67	39.22	3.47	36.59	4.52	25.20
F <sub>3</sub> (15% FA)	24.44	39.75	3.48	36.96	5.02	29.40
F <sub>4</sub> (20% FA)	26.22	40.3	3.50	37.27	5.22	30.50
F <sub>5</sub> (25% FA)	14.22	25.33	3.47	35.44	4.10	21.40

First the cement is replaced by Fly ash and conducts various tests. From the above result, up to 20% of the cement replacement by fly ash shows better result compared to the control mix. Beyond this limit, strength reduced. After that the different percentages of GGBS was added in to the optimum value of fly ash with 1% of hooked fiber. The results are shown in table 5.

**Table 5: Test results of Fly ash with GGBS**

Mixes	Compressive Strength (N/mm <sup>2</sup> )		Split Tensile Strength (N/mm <sup>2</sup> )	Modulus of Elasticity (GPa)	Flexural Strength (N/mm <sup>2</sup> )	Breaking load (KN)
	7 <sup>th</sup> day	28 <sup>th</sup> day				
F <sub>21</sub> (20%F A+10% GGBS)	24.22	38.85	3.45	36.52	4.56	23.22
F <sub>22</sub> (20%F A+20% GGBS)	20.26	34.32	3.43	35.92	4.15	21.30
F <sub>23</sub> (10%F A+30% GGBS)	19.85	33.63	3.40	33.53	3.62	19.35

From the above test results 20% of fly ash and 10% of GGBS gives better strength as compared to the other mixes. But the results are not more the binary mix.

Next, the cement can be replaced by different percentages of GGBS which is shown in table 6.

**Table 6: Results of GGBS replacement**

Mixes	Compressive Strength (N/mm <sup>2</sup> )		Split Tensile Strength (N/mm <sup>2</sup> )	Modulus of Elasticity (GPa)	Flexural Strength (N/mm <sup>2</sup> )	Breaking load (KN)
	7 <sup>th</sup> day	28 <sup>th</sup> day				
CM	20.74	38.5	3.42	36.2	4.34	22
G <sub>1</sub> (10% GGBS)	22.5	39.55	3.45	36.45	4.65	24.42
G <sub>2</sub> (20% GGBS)	25.65	41.72	3.49	36.82	5.17	29.6
G <sub>3</sub> (30% GGBS)	26.14	42.50	3.51	37.20	5.26	31.56
G <sub>4</sub> (40% GGBS)	26.22	43.15	3.53	37.52	5.38	32
G <sub>5</sub> (50% GGBS)	24.15	39.72	3.47	35.95	5.07	30.2

From the above test results 40% of cement replacement by GGBS gives better results than control mix. After that the different percentages of fly ash was added in to the optimum value of GGBS with 1% of hooked fiber. The results are shown in table 7.

**Table 7: Test results of GGBS with fly ash**

Mixes	Compressive Strength (N/mm <sup>2</sup> )		Split Tensile Strength (N/mm <sup>2</sup> )	Modulus of Elasticity (GPa)	Flexural Strength (N/mm <sup>2</sup> )	Breaking load (KN)
	7 <sup>th</sup> day	28 <sup>th</sup> day				
G <sub>41</sub> (40%G GBS+5% FA)	25.94	42.24	3.55	38.12	5.32	33.2
G <sub>42</sub> (40%G GBS+10% FA)	26.54	45.15	3.53	37.62	5.51	35.6
G <sub>43</sub> (40%G GBS+15% FA)	24.32	39.26	3.49	36.51	4.9	31.65

From the above test results the 40% GGBS and 10% FA gives high compressive strength, flexural strength and breaking load. 40% GGBS and 5% FA gives high split tensile strength and modulus of elasticity. The compressive strength graph of optimum value of GGBS and fly ash is Shown in fig :1



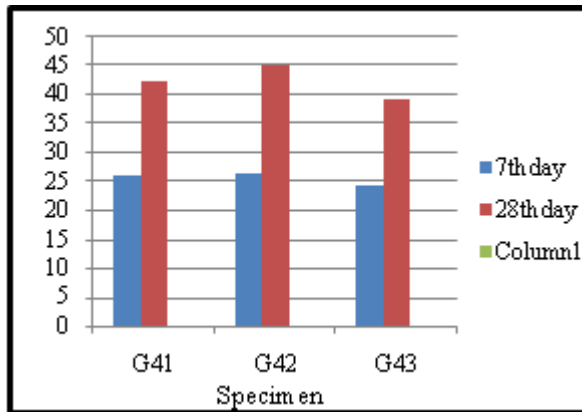


Figure 1: Compressive strength of GGBS with fly ash

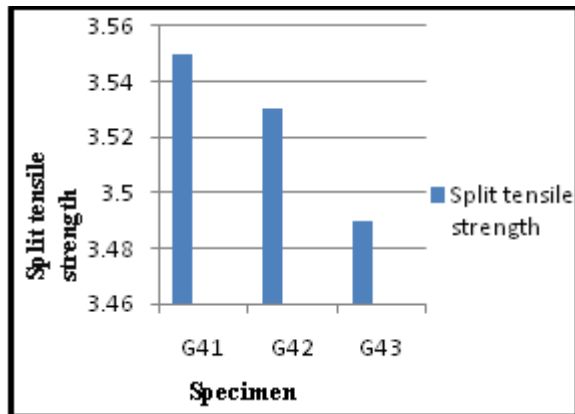


Figure 2: Split tensile strength

The Split tensile strength of GGBS with fly ash is shown in fig 2. And the Modulus of Elasticity graph is shown in fig 3.

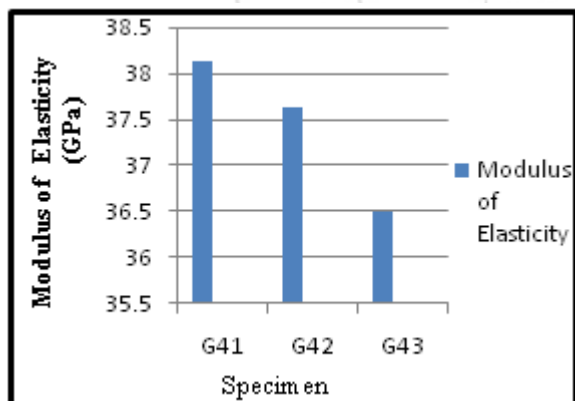


Figure 3: Modulus of Elasticity

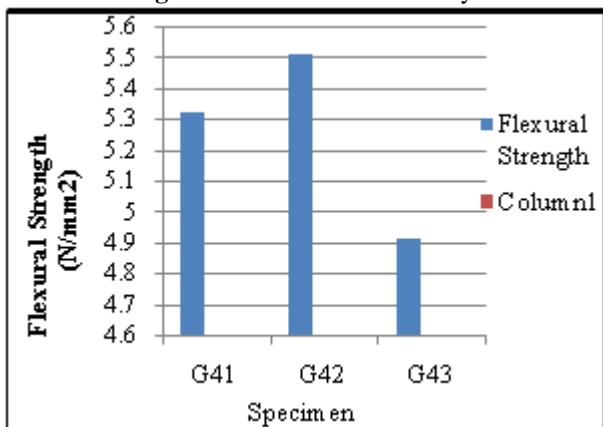


Figure 4: Flexural Strength

The flexural strength graph is shown in fig 4.

## 9. Conclusions

Based on the different mixes and various tests conducted the conclusions are

- 20% replacement of fly ash gives high strength as compared to control mix. But when the GGBS is added into the fly ash the strength properties are reduced.
- With the replacement of cement by 40% GGBS and 10% fly ash gives high compressive strength, flexural strength and breaking load.
- With the replacement of cement by 40% GGBS and 5% fly ash gives high split tensile strength and modulus of elasticity.
- Concluded that increase of fly ash content can be reduce the strength properties of ternary blended concrete and the GGBS provide good workability as compared to fly ash.

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