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Evaluating Strength Parameters of Triple Blended Concrete Using Composite Cement

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ABSTRACT

In the present study, an investigation is made to evaluate the properties of concrete by replacing cement by GGBS at 30%, 40%, 50% and Fly ash at 15%, 25%, 35%. Different blends of fly ash and GGBS are tried according to Codal provisions for composite cements and M-Sand as the replacement to fine aggregates keeping other constituents of concrete constant. These ternary mixes were tested for workability, strength and durability properties of concrete. The results were tested at 7 and 28 curing days. From test results, it is observed that workability of concrete surges with increases in Fly ash and GGBS content. 15% Fly ash and 30% GGBS mix shows the maximum compressive strength and tensile strength for triple blended concrete. The ternary mixes gives worthy permeability results when compared to controlled mix. Finally, from the experimental study we can conclude that composite cement with performance equivalent to control PPC or PSC can be prepared by using ternary mix of GGBS and Fly ash in the range of 30-50% and 15-35% respectively.
Keywords— Flyash, GGBS, Composite Cement.

I. INTRODUCTION

Concrete is the most widely used construction material beside steel in Civil Engineering applications. The recent surveys says that the construction industry produces about 31giga tonnes of concrete annually, consuming about 4gigatonnes of cement. This digit is surging constantly due to growth in global population and the vast expansion of construction industries. The consumption of crude materials for the production of cement has worse effects on the environment their by emancipating carbon dioxide to airspace. Around 1.5 to 1.85 tonnes of crude materials are consumed for producing one tonne of cement by releasing 0.8 tonnes of carbon dioxide. The surveys states that, cement industries is contemplated as the 2nd largest producer of greenhouse gases, where it deliberates around 5 to 8 percentage of carbon dioxide emissions globally. This factor leads in investigating the solutions for these global problems and the experimental studies shows the usage of alternative materials which are eco-friendly and can gratify the sustainable development aims. These alternatives materials are called as Cement Replacement Martials (CRM) or Complimentary Cementitious Materials (CCM).It is familiar that the use of mineral admixtures like ground granulated blast furnace slag and fly ash in concrete mixes has greater possessions in reduction of industrial wastes/by products. It was found that the generation of flyash and ground granulated blast furnace slag from the construction industries were nearly 0.45 billion & 0.53 billion tonnes respectively. Discarding the large amounts of these materials proved to be uneconomical and also its not eco-friendly. From the past 20 years, huge numbers of experimental studies were carried out to analyse the enactment of ternary concretes comprising fly ash and ground granulated blast furnace slag. It is reported that the use of GGBS & fly ash diminishes expenses in production of concrete and waste disposal, especially for high volume replacement.

Hydraulic cements stated by BIS comprises of Ordinary Portland Cement of 33, 43 & 53 Grades, Portland Pozzolona Cement, Portland Slag Cement & several distinct obstinacy cements. GGBS conforming to IS 12089:1987 and Fly ash conforming to IS 3812 (Part-1): 2013 are used in the production of Portland Slag

Cement and Portland Pozzolona Cement respectively. In present scenario, blending of these materials in production of Cement is not employed. Composite cements are the blended cements which are manufactured by using more than one mineral admixture. National Council for Cement and Building materials (NCB) conducted a pre-requisite work on usage of GGBS and Fly ash for concocting composite cement and in later stages they carried out an experimental study on composite cement wherein combinations of fly ash and granulated blast furnace slag were used for preparing composite cement blends. The results indicated that slag and fly ash could be added simultaneously as the mineral admixture in preparation of composite cement. However, the properties of composite cement depended on the quality of clinker and mineral additions, besides fineness and particle size distribution. In this phase, to attain better knowledge in composite cements, additional studies on production and evaluation of strength with durability parameters are crucial and also fresh and mechanical properties are carried out to get better empathies on composite cements. GGBS and Fly ash in combination with OPC are presently not being used for preparing composite cement in our country but soon it will be adopted as we have got code regulations for composite cements. Bureau of Indian standards (IS 16415: 2015) have specifications on Composite Cement permitting simultaneous use of mineral admixtures like granulated blast furnace slag and pozzolana/ fly ash, with total additions in the range of 15-50%.

II. OBJECTIVES

The main aim of this study is to investigate the use fly ash and ground granulated blast furnace slag as cement replacements and Manufacturing sand as fine aggregate material. To evaluate the changes in the workability, strength and durability properties of concrete when different percentages of FA and GGBS are added.

- To investigate the effectiveness of FA and GGBS as cement replacements.
- To establish the optimum mix
- To study the strength behaviour of triple blended concrete
- To examine the effect of composite cement & Manufacturing sand on the strength and durability properties of triple blended concrete.

III. EXPERIMENTAL PROGRAMME

A. Materials Used

- **Portland cement:** In this work Ordinary Portland Cement (OPC) of 53 grade conforming to code IS 269:2015 were used and tested for chemical & physical properties as per code IS 4031:1996.
- **Fine Aggregate:** Manufactured sand obtained from a manufacturing plant (i.e. Crushers) conforming to code IS: 383:2016 was used as fine aggregate.
- **Coarse Aggregate:** Coarse aggregate of 20 mm and 12.5mm size was used as coarse aggregate conforming to code IS 383:2016.
- **Fly Ash:** Fly Ash used in the manufacture of composite cement is RTPP.AP and it shall conform to IS 3812: 2013.
- **Ground Granulated Blast Furnace Slag:** Granulated slag used in the manufacture of composite cement is JSW steel Ltd. and it shall conform to IS 4031 (Part 4 & 6): 1998 and IS 16714:2018.
- **Super plasticizer:** The Super plasticizer SP430-ES2 of Poly Carboxylic Ethers type manufactured by FOSROC Company is used in this experimental work. It conforms to code IS 9103: 1999.
- **Water:** The potable water conforming to IS 456:2000 was used in the present experimental work.

B. Collection of materials

The essential materials adopted in this experimental work were bought from local sources. The materials used in this experimental work are Portland cement, GGBS, Fly ash, Manufactured Sand, Coarse aggregate of size 20mm & 12.5mm and Potable water.

C. Mixing

The concrete was blended using machine mixer in laboratory throughout the experimental work. Initially all the materials were weighed using weighing machine precisely. Both fine and coarse aggregates are mixed for about a minute in dry state. Portland cement, GGBS and Fly ash are then added and unified for one more minute when mix is no longer wet. $2/3^{rd}$ of potable water and super plasticizer was added and sustained for another minute. The remaining water and plasticizer were added and blended until uniform mix is achieved.

D. Casting of specimens

For casting specimens, standard cast iron-metal moulds was used.150×150×150 mm cubes of 54 numbers were used for testing compressive strength as per IS 516:1999 and 150×300 mm cylinders of 54

numbers were used for testing tensile strength for 7 and 28 days as per IS 5816:1999. The same was used for conducting Permeability test and Modulus of Elasticity test at 28 curing days.

E. Curing of specimens

Water curing is adopted in this experiment as the curing requisites are gratified, like preferment of hydration, absorbing heat of hydration & abolition of shrinkage. After casting, moulds were kept at ambient temperature for 24 hours. After this period, Curing of specimen is carried out in potable water at room temperature for 7 days and 28 days.

F. Testing of Specimens

The properties are checked in fresh state and hardened state and the test results are compared for ideal combination to improve the performance of concrete in workability, strength and durability. Fresh concrete are cast into cubes and cylinders. The tests are conducted at 7 and 28 days curing for hardened concrete.

G. Concrete Mix Designs

M30 grade of concrete was designed as per the Indian Standard code of practice. The stipulations for proportions and test data of materials will be discussed as below.

Table 1: Ternary concrete mix proportions

Concrete Mix Designs									
Materials per cubic meter in Kg's									
Mix	**C100**	**G 50**	**F30 G35**	**F15 G50**	**F25 G40**	**F35 G30**	**F15 G40**	**F25 G30**	**F15 G30**
Grade of Concrete	M30	M 30	M30	M30	M30	M30	M30	M30	M30
Cement	350	185	137	137	137	137	176	176	215
GGBS	0	185	137	195	156	117	156	117	117
Fly Ash	0	0	117	59	98	137	59	98	59
Free Water	193	194	194	194	194	194	194	194	194
Sand	779	764	738	748	743	739	749	745	750
20 mm	675	662	640	648	644	641	649	646	650
12.5 mm	449	440	425	431	428	426	432	429	432
Admixture	0.88	0.93	0.78	0.78	0.78	0.78	0.78	0.78	0.78
W/c Ratio	0.45	0.43	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Note: Water cement ratio is considered based on stipulated permissible Slump values									

IV. EXPERIMENTAL RESULTS

A. Fresh properties of concrete

Slump Test

Figure 1 shows the slump values of normal mix & ternary mixes. From below figure we can conclude that triple blended concrete with water cement ratio 0.41 shows better slump values than the normal concrete with water cement ratio 0.45. Increase in slump value is in the range of 0% to 11.76% with respect to control mix. Workability increases as the percentage of Fly ash increases. This is due to the increase of considerable amount of fine materials in the ternary mixes. From these values we can conclude that the optimum ternary mixes F30G35, F25G40 and F35G30 are more workable than other mixes.

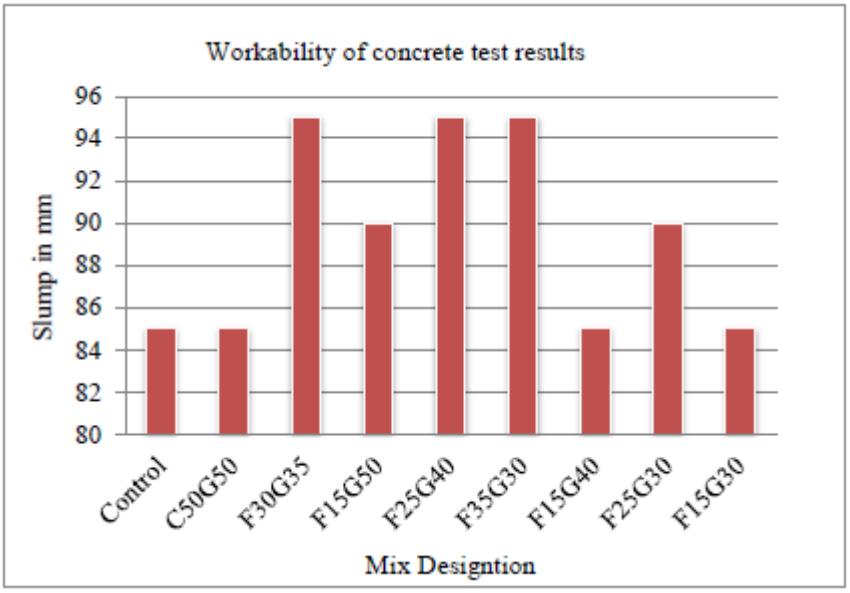

Figure 1: Slump test results of GGBS and Fly ash mixes

B. Hardened properties of concrete

Compressive strength of concrete for 7 & 28 Days

Figure 2 shows the comparison of cube compressive strength of concrete for different proportions for 7 and 28 curing days. It is perceived that the cube compressive strength of control mix fluctuates with curing days & cube strength of triple blended concrete alters with respect to different percentages of GGBS and Fly ash as well as curing days. From the experimental analysis, the addition of GGBS and Fly ash enhanced the strength parameters of triple blends, which is on par with ordinary mix. From the figure it is perceived that typical concrete ranges from 29.86MPa to 46.19MPa and the optimum strength of triple blended concrete ranges from 26.41MPa to 42.96MPa and increase in compressive strength of triple blended mix ranges from 35.44% to 40.63% for 7 to 28 curing days.

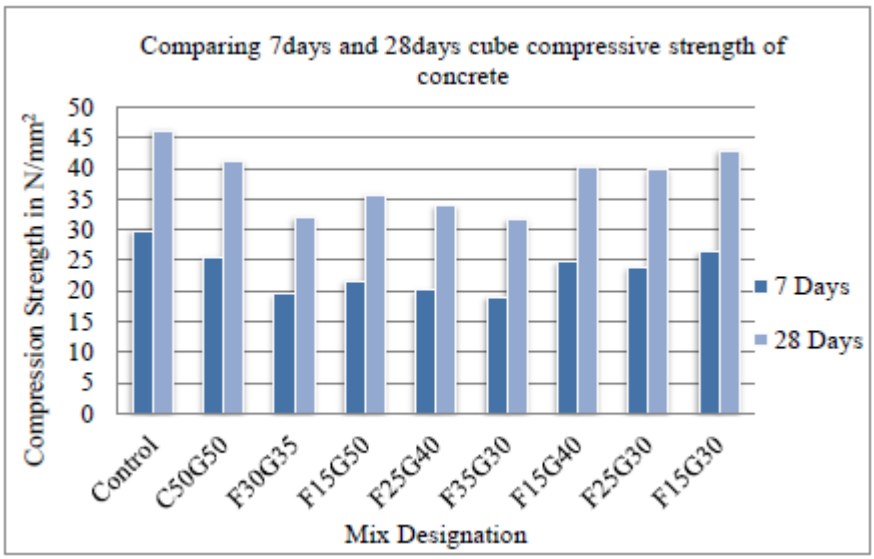

Figure 2: Comparison of compressive strength of concrete of different proportions for 7 and 28 days

Tensile strength of concrete for 7 and 28 Days

Figure 3 gives the comparison of cylinder/typical strength of concrete for different proportions for 7 and 28days. From the figure it is perceived that the conventional concrete varies from 2.69MPa to 4.05MPa and

the optimum cylinder strength of triple blended concrete ranges from 2.56MPa to 3.95MPa and increase in cylinder strength of triple blended mix ranges from 50.55% to 58.74% for 7 to 28 curing days.

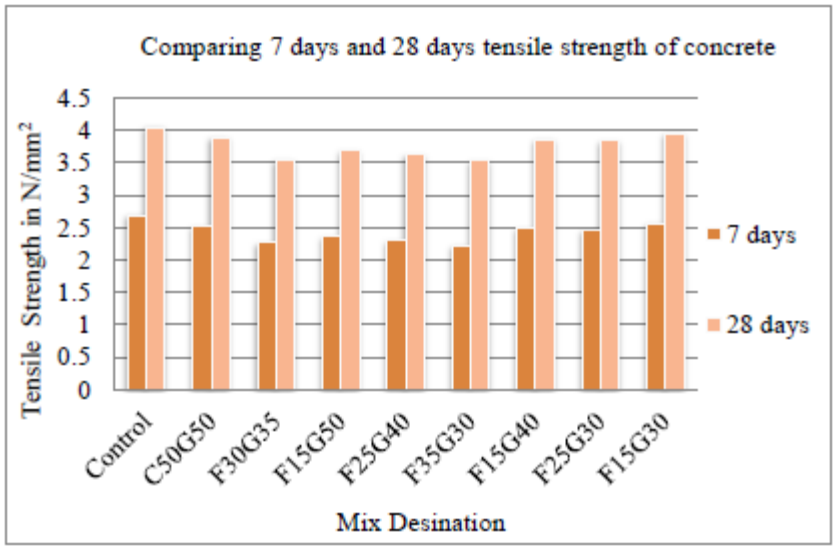

Figure 3: Comparison of tensile strength of concrete of different proportions for 7 and 28 days

- **Water permeability Test**

Figure 4 shows the comparison of permeability test results for different mixes at 28 curing days. Maximum permeability value is noticed in controlled concrete which is 19mm. Minimum permeability value is observed in mixes F30G35 and F35G30 which is 12mm, this is due to presence of higher percentages of fly ash. Fly ash has specific surface value nearby 3500 to 5000 cm^2/g, i.e. it is finer than the OPC & GGBS and therefore it reduces the permeability of concrete.

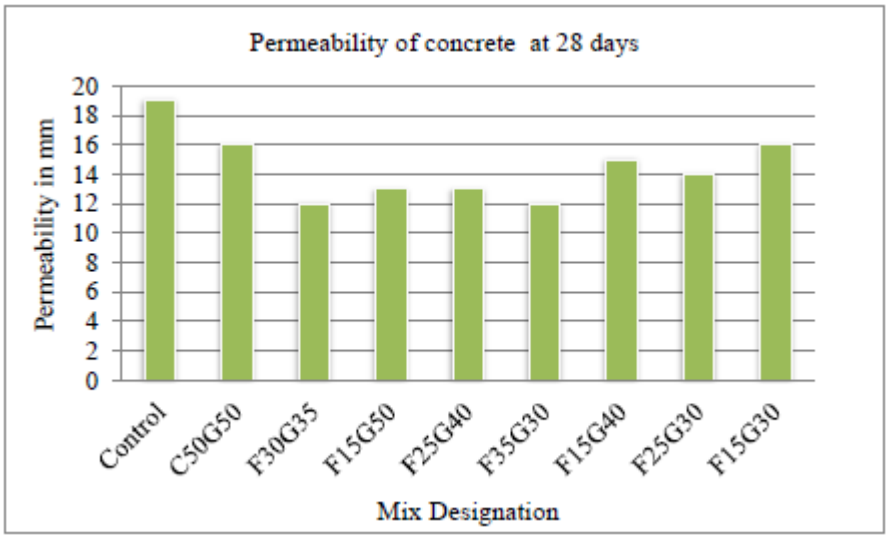

Figure 4: Comparison of permeability test results for 28 days

- **Modulus of Elasticity**

Figure 5 shows the comparison of modulus of elasticity test results for different mixes at 28 curing days. The modulus of elasticity of control mix is 28.23GPa. It is perceived that the optimal Modulus of elasticity of ternary mix with 50% of cement and 50% of GGBS is 29.42GPa. The mixes with fly ash developed a lower and the mixes with ground granulated blast furnace slag developed higher modulus of elasticity values

compared to typical mix. The modulus of elasticity values shows similar trends as the compressive strength of concrete at 28 curing days.

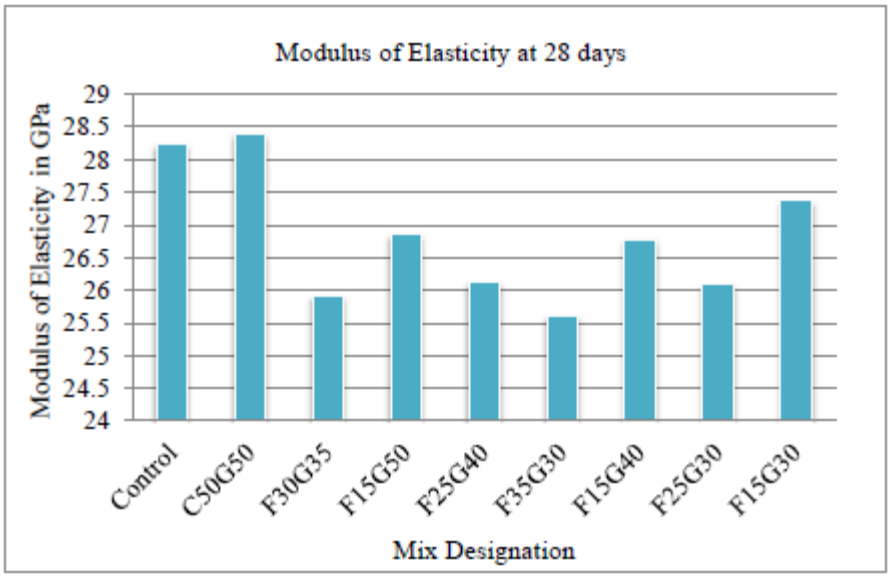

Figure 5: Comparison of modulus of elasticity test results for 28 days

V. CONCLUSIONS

An Experimental study on triple blended concrete was conducted to assess the effect of GGBS and fly ash in fractional replacement to Portland cement and Manufactured Sand in replacement to fine aggregate. Cement was replaced with fly ash of 15%, 25%, 35% by weight of cement and Ground Granulated Blast Furnace Slag (GGBS) of 30%, 40%, 50% by weight of cement. Different tests were carried out and the results are discussed.

The subsequent conclusions are drawn from the present experimental work.

- The workability of concrete surges with increase in Fly ash and GGBS content.
- The optimum compressive strength and tensile strength of triple blended concrete is observed in mix F15G30 which is 42.96MPa and 4.05MPa respectively and it is noted that compressive strength of triple blended concrete is lower than the ordinary concrete, but few mixes achieves stipulated target compressive strength of M30 concrete at 28 curing days.
- Ternary mixes with 35% of cement content shows lesser results than the stipulated target compression strength of triple blended concrete at 28 curing days. But it may improve in later stages, may be beyond 90days, because Fly ash is pozzolonic in nature and has the slower setting nature.
- As the fly ash percentage increases in the ternary mix, the targeted mean strength decreases. Due to lag in gaining of compressive strength of the concrete, the de-shuttering time in site increases.
- Maximum permeability value is noticed in controlled concrete which is 19mm and minimum permeability value is observed in mixes F30G35 and F35G30 which is 12mm.
- The results of Modulus of elasticity of concrete replicate similar tendencies as cube compression strength of concrete.
- The partial replacement of cement with pozzolonic materials facilitates Environmental friendly disposal of the waste which is generated in enormous quantities.
- Composite cement is environmental friendly and recommended for gradual replacement of Ordinary Portland Cement (OPC).

Finally, from the experimental study we can conclude that composite cement with performance equivalent to control PPC or PSC can be prepared by using ternary mix of GGBS and Fly ash in the range of 30-50% and 15-35% respectively.

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