

A Study on the Effect of Inclusion of Fly Ash as Partial Replacement of Cement and Granulated Blast Furnace Slag as Partial Replacement of Sand in Concrete

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Abstract-This research deals with the effective usage of industrial wastes such as bottom ash or Fly ash and granulated blast furnace slag in the production of concrete. The binding material cement was replaced by fly ash by 10%,20% and 30%. Fine aggregate was replaced by GBS by 20%,40% and 60%. Fly ash and Granulated Blast Furnace slag is used as replacement. Here keeping cement replacement constant for a particular mix and varying the replacement of sand for M40 grade concrete mix various tests were carried out. On green concrete slump cone test was conducted to measure the workability and on the hardened concrete compressive strength, flexural strength and split tensile strength was conducted. Compressive strength was conducted for 7,28,56 days. Flexural and split tensile strength was conducted for 28 days to determine the strength properties of the hardened concrete.

Key words :FA-Fly ash, GBS-Granulated Blast furnace slag, SP-Super plasticizer, CA- Coarse aggregate.

I INTRODUCTION

Concrete is the most widely used man made construction material in the world and second only to the water as the most utilized substance on the planet. It is obtained by mixing cementitious materials, water and aggregates in required proportions. Portland cement concrete lends itself to a variety of innovative design as a result of its many desirable properties. Concrete possesses high compressive strength and stiffness with adequate durable properties under normal environmental conditions. The useful physical properties and relatively low cost make cement based material the most widely used civil engineering material. But this material, concrete has some drawbacks: it is brittle, has a low failure strain and is weak in tension. The key of producing a strong, durable and uniform concrete i.e. high performance concrete lies in the careful control of its basic and process components.

A:Fly ash:

Fly ash is generally obtained from thermal power plants stored at coal power plants or placed at land fills obtained after the combustion of coal. Fly ash was generally released into the atmosphere, but pollution control board mandated in recent decades that it should be captured prior to release. About 43% is recycled using as pozzolanic admixture in cement. In India the total production of fly ash is nearly as much as that of cement(75 million tons). But the utilization of fly ash is only 5% of the total production of cement. Utilization of more fly ash in construction activity reduces problems associated with the disposal of fly ash.

B:Granulated Blast furnace Slag:

Steel industries are the main sources of Granulated Blast furnace slag. It is also known as steel slag or slag sand obtained from steel plants. Molten slag obtained at the bottom of furnace is quenched with the jet of water and cooled. After that the granules formed will be grinded in to required size. Due to higher alkali binding capacity of hydration products of slag has greater water logging capacity and hence the greater durability. It reduces the disposal problem of steel industrial waste. Granulated blast furnace slag is very effective in reducing the expansion due to alkali aggregate.

C:Objectives:

- To study the strength properties of concrete like compressive strength ,flexural strength and split tensile strength
- To Know the optimum percentage of fly ash in concrete as the partial replacement of cement so that reduction in the disposal problem of fly ash is made by replacing it for cement in concrete.
- To know the optimum percentage of GBS as replacement of sand in concrete so that reduction in the disposal problem of slag is made by using it in concrete.

- To propose an alternative building material that could reach requirements of good building material. And also to arrive at a solution for the problem of imbalance between the availability and the demand of conventional building materials.

II LITERATURE REVIEW

Patil et al(2012): Carried out investigation to use fly ash effectively as partial replacement in cement concrete. The cement in concrete is replaced from 5% to 25% at a rate of 5% increase to study the compressive strength of fly ash concrete. In the study M20 grade with the nominal mix as per IS456 was used. The concrete mix proportion was 1:1.5:3 by volume and water cement ratio 0.5 is taken. Concrete mould of size 150X150X150mm were casted. Fly ash is added in place of cement in concrete in 6 different percentages starting from 0% and up to 25% at an interval of 5%. 18 cubes are casted for each replacement and tested for 3,7,21,28,60,90 days. 5% fly ash has maximum rate of compressive strength development up to the age of 21 days and then after its rate decreases. For fly ash replacement greater than 10% the rate of strength development as well as final strength reduces. At the 90 days we get maximum strength for 10% fly ash addition. Finally concluded that fly ash can be successfully used in the cement concrete in minor amount as additive. Initial rate of strength development will be less but finally maximum strength can be attained and finds specific application in mass concreting.

Jayeshkumar et al(2012): This research work describes the usage of thermal industry waste in concrete production as partial replacement of cement. The cement has been replaced by fly ash accordingly 0%,10%,20%,30%,40% by weight of cement for M25 and M40 grade concrete. Cement used is OPC53 grade conforming to IS8112-1989. Coarse aggregate of 20mm down size and fine aggregate fractions from 4.75mm to 150 micron are used. Water cement ratio of 0.4 for M25 and 0.3 for M40 is used. Mixes were designed as per IS 10262:2009. Standard cubes of 150X150X150 mm are casted for compressive strength and split tensile strength and tested for 7,14,28 day strength. Final Compressive strength of 34.67N/mm² for 10% replacement in M25grade and 38.22N/mm² is observed and after that reduction in final strength is observed in both mix. Split tensile strength of 3.52N/mm² for M25 grade and 4.10mm² for M40 grade is observed and reduction is noticed for higher replacements. Finally it is concluded that compressive strength will reduced as percentage of fly ash increases.

Mohammed and Arun(2012):Experimental investigation carried out to evaluate effects of replacing coarse and fine aggregates with crystallized and granular slag. This study was conducted in 3 phases, in the first phase natural coarse aggregate was replaced by crystallized sand keeping fine aggregate common, in the second phase fine aggregate was replaced by granular slag keeping natural coarse aggregate common, in the third phase both aggregates were replaced by crystallized and granular slag. Concrete of M20,M30,M40 grade were considered for w/c ration 0.55,0.45,0.40 respectively with target slump 100 +25 Or 100-25 mm for the

replacement of 0%,30%,50%,70%,100% aggregates with slag aggregates. 100mm cubes set Of 3 were cast for compressive(7,28,56,91,119 days), split strength(7,28 days),and 100mm beam mould for flexure strength(7,28 days). Lower w/c ratio slag replacement for fine aggregate from 0-50% with fine aggregate are positively affecting compressive strength, same is observed for split and flexural strength. The result indicated that compressive strength was higher y 4-6% in all the mixes for the replacement level between 30-50%. Strength reduction was observed at 100% replacement of fine aggregate with granular slag by 7-10%. Split tensile strength and flexural found to be increased y 5-6% at 30-50% replacement levels but it reduced by 6-8% for 100% replacements. Slag due to its chemical composition and its chemical inertness of soundness of aggregates and concrete , it could be effectively used as aggregates in all the concrete constructions in the observed range of 30-50%.

Riyaz and Shinde(2013): This work includes the determination of different properties of locally available steel slag and utilization of steel slag in concrete by replacing it partially and fully by fine aggregate keeping the other parameters constant various investigation for compressive strength, flexural strength and split tensile strength on M20 grade concrete with w/c ratio 0.5 . Steel slag replacement of 0,20,40,60,80 an 100% are used for fine aggregate replacement. Material used in this study were OPC53 grade cement confirming IS 8112. Fine aggregate and coarse aggregate confirming IS383-1970. Designed concrete mix of M20 having mix proportion 1:1.9:2.96.

Beams of size 700X150X150mm for flexural strength , cylinders of size 150mm dia and 300mm length for split tensile strength. Cube of 150X150X150mm for compressive strength were casted. All the samples were water cured 14 days and 28 days. UTM was used for all type of tests. It is observed that compressive strength of 35 N/mm² is obtained for 60% percent and there is a increase in strength for 0,20,40 % and maximum is obtained for 60% replacement of fine aggregate by slag sand. Same thing is observed for flexural strength and maximum flexural strength of 8.815N/mm² is obtained for 60% replacement of fine aggregate. Maximum split tensile of 3.284N/mm² is obtained for 60% replacement. It is concluded that there is 25% increase in compressive strength ,12% increase in flexural strength and 56% increase in split tensile strength compared to controlled mix. 60% of steel slag is permitted to replace fine aggregate.

III MATERIALS AND METHODOLOGY

A . Cement

Ordinary Portland cement of 43 grade (Ramco) conforming to IS 8112-1989 is used. Table1 shows the test results of basic properties of cement.

Table 1: Basic Properties of Cement

Properties	Cement
Specific gravity	3.1
Standard consistency	31%
Initial setting time	38min
Final setting time	480min
Fineness	5.3%

B. Fine Aggregate

Natural river sand of size 4.75mm-0.015mm conforming zone II of IS 383-1970 is used as fine aggregate. Table 2 shows the test results of basic properties of fine aggregates.

Table 2: Basic Properties of Fine Aggregates

Properties	Fine Aggregate
Specific gravity	2.62
Water absorption	1.45%

C. Coarse Aggregate

Natural crushed stone collected from local quarry with 20mm-4.75mm size is used as coarse aggregate. Table 3 shows the test results of basic properties of coarse aggregates.

Table 3: Basic Properties of Coarse Aggregates

Properties	Coarse Aggregate
Specific gravity	2.65
Water absorption	0.39%

D. Fly Ash

In this experiment Class F fly ash was used which was collected from UPCL, Padubidre Udipi district Karnataka. Table 4 shows the test results of basic properties of fly ash.

Table 4: Basic Properties of Fly Ash

Properties	Fly Ash
Specific gravity	2.5
Fineness	2.28%

E. Granulated Blast Furnace slag

GBS which is a waste material was collected from Jindal Steel works Bellary. Table 5 shows the test results of basic properties of GBS.

Table 5: Basic Properties of Granulated Blast Furnace slag

Properties	GBS
Specific gravity	2.63
Water absorption	5.9%

F. Water

Ordinary portable water is used in this investigation both for mixing and curing with pH of 7.5

G. Super plasticizer (SP)

Conplast SP430 is used as a super plasticizer. It is a chloride free, super plasticizing admixture. It is supplied as a brown solution which instantly disperses in water.

H. Concrete Mix Design

Mix proportion used in this study is 1:1.61:2.65 (M40) with water-cement ratio of 0.4 and super plasticizer of 0.75%.

I. Batching and Mixing of Materials

Weight batching and machine mixing are adopted in this study for concrete production. The percentage replacement of ordinary cement by FA and GBS and their material weight are shown in Table 6

Table 6: Mix Proportion Per Cubic Meter

Mix	GBS Kg	FA Kg	Cement Kg	Fine aggregate Kg	CA Kg	Water w/c 0.4 L	.75 % SP L
CM	-	-	425	684.25	1126.2	170	3.2
M1-0%FA,20%GBS	136.8	0	425	547.4	1126.2	170	3.2
M2-0%FA,40%GBS	273.7	0	425	410.55	1126.2	170	3.2
M3-0%FA,60%GBS	410.5	0	425	273.7	1126.2	170	3.2
M4-10%FA,0%GBS	0	42.5	382.5	684.25	1126.2	170	3.2
M5-10%FA,20%GBS	136.8	42.5	382.5	547.4	1126.2	170	3.2
M6-10%FA,40%GBS	273.7	42.5	382.5	410.55	1126.2	170	3.2
M7-10%FA,60%GBS	410.5	42.5	382.5	273.7	1126.2	170	3.2
M8-20%FA,0%GBS	0	85	340	684.25	1126.2	170	3.2
M9-20%FA,20%GBS	136.8	85	340	547.4	1126.2	170	3.2
M10-20%FA,40%GBS	273.7	85	340	410.55	1126.2	170	3.2

S							
M11- 20%FA, 60%GB S	410. 5	85	340	273.7	1126. 2	170	3.2
M12- 30%FA, 0%GBS	0	127. 5	297.5	684.25	1126. 2	170	3.2
M13- 30%FA, 20%GB S	136. 8	127. 5	297.5	547.4	1126. 2	170	3.2
M14- 30%FA, 40%GB S	273. 7	127. 5	297.5	410.55	1126. 2	170	3.2
M15- 30%FA, 60%GB S	410. 5	127. 5	297.5	273.7	1126. 2	170	3.2

J. Casting of Specimens

Mixing is done by using concrete mixer. For each proportion 12 cubes of size 100*100*100mm, 3 cylinder of 100mm dia and 200mm in height and 3 beams of 100*100*500mm are casted. Mixing is done by adding coarse aggregate to drum first, followed by 25% of total water and super plasticizer. Super plasticizer will be added to water measured and stirred well. Then sand is added with 25% of water and super plasticizer again. After through mixing of aggregates, cement with admixtures if any is added and remaining 50% of water and super plasticizer is added. For each mix slump cone test is conducted to measure workability. Totally 180 cubes, 45 cylinder and 45 beams are casted. After mixing concrete is filled into moulds and compacted on vibration table. De moulding was done after 24 hours of casting. specimens are cured in curing tank. Water immersion method for curing is adopted. Cubes are cured for 7, 28, 56days and remaining specimens are cured for 28 days. Figure 1 shows the concrete placed in moulds.



Fig 1. Concrete placed in moulds

K. Testing of Specimen

Compressive strength test were carried on cubes, split tensile strength test on cylinders and flexural strength test on beams. All the test are done using compressive testing machine as shown in fig2,fig3,fig4.



Fig 2. Compressive strength test



Fig 3. Split Tensile strength test



Fig 4. Flexural strength Test

IV RESULTS AND DISCUSSIONS

A. Compressive strength

Compression strength of cubes for 7,28,56 days for various mixes are given and discussed in the below figures.

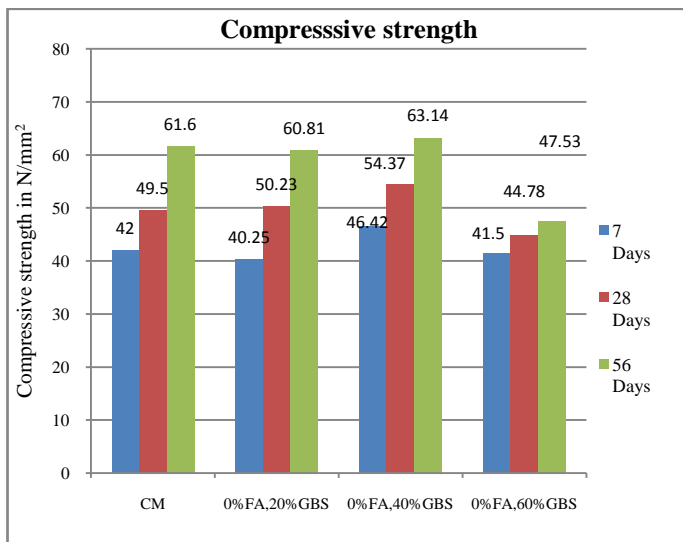


Fig. 4

Fig 4 shows the 7,28,56 days compressive strength results for the replacement of sand by GBS. Increase in Strength observed for sand replacement and maximum is observed for 40% replacement and further addition decreases the strength.

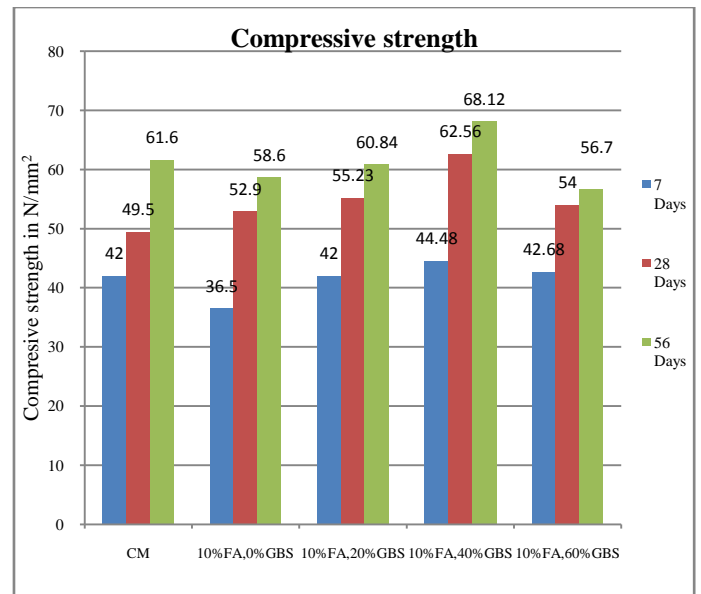


Fig. 5

Fig 5 shows the 7,28,56days compressive strength result for the 10% cement replacement by fly ash and replacement of sand by GBS for 0%, 20%,40%,60%. It is observed that there is decrease in 7 day compressive strength. Increase in strength is observed for 7 and 28 days. Increase in strength is observed for 10%FA and 40%GBS and decrease in strength is observed for further increase in GBS content.

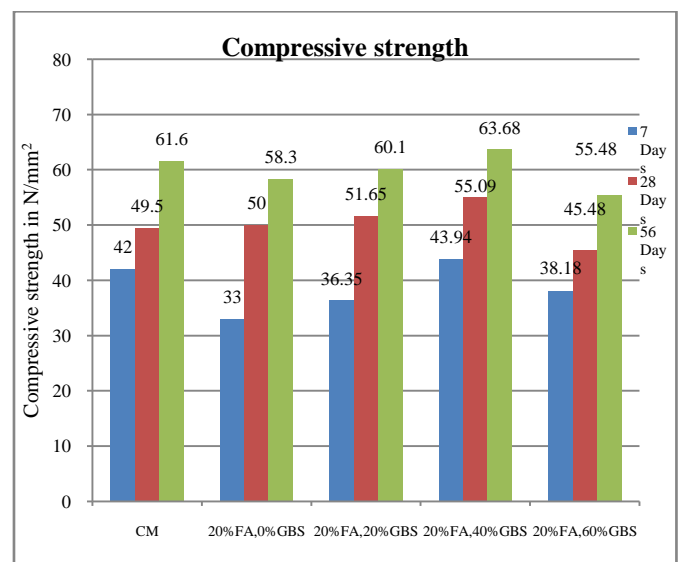


Fig. 6

Fig 6 shows the 7,28,56days compressive strength results for the 20% cement replacement by fly ash and sand replacement by GBS by 0%, 20%,40% and 60%. It is observed that decrease in 7 days compressive strength for 7 days which is lower to 10% FA replacement. Increase in strength is observed for 28 and 56 days. Maximum strength was achieved for 20% fly ash and 40%GBS replacement. Comparatively less to 10%FA and 40%GBS content

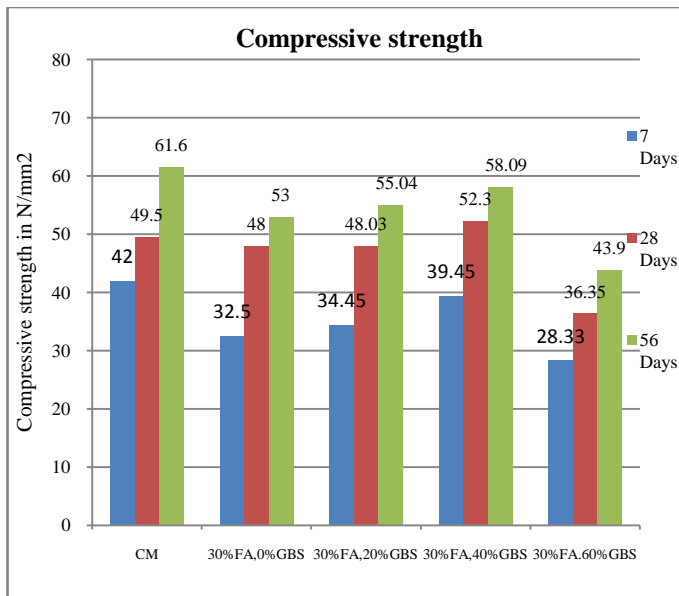


Fig. 7

Fig 7 gives the 7,28,56days compressive strength results for the replacement of cement by fly ash by 30% and sand by GBS by 0% 20%,40%,60%. Decrease in strength is observed for all ages in fly ash and Maximum strength is observed 40% replacement of sand by GBS and cement by fly ash of 30%.

B. Flexural strength

Flexural strength of beams for 28 days are given and discussed in the figures given below

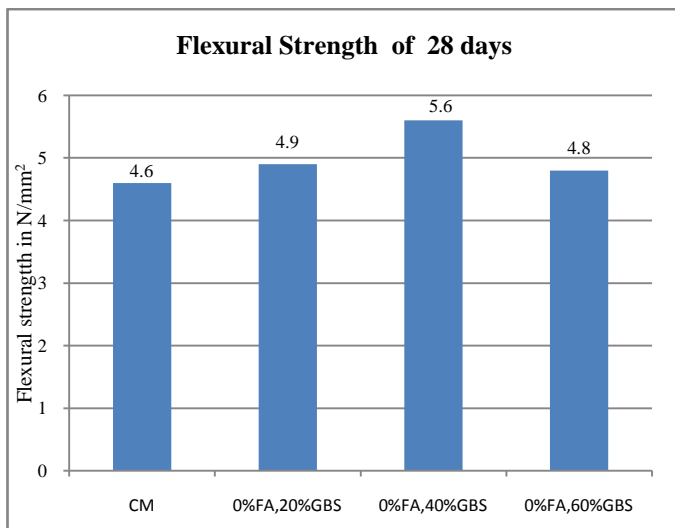


Fig. 8

Fig 8 gives the 28 days flexural strength of concrete for the replacement of cement by 0% fly ash and sand by 20%,40%,60% GBS . It can be seen that flexural strength increases with increase in GBS up to 40% replacement. After that for higher replacement decrease in strength in observed. maximum strength is observed for 40% sand replacement by GBS.

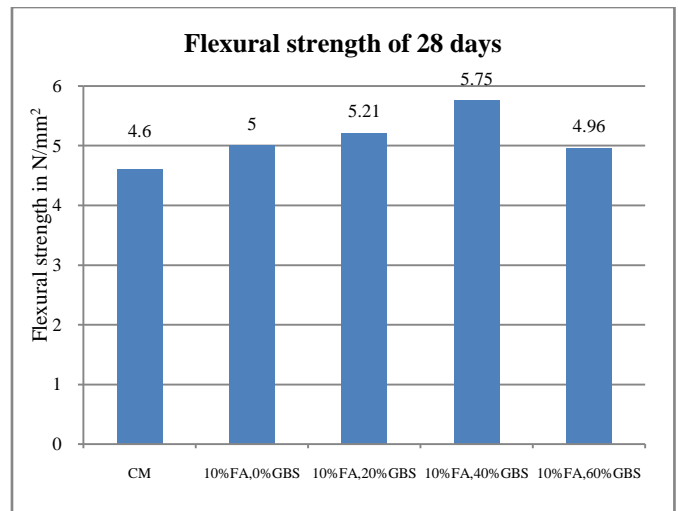


Fig. 9

Fig 9 gives 28 days flexural strength results for the varying of sand by 20%,40% and 60% by GBS and cement by 10% fly ash. Increase in flexure is observed for fly addition and for GBS more increase in strength is observed. Maximum strength is observed for 40% replacement of sand by GBS and cement by 10% fly ash.

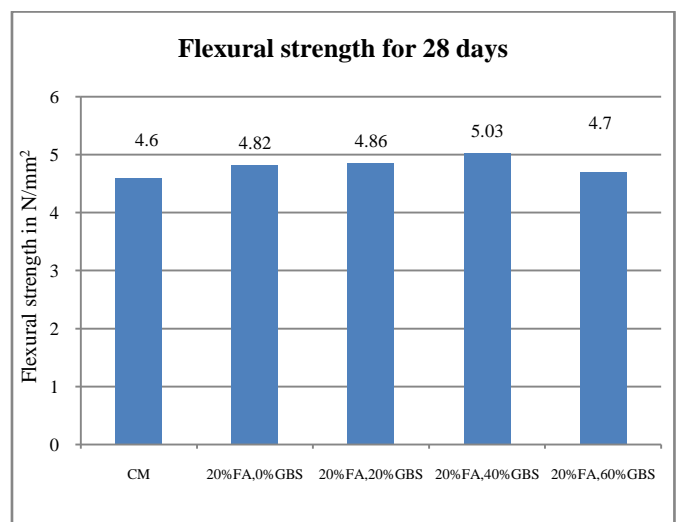


Fig .10

Fig 10 gives the 28 days flexural strength of concrete for the replacement of cement by 20% fly ash and sand by 20%,40% and 60%GBS. Increase in flexure is observed for 20% replacement of cement by fly ash but compared to 10% fly ash it has gained lesser strength and for 10%FA, 40% replacement of sand by GBS maximum strength is gained.

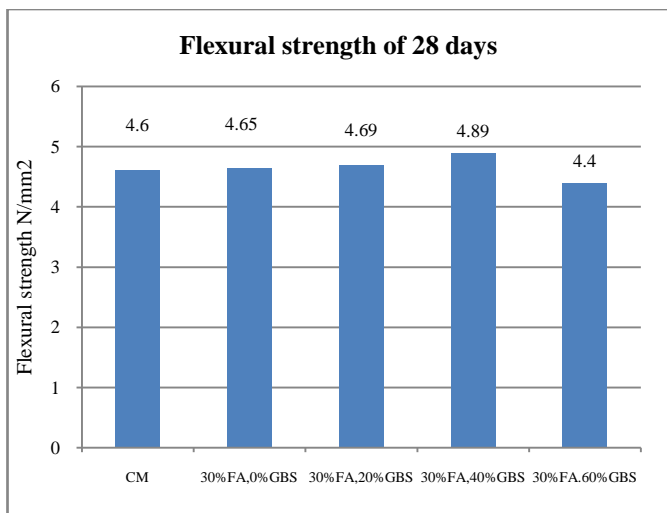


Fig .11

Fig 11 gives the flexural strength of the concrete for the replacement of cement by 30% fly ash and sand by 20%,40% and 60% GBS. For fly ash replacement there is no much increase in strength is observed and with the addition of GBS some increase in flexure is observed along with fly ash combination. Maximum flexural strength is observed for 30% cement replacement by fly ash and 40% sand replacement by GBS.

C. Split tensile strength

Split tensile strength for 28 days are given below and discussed for various mixes

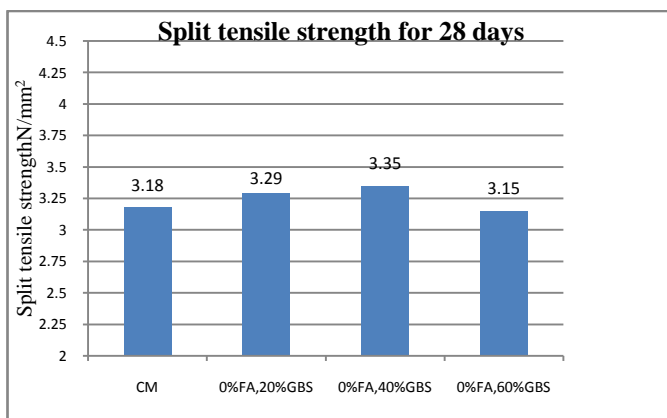


Fig .12

Fig 12 gives the split tensile strength of the concrete for the replacement of cement by 0% fly ash and sand by 20%,40%,60% GBS. Increase in split tensile strength is observed for increase in GBS. Maximum strength is obtained for 40% replacement of sand by GBS.

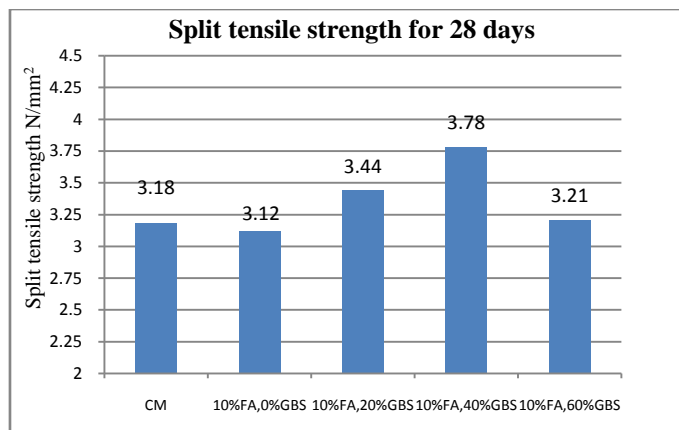


Fig. 13

Fig 13 gives the split tensile strength of the concrete for the replacement of sand by 20%,40% and 60% GBS and cement by 10% fly ash. For fly ash replacement decrease in small amount of strength is observed and with the addition of GBS increase in strength is observed. Maximum strength is observed for 10% cement replacement by fly ash and sand by 40% GBS.

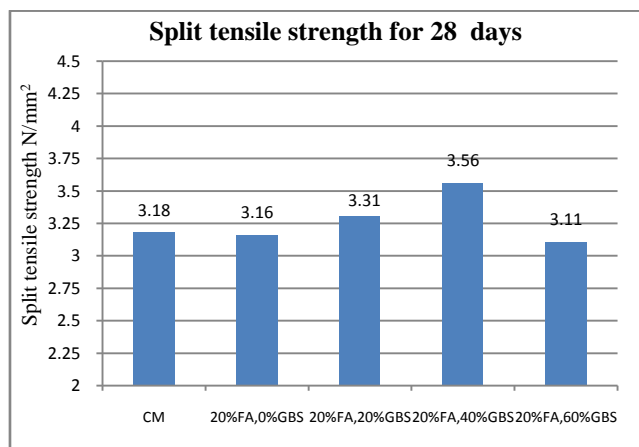


Fig .14

Fig 14 gives split tensile strength of the concrete for replacement of cement by 20% fly ash and sand by 20%,40% and 60% GBS. Increase in strength compared to 10% FA is observed for 20%FA. In the combination increase in split tensile strength is observed for 20% replacement of cement by fly ash and 40% sand replacement by GBS

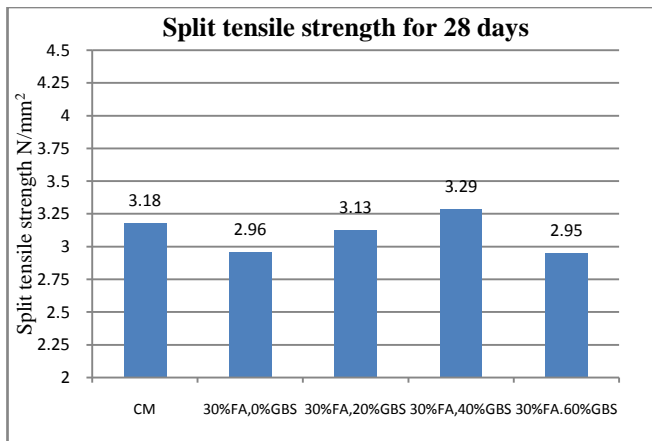


Fig .15

Fig 15 gives the split tensile strength of the concrete for the replacement of the cement by 30% fly ash and sand by 20%,40% and 60% GBS. Decrease in split tensile is observed for 30%FA. Increase in split tensile strength is observed after GBS addition. 30% cement replacement by fly ash and 40% sand replacement by GBS gives maximum strength.

D. Slump

Slump is the main factor for the good concrete. Slump obtained at the time of mixing for the various mixes are given below

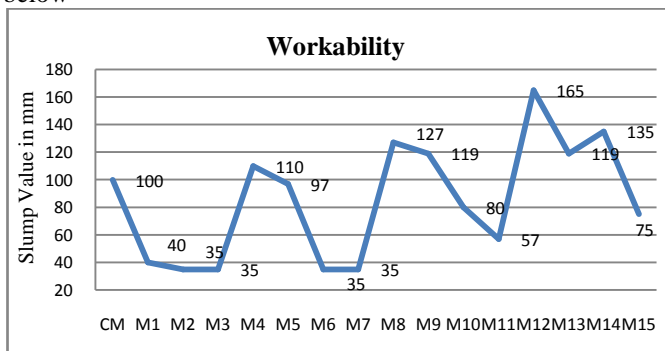


Fig .16

Fig 16 gives the slump variation for various mixes, increase in slump is observed as content of fly ash increases. As the GBS content increases with the combination of fly ash slump decreases correspondingly. Maximum slump observed for 30% fly ash replacement and increase in the GBS decreases the workability.

V CONCLUSION

After doing the experimental investigation, the following are concluded

- The replacement of sand by GBS up to 40% increases the strength;
- Maximum compressive strength has been achieved for the replacement of cement by 10%fly ash and sand by 40%GBS
- Increase in workability has been achieved by the addition of fly ash and the decrease in workability is seen when the sand is replaced by GBS.
- Increase in the flexural strength is seen when the cement is replaced by 10% fly ash and sand by 40%GBS..

- Increase in the split tensile strength is seen when the cement is replaced by 10% fly ash and sand by 40%GBS..
- As the percentage of GBS and fly ash increases. Decrease in the mechanical properties of the concrete is seen.

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