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# 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

Gururaj T[1], Ajith B T[2] , Chandrashekara A[3]
[1]PG Student, [2]Asst.Professor
KVG College of Engineering, Sullia, DK, India

***Abstract*-This paper describes the effective usage of industrial wastes such as fly ash and granulated blast furnace slag in the production of concrete. The cement was replaced by fly ash by 10%,20% and 30%. Sand was replace by Granulated Blast Furnace slag by 20%,40% and 60%.. Fly ash and Granulated Blast Furnace slag is used as a supplement of replacements were taken here by keeping cement replacement constant for a particular mix and varying the replacement of sand for M40 grade concrete mix. On fresh 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 and days. Flexural and split tensile strength was conducted for 28 days to determine the mechanical 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.

Fly ash is generally obtained from thermal power plants stored at coal power plants or placed at land fills. 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 about 5% of the production of cement. Utilization of more fly ash in construction activities reduces problems associated with the disposal of fly ash.

Production of steel and iron is associated with generation of solid waste like slag. It is also known as steel slag or slag sand obtained from steel plants. It silica reaction in concrete due to higher alkali binding capacity of hydration products of slag has gr eater 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.

## 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 confining 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 for cylinders 100X300mm and tested for 7,14,28 day strength. Final Compressive strength of 34.67N/mm$^2$ for 10% replacement in M25grade and 38.22N/mm$^2$ is observed and after that reduction in final strength is observed in both mix. Split tensile strength of 3.52N/mm$^2$ for M25 grade and 4.10mm$^2$ 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 0r 100-25 mm for the replacement of 0%,30%,50%,70%,100% aggregates with slag aggregates. 100X100mm cubes set 0f 3 were cast for compressive(7,28,56,91,119 days), split strength(7,28 days),and 100X100X500mm 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 by 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 by 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 and 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 3.28N/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. Table 1 shows the test results of basic properties of cement.

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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 (CA)*

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(FA)*

In this experiment ClassF fly ash was used which was collected from UPCL, Padubidre,Udupi 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)*

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

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. Superplasticizer(SP)*

Conplast SP430 is used as a superplasticizer. It is a chloride free, super plasticizing admixture. It is supplied as a brown solution

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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 superplasticizer 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 |
| M11-20%FA,60%GBS | 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 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| M13-30%FA,20%GBS | 136.8 | 127.5 | 297.5 | 547.4 | 1126.2 | 170 | 3.2 |
| M14-30%FA,40%GBS | 273.7 | 127.5 | 297.5 | 410.55 | 1126.2 | 170 | 3.2 |
| M15-30%FA,60%GBS | 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, Water will be added with measured super plasticizer and kept. 25% of Water and plasticizer mix added to the drum. Then sand is added with 25% of water and superplasticizer again. After through mixing of aggregates, cement with admixtures if any is added and remaining 50% of water and superplasticizer 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. Demoulding 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, 56, days 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 figure. Slump cone test is conducted to study the workability of the concrete at the time of casting

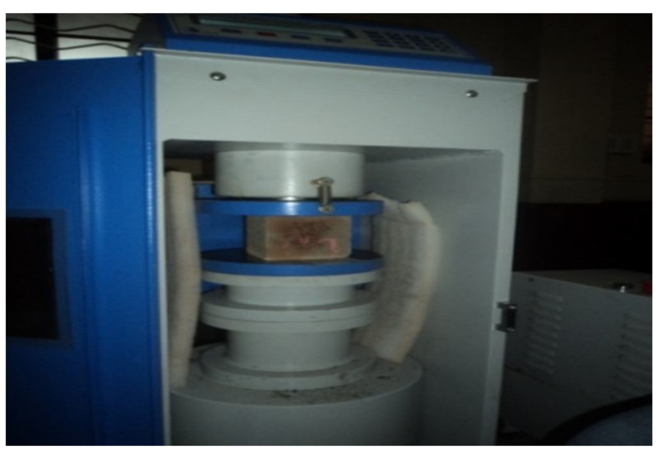

Fig 2 Compressive strength

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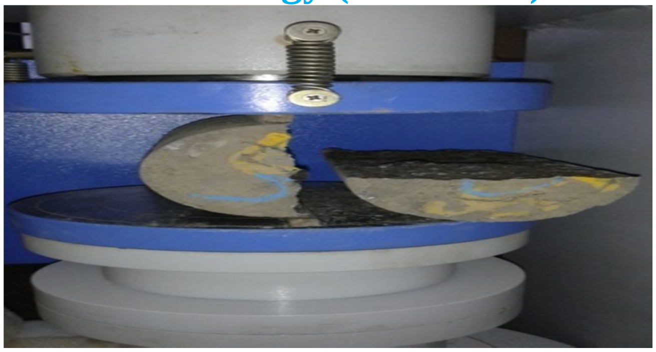

Fig 3 Split Tensile strength

Fig 4 Flexural strength Test

Fig 4 Slump Test

## IV. RESULTS AND DISCUSSIONS

### *A. Compressive strength*

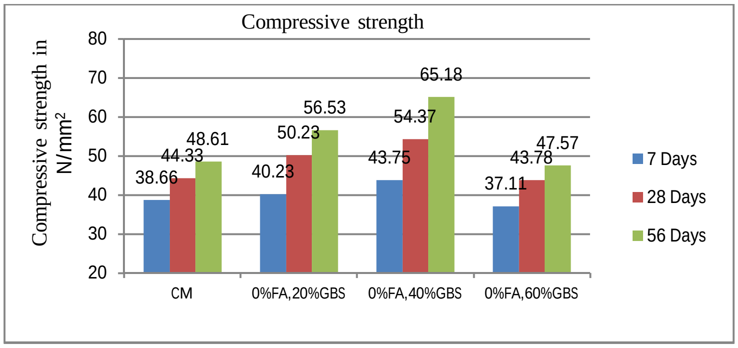


Chart 1

Chart 1 shows the 7,28,56 days compressive strength results for the replacement osand by GBS. Increase in Strength observed for sand replacement and maximum is observed for 40% replacement and further adddition decreases the strength.

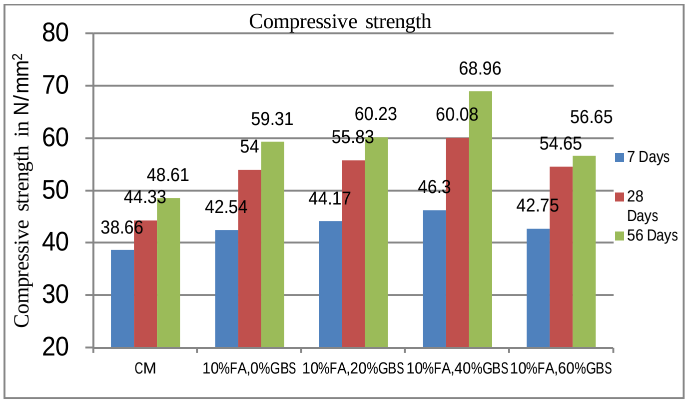


Chart 2

Chart 2 shows the 7,28,56days compressive strength result for the 10% cement replacement by fly ash and replacement of sand by GBS for0%, 20%,40%,60%. Increase in strength is observed for 10%FA and 40%GBS and decrease in strength is observed for further increase in GBS content.

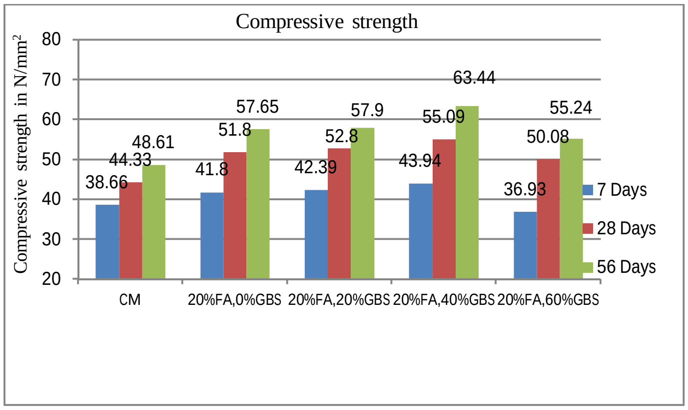


*Chart 3*

Chart 3 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% and60%. Maximum strength was achieved for 20% fly ash and 40%GBS replacement.

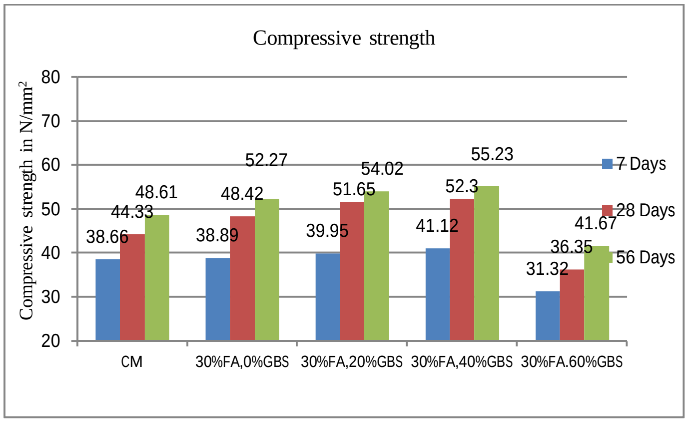


Chart 4

Chart 4 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%. Maximum strength is observed 40% replacement of sand by GBS and cement by fly ash of 30%.

*B. Flexural strength*

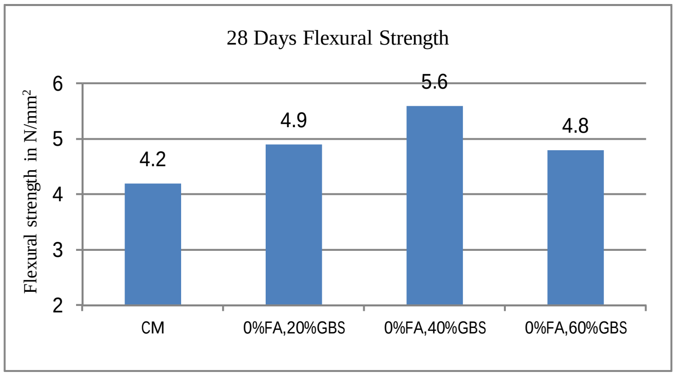


Chart 5

Chart 5 gives the flexural strength of concrete for the replacement of cement by 0% fly ash and sand by 20%,40%,60% GBS maximum strength is observed for 40% sand replacement by GBS.

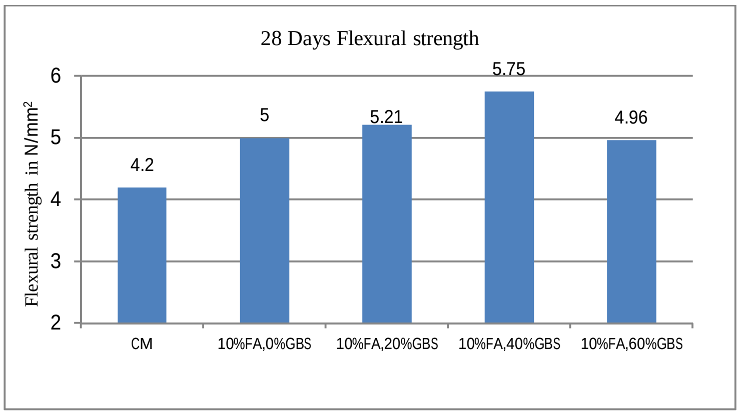


Chart 6

Chart 6 gives 28 days flexural strength results for the varying of sand by 20%,40% and 60% GBS and cement by 10% flyash. Increase in flexure is observed for 40% replacement of sand by GBS and cement by 10% flyash.

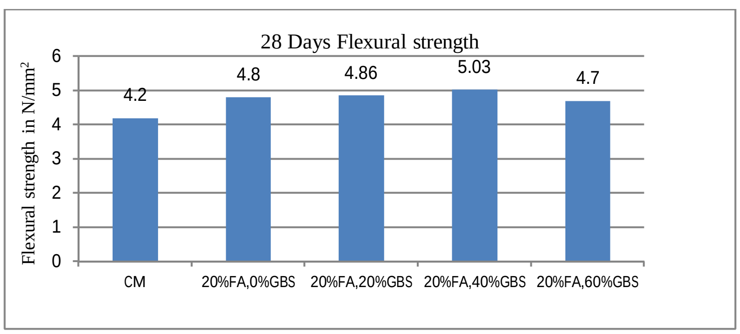


Chart 7

Chart 7 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 and 40% replacement of sand by GBS.

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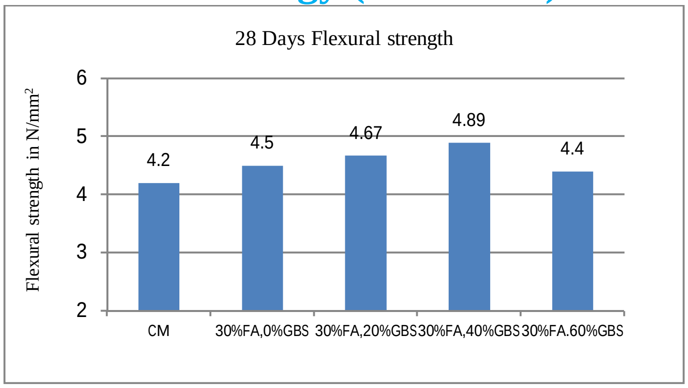


Chart 8

Chart 8 gives the flexural strength of the concrete for the replacement of cement by 30% fly ash and sand by 20%,40% and 60% GBS. Maximum flexural strength is observed for 30% cement replacement by fly ash and 40% sand replacement by GBS.

*C. Split tensile strength*

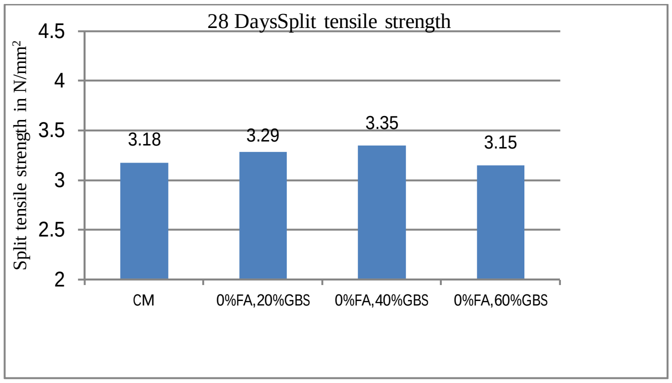


Chart 9

Chart 9 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 40% replacement of sand by GBS.

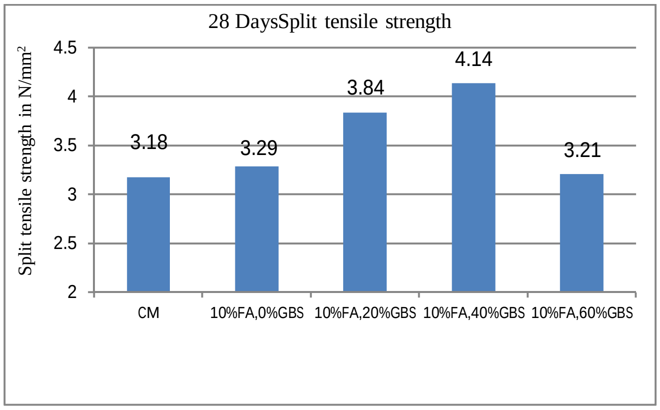


Chart 10

Chart 10 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. Maximum strength is observed for 10% cement replacement by fly ash and sand by 40%GBS.

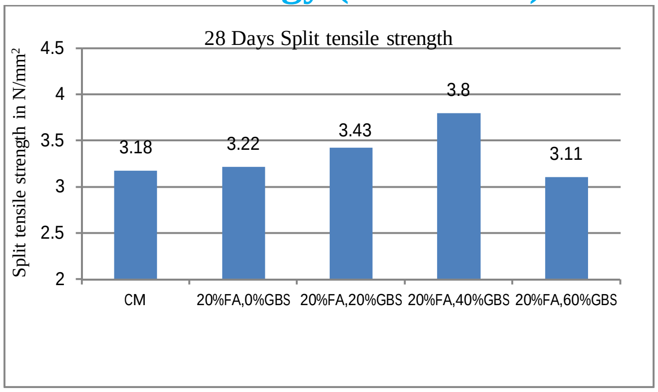


Chart 11

Chart 11 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 split tensile strength is observed for 20% replacement of cement by fly ash and 40% sand replacement by GBS.

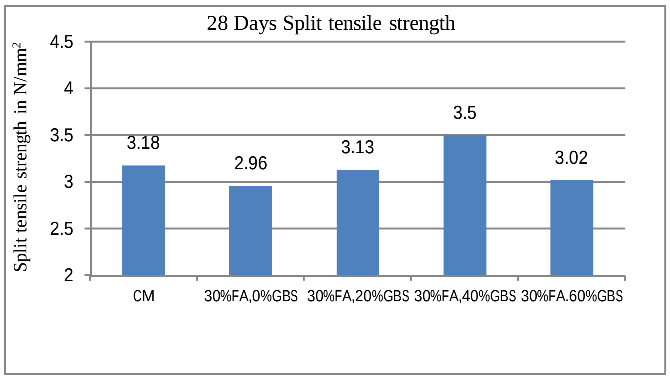


Chart 12

Chart 12 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. Increase in split tensile strength is observed for 30% cement replacement by fly ash and 40% sand replacement by GBS.

*D. Slump*

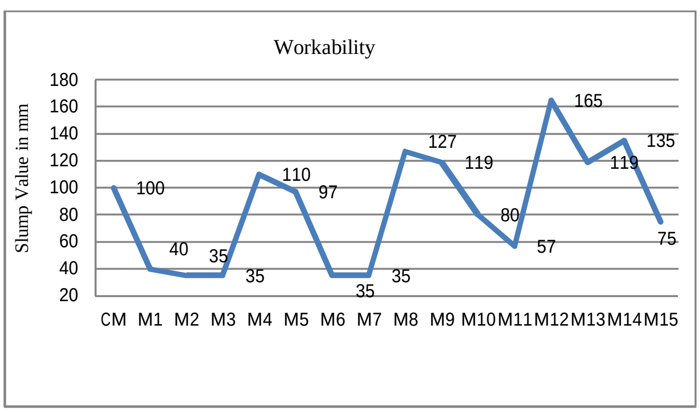


Chart 13

Chart 13 gives the slump values for various mixes. As content of fly ash increases, slump also increases. Increase in the GBS content decreases the workability

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## V. CONCLUSION

After doing the experimental investigation, the following are concluded

*A.* The replacement of sand by GBS up to 40% has given higher strength;
*B.* Maximum compressive strength has been achieved for the replacement of cement by 10%fly ash and sand by 40%GBS
*C.* 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.
*D.* Increase in the flexural strength is seen when the cement is replaced by 10% fly ash and sand by 40%GBS..
*E.* Increase in the split tensile strength is seen when the cement is replaced by 10% fly ash and sand by 40%GBS..
*F.* As the percentage of GBS and fly ash increases. Decrease in the mechanical properties of the concrete is seen.

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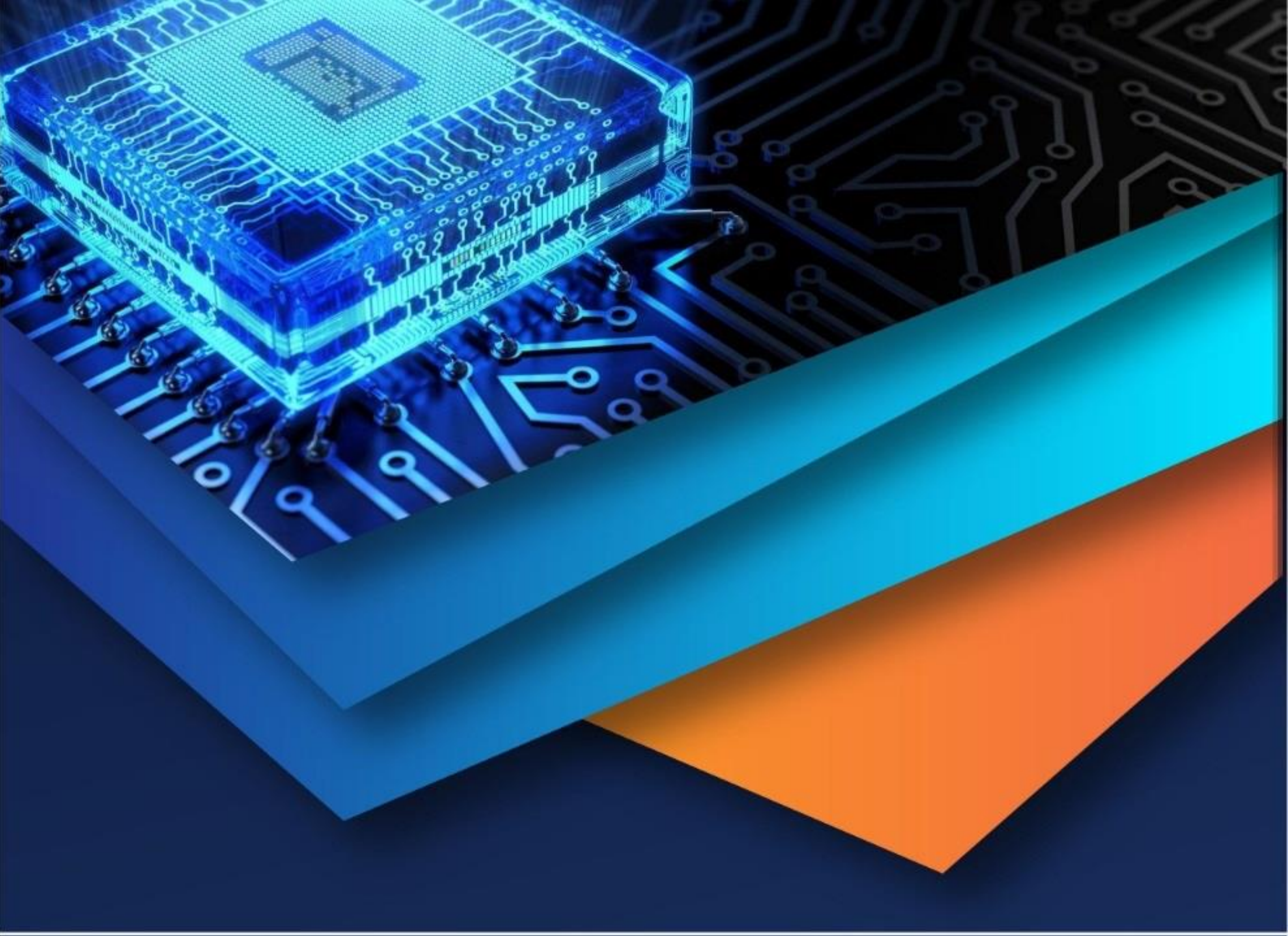

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