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Experimental Investigations on Properties of Concrete with Silica Fume, GGBS and PVC Dust

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Abstract: The present paper is an effort to investigate the strength properties of GGBS (Ground Granulated Blast Furnace Slag) and Silica Fume along with Polyvinyl Chloride dust at the various replacement levels. Large scale production of cement is causing environmental problems. This has made the researchers to use supplementary cementatious material in making concrete. Polyvinyl Chloride dust is a waste material produced in pipe industry. PVC dust is used as filler material to way towards the waste utilization. M40 grade of concrete is used in the study and mix design was carried out according to guidelines10262 (2009). A constant 8% of Silica Fume was used as on cement replacement for all the mix. Effect of GGBS was studied by replacing cement by 30 to 50% along with PVC dust 0 to 10% as additive. Mechanical Strengths such as compressive, Split Tensile strength and Flexural strength are investigated.

Keywords: Silica Fume (SF), Ground Granulated Blast Furnace Slag (GGBS),Polyvinyl chloride (PVC) DUST Compressive Strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

Concrete is a mixture of naturally, cheaply and easily available ingredients as cement, sand, aggregate and water. Cement is occupied second place as most used material in the world after water. The rapid production of cement creates big problems to environment. First environment problem is emission of CO_2 during the production process of the cement. The CO_2 emission is very harmful which creates big changes in environment. According to the estimation, 1 tonne of carbon dioxide is released to the atmosphere when 1 tonne of ordinary Portland is manufactured. As there is no alternative building material which totally replace the cement. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Meta kaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement.

Concrete, as a material, has significantly been benefited from the usage of fly ash, silica fumes, and GGBS. Silica fume has a very high reactivity with calcium hydroxide, and this reactivity permits silica fume as a replacement for a small proportion of Portland cement. Silica Fumes are more commonly used as mineral admixtures in the development of high performance concrete mixes. It was first used in 1969 in Norway but systematically employed in North America and Europe in the early 1980s. The small particles of silica fume can enter the space between the particles of cement and improve the bonding. Most of the researchers agree that the C-S-H formed by the reaction of micro silica and $Ca\,(OH)_2$. This gel has been appeared as dense and amorphous.

Ground Granulated Blast Furnace Slag is one of the important mineral admixtures. It is recyclable material created when the molten slag is chilled rapidly by quenching from melted iron ore and then ground into a powder. This is materials has cementitious properties. It can be used in concrete as a replacement for cement. When GGBS is added to mixture, it also reacts with water and produces C-S-H from its available supply of calcium oxide and silica. The pozzolanic reaction also takes place which uses the excess SiO_2 from the slag source and produces $Ca\,(OH)_2$ during heat of hydration.

Polyvinyl chloride is the third most widely produced synthetic plastic polymer. It is abbreviated as PVC. PVC is made from petroleum. The production process also uses sodium chloride. Recycled PVC is broken down into small chips, impurities removed, and the product refined to make pure white PVC. It can be recycled roughly seven times and has life span of around 140 years. Polyvinyl chloride is very light and can be easily exposed into air during manufacturing of PVC pipes. This exposed Polyvinyl chloride is called PVC Dust. The PVC have to be disposed off carefully in an environment friendly way.PVC dust is used as filler material to convert it as an environmental friendly and cost effective construction material. The main objective of this investigation

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is to compare the strength parameter of silica fume concrete with GGBS and PVC dust. This present work is to develop a construction material like concrete, by incorporating the industrial waste materials like PVC dust as filler material and to convert it as an environmental friendly.

II. BACKGROUND AND RELATED WORK

Many investigations have been done on replacement of GGBS and Silica Fume with cement in concrete and observed very enthusiastic results. The authors concluded that the early compressive strength of concrete (7 days's) is less than the control mix if GGBS is used as replacement of cement and silica Fume.[Chinnaraju et,al.,2009]. The mix shows dense microstructure when cement is replaced by constant silica fume of 6% and 50% of GGBS than conventional concrete.[Sowmya et.al .,2014]. The increasing percentage of silica fume up to 10% has improved the strength of concrete by 8.93%. Hence the author considered 10% as optimum replacement.[Murali et.al. ,2012].According to the research work, the author concluded that the silica fume can be replaced 8 to 20 % by weight of cement. The improvement of compression strength, split tensile strength and flexural strength can be achieved and it can be used for high performance concrete.[Bhikshama et.al.2009, Ajay verma et.al,2013]. Vinayagham (2012), investigated the use of silica fume in concrete reduces the workability and increases the strength in high performance concrete.

III. MATERIALS AND METHODS

A. Materials

1) Cement: Ordinary Portland cement of 43 grade of conforming to IS 8112-1989 was used. Table 1 shows the physical properties of cement.

Table 1: Physical Properties of Cement

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

2) Fine Aggregate: Natural river sand of size below 4.75mm conforming to zone II of IS 383-1970 was used as fine aggregate. Table 2 shows the Physical properties of fine aggregates.

Table 2: Physical Properties of Fine Aggregates

Properties	Results
Specific gravity	2.62
Water absorption	1.45%

3) Coarse Aggregate: Natural crushed stone with 20mm down size was used as coarse aggregate. Table 3 shows the physical properties of coarse aggregates.

Table 3: Physical Properties of Coarse Aggregates

Properties	Results
Specific gravity	2.65
Water absorption	0.39%

4) Silica Fume: CORNICHE SF was used in the present investigation, conforming to IS 15388-2003. Table 4 shows the test results of basic properties of Silica Fume

Table 4: Physical Properties of Silica Fume

Properties	Results
Specific gravity	2.23

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5) Ground Granulated Blast Furnace Slag: GGBS conforming to IS 12089-1981 was used in the investigation. Table 5 shows the physical properties GGBS

Table 5: Physical Properties of GGBS

Properties	Results
Specific gravity	2.86
Water absorption	0.14%

6) PVC Dust: PVC dust was collected from RAINBOW GROUP, manipal, Karnataka. Table 6 shows the physical properties of PVC Dust

Table 6: Physical Properties of PVC Dust

Properties	Results
Specific gravity	1.3

7) Water: Potable water was used in this investigation of both for mixing and curing.

8) Superplasticizer(SP): CONPLAST SP430 is used as a superplasticizer. It is a chloride free, super plasticizing admixture. It is supplied as a brown solution which instantly disperses in water.

B. Concrete Mix Design

The M40 Mix proportion was designed as per guidelines, according to the Indian standard recommended method IS 10262-2009. Total binder content was 425 kg/m^3, fine aggregate was taken 684.25 kg/m3 and coarse aggregate was taken 1126.25 kg/m3 with water-cement ratio of 0.4 and superplasticizer of 0.75%. Concrete is considered to perform the test by weight basis. The mix proportions was calculated and presented in Table 7.

Table 7: Mix Proportion per Cubic Meter

Mix	SF (Kg)	ggbs (Kg)	Cement (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Water (w/c 0.4) (liters)	Pvc Dust (kg)
M	-	-	425	684.25	1126.25	170	-
M1	34	-	391				-
M2	34	-	391				21.25
M3	34	-	391				42.5
M4	34	127.5	263.5				-
M5	34	127.5	263.5				21.25
M6	34	127.5	263.5				42.5
M7	34	170	221				-
M8	34	170	221				21.25
M9	34	170	221				42.5
M10	34	212.5	178.5				-
M11	34	212.5	178.5				21.25
M12	34	212.5	178.5				42.5

1) *Casting and Curing of Test Specimens:* Mixing was done by using concrete mixer. For each proportion 12 cubes of size 100x100x100mm, 3 cylinder of 100mm diameter and 200mm in height and 3 beams of 100x100x500mm were casted. Mixing

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was done by adding aggregate to mixing drum first, followed by 25% of total water and superplasticizer to prevent cement sticking to blades or at the bottom of the drum. Superplasticizer was added to water measured water and stirred well. Then sand was added with 25% of water and superplasticizer again. After mixing of aggregates, cement with admixtures if any was added and remaining 50% of water and superplasticizer were introduced. For each mix slump test was conducted to measure workability. Totally 156cubes, 39 cylinder and 39 beams were casted. After casting concrete was filled into moulds and compacted on vibration table. Demoulding was done after 24 hours of casting specimens were cured in curing tank. Water immersion method of curing was adopted. Cubes were cured for 7, 28, 56, 90 days and remaining specimens were cured for 28 days. Figure 1 show the concrete placed in moulds.

Figure 1 Concrete placed in moulds

2) *Testing of Specimen:* Testing was done as per IS code. The testing were carried out for Compressive strength test on cubes as per IS:516-1959, split tensile strength test on cylinders as per IS: 5816-1976 and flexural strength test on beams as per IS:516-1959 . All the tests are done on compressive testing machine as shown in Figure 2.

Figure 2 Compressive Strength Test

Figures 3 Split Tensile Strength Test

Figure 4 Flexural Strength Test

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IV. RESULTS AND DISCUSSIONS

A. Slump Test

Slump values of various mix proportions of GGBS with constant Silica Fume replacing cement in M40 grade concrete are shown in Figure5.It is clear from the figure, Constant 8% Silica fume has shown more cohesiveness. But the stickiness in concrete was observed with increase percentage of GGBS i.e. 30% to 50% and increase percentage of PVC dust i.e. 0% to 10% with constant Silica Fume, the stickiness in concrete was observed.

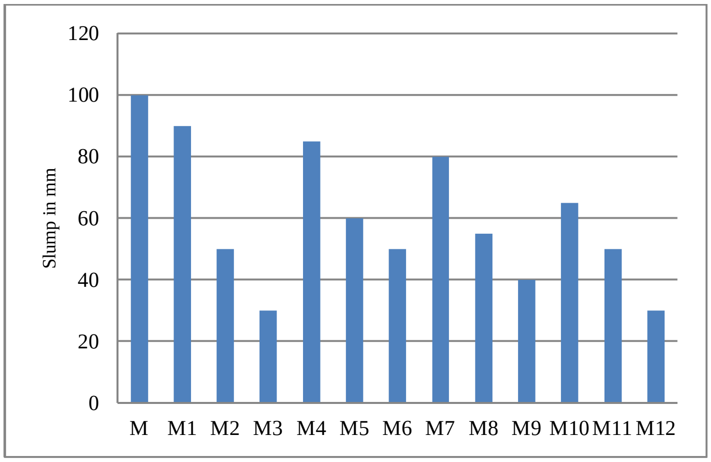

Figure 5 Slump value with various proportions of GGBS with constant Silica Fume and with and without PVC Dust

B. Compression Strength

Figure 6 shows the variation of compressive strength of concrete with partial replacement of cement by Silica Fume of 8%.The compressive strength of Concrete with silica fume and without PVC dust and without GGBS was found to be higher than control mix. Compressive strength of Silica Fume without GGBS and PVC dust of 5% was also achieved more strength than the control mix.

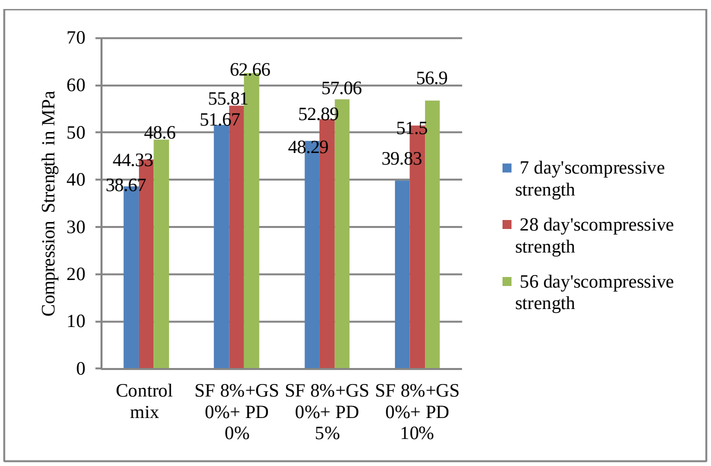

Figure 6. Compressive strength of concrete with 8% Silica Fume, without GGBS & different of PVC dust

Figure 7 shows the variation of compressive strength of concrete with 8% of silica fume and different percentages of GGBS as cement replacement. Significant improvement in the compressive strength was obtained for the percentage of 8% of SF without GGBS than normal concrete. The higher strength was gained upto 50% of cement replacement with GGBS than the normal concrete without PVC dust.

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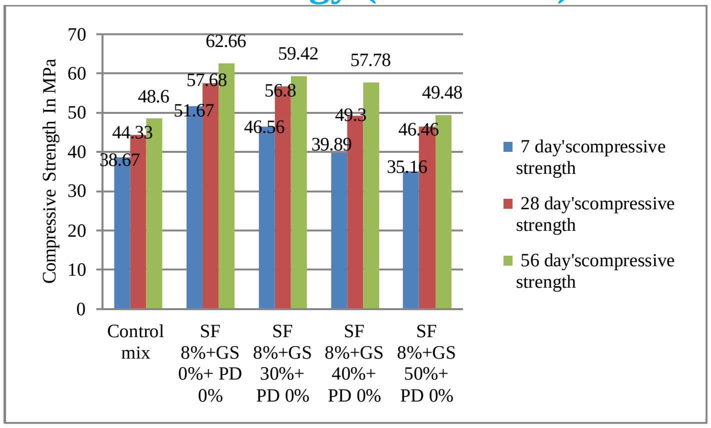

Figure 7. Compressive strength of concrete with 8% Silica Fume, without PVC dust & different % of GGBS

Figure 8 and 9 show the variation of compressive strength of concrete with partial replacement of cement by Silica Fume of 8% with PVC Dust. The Figure 7 shows the variation of compressive strength of Concrete with silica fume and different percentage of GGBS. It can be observe that the compressive strength of concrete with GGBS up to 40% was found to be greater than control mix. The strength is decreased for higher percentage of GGBS i.e. 50%. From Figure 8 it can be depicted that use of PVC dust of 10% tends to reduce the strength. This can be compensated with the help of Silica Fume.

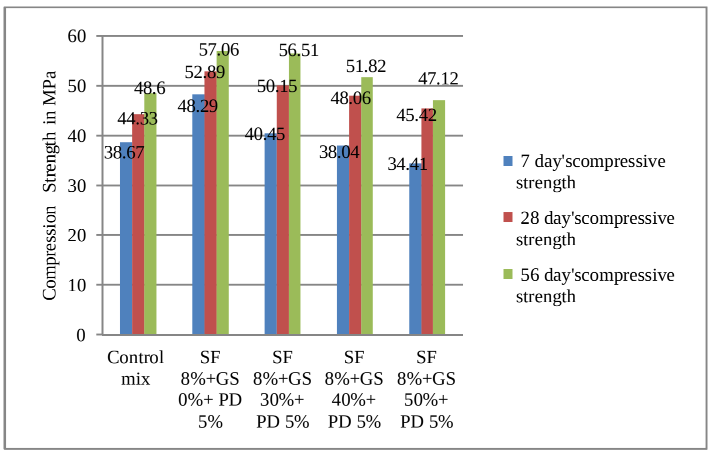

Figure 8. Compressive strength of concrete with Silica Fume, PVC dust of 5% & Different % of GGBS

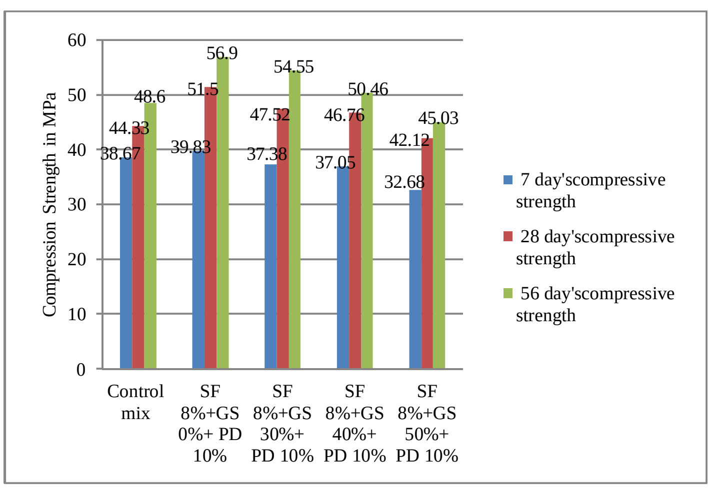

Figure 9. Compressive strength of concrete with Silica Fume, PVC dust of10% & Different % of GGBS

C. Split Tensile Strength

Figure 10 show the variation of tensile strength of concrete with 8% of silica fume and different percentages of GGBS as cement replacement. Tensile strength is increased for 8% of Silica fume used as a replacement of cement. The tensile strength was reduced when PVC dust is used in the concrete when comparing with normal concrete.

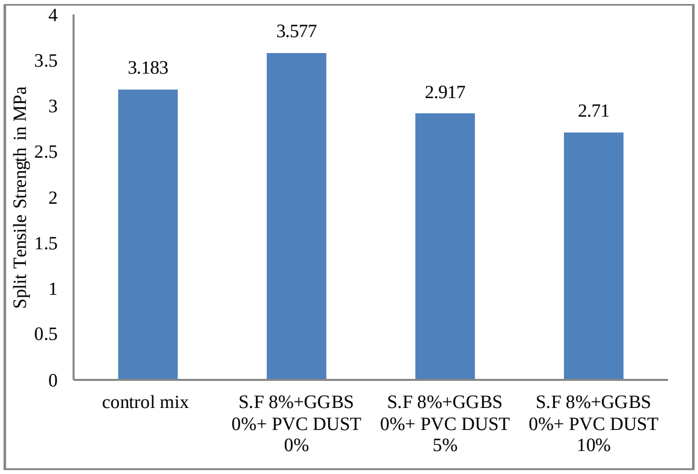

Figure 10. 28 day’s tensile strength of concrete with Silica Fume, GGBS of 0% & different % of PVC dust

Figure 11 show the variation of tensile strength of concrete with silica fume of 8% and different percentage of GGBS. It can be observed that the tensile strength of concrete increases up to 30% after that it reduces with increase percentage. The PVC cannot be provide a good tensile strength.

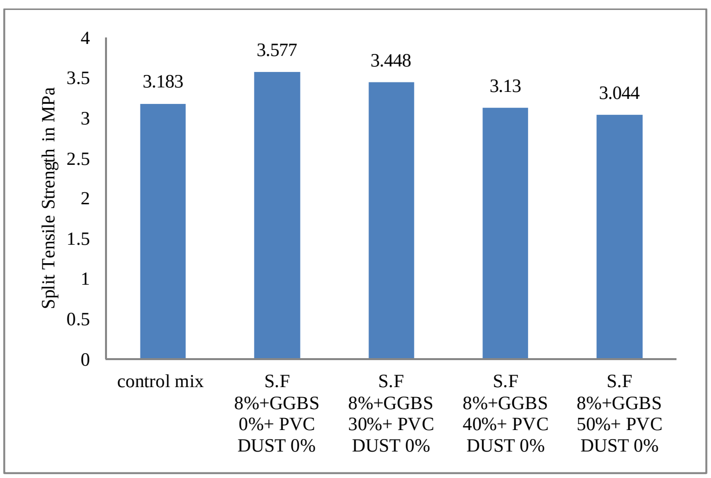

Figure 11. 28 day’s tensile strength of concrete with Silica Fume, without PVC dust & different % of GGBS

Figure 12 and 13 shows variation of tensile strength with Silica fume of 8% with different percentage of GGBS. Tensile strength of concrete with 5% of PVC dust is less than the normal concrete, but it must be nearer to the normal concrete. The strength is decreases with 10% of PVC Dust.

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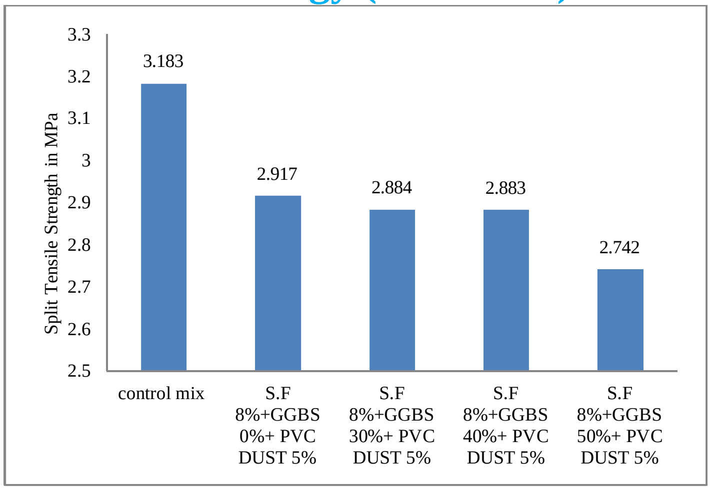

Figure12. 28 day's tensile strength of concrete with Silica Fume, PVC dust of 5% & Different % of GGBS

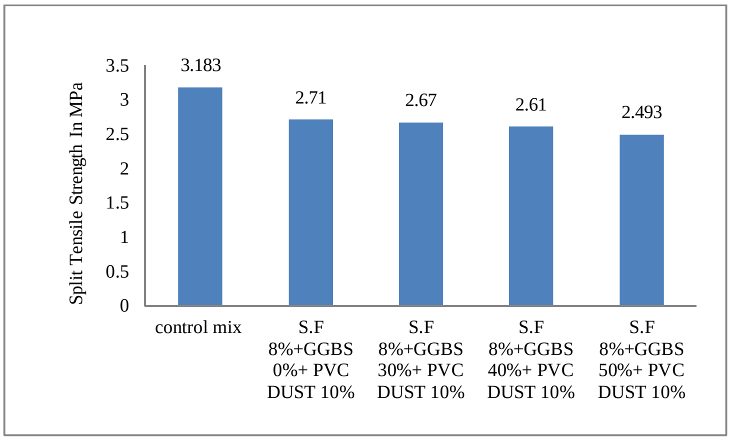

Figure 13. 28 day's tensile strength of concrete with Silica Fume, PVC dust of 10% & Different % of GGBS

D. Flexural Strength

Figure 14 show the variation of Flexural strength of concrete with 8% of silica fume and different percentages of GGBS as cement replacement. Flexural strength is increased for 8% of Silica fume used as a replacement of cement than normal concrete. If PVC dust is added to the concrete variation of flexural strength between the mixes are very small with constant replacement of Silica fume by weight of cement. The flexural strength of the concrete is decreases with increase percentage of PVC Dust as shown in the figure 15, 16, 17.

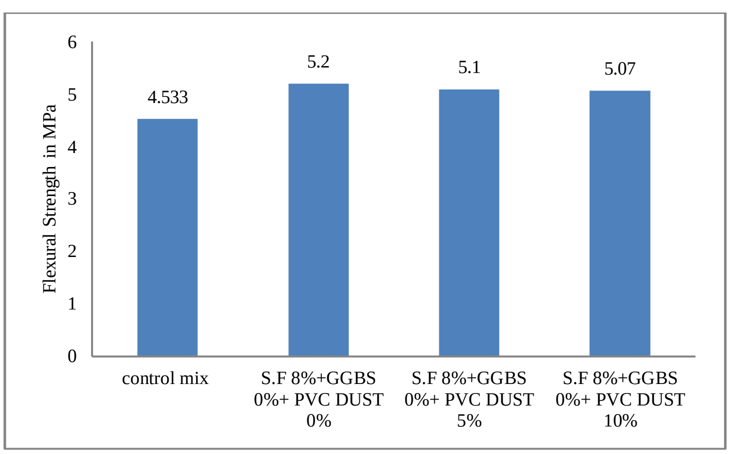

Figure14. 28 day's Flexural strength of concrete with Silica Fume, GGBS of 0% & Different % PVC dust

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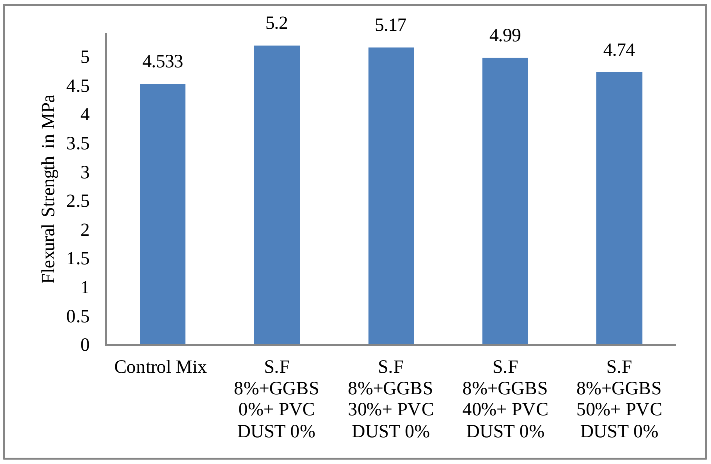

Figure15. 28 day's Flexural strength of concrete with Silica Fume & Different % of GGBS

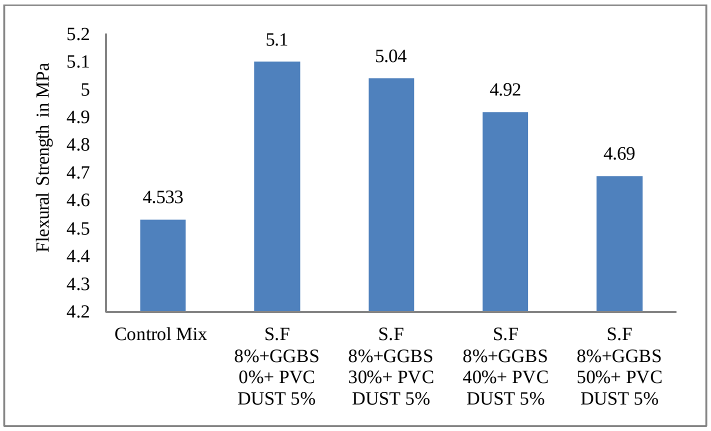

Figure 16. 28 day's Flexural strength of concrete with Silica Fume, PVC dust of 5% & Different % of GGBS

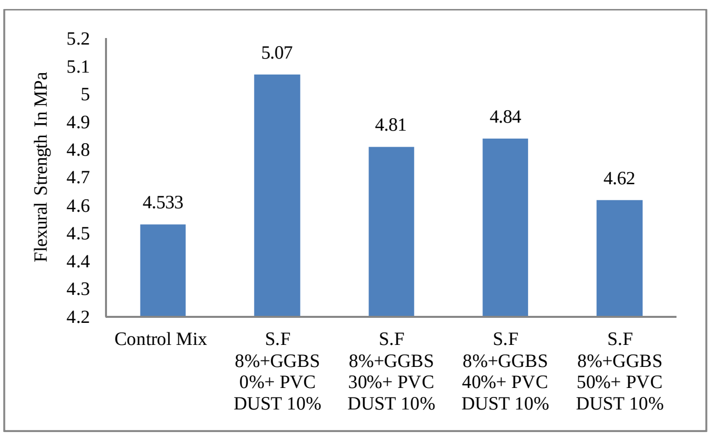

Figure 17. 28 day's Flexural strength of concrete with Silica Fume, PVC dust of 10% & Variable % of GGBS

V. CONCLUSION

Based on the experimental investigation the following conclusion are drawn

A. Compressive strength of Silica Fume with GGBS and without PVC dust was achieved more strength than the control Mix.

B. The higher strength was gained up to 40% of cement replacement with GGBS than the normal concrete and then after strength decreases.

C. Split and Flexural strength can be attained only when silica fume is replaced by cement.

D. PVC Dust can be utilised in the concrete with cementitious material.

E. There is a decrease in workability with constant 8% Silica Fume and increase replacement level of GGBS (30% to 50%) and with 0% to 10% of PVC Dust.

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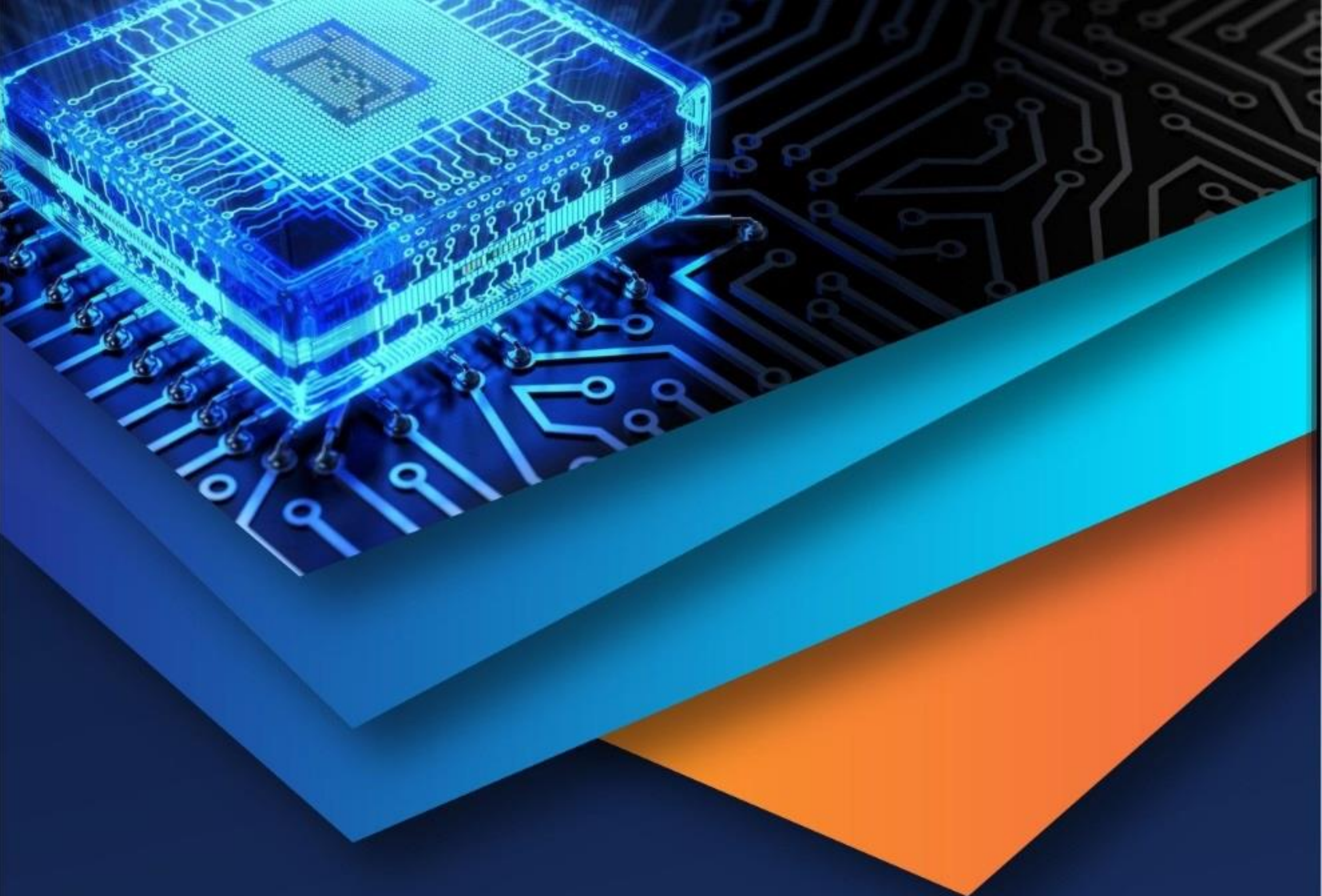

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