Experimental Research on Geo-Polymer Concrete Incorporated with Silica Fumes

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***Abstract* - Geopolymer concrete is a type of concrete that is produces by using the byproducts of different industries such as thermal power plant, silicon manufacture industries. The material used in the manufacturing process of GPC are FLY ASH, GGBS, RHA, METAKAOLIN. The purpose of shifting to a new binding material is pollution caused due to the manufacturing process of OPC. While manufacturing OPC billions of tons of carbon dioxide gas is released into atmosphere which is a major reason for climate change. A research says that 7% of total carbon dioxide produced throughout the world is only because of OPC. So there is an urgent need to shift to a new binding material which has similar properties that of OPC. This experimental research investigated the effect of silica fume on the fresh and hardened properties of geo-polymer concrete such as workability, compressive strength, split tensile strength and flexural strength. Test results shows that as the percentage of silica fume was being increased there was an increase till 12% there was increase in all three type of strength but further increment in the percentage of silica fumes leads to the reduction of strength as well as workability and makes the concrete tough to handle.**

***Index Terms* - Geo Polymer Concrete, Compressive Strength, Split Tensile Strength, Flexural Strength, Eco Friendly Material.**

I.INTRODUCTION

The major problem that we all are facing today is Global warming and the reason behind this problem are greenhouse gases. Greenhouse gases constitutes of Carbon Dioxide, Methane, Nitrous Oxide, Fluorinated Gases. A research says that 7% of total carbon dioxide produced throughout the globe is released in the manufacturing of the cement. as the rate of construction is increasing very rapidly which leads to the increase in the requirement of cement which further leads to the global warming.

Studies says that manufacturing 1 ton of cement releases 1 ton of carbon dioxide gas to overcome this problem we need to shift to another material which has similar binding properties that of cement i.e strength and durability. After many researches a new binding material was found that's inhibits the similar properties that of cement concrete and that material is Geopolymer concrete.

As the name Geo means material that are of geological origin and polymer tends to the polymerization reaction occurring between the materials used to gain the strength. Some materials that can be used in the manufacturing of geopolymer concrete are

- Fly ash
- Metakaoline
- Rice husk ash
- Silica fumes.
- GGBS.

The materials mentioned above are the byproduct of different industries such as flyash is a byproduct of thermal power plant, silica fumes is a byproduct of silicon manufacturing industries. So by using these materials we are not only reducing the release of carbon dioxide into the atmosphere but also increases the requirement of land for the disposal of flyash produced by thermal power plants and reduced the air, water and land pollution.

II. LITERATURE REVIEW

[1] Ashraf Mohamed Henigal et al (2017) This research investigated different aspects such as fresh properties of SCGPC, effect of course to fine aggregate ratio on the fresh properties of SCGPC, how molarity effects the strength of concrete and also how flyash content effect the strength properties of SCGPC thirty different mixes were prepared by varying the percentage of fly ash, molarity and fine to course

aggregate ratio there samples were over cured at 70°C for 48 hours and based on the test results it was found that as the content of flyash was increased form 400kg/m3 to 500kg/m3 there was an enhancement in the strength of concrete. as the percentage of CA was increased there was increase in the compressive strength of concrete.

[2] Mehmet Eren Güls et al(2019) This studied mainly focused on how nano silica and steel fibers affect the fresh and hardened properties of SCGPC to study this effect nine different mixes were prepared with and without nano silica (0%, 1%, 2%), with and without steel fiber (0%, 0.5%, 1%) on basis of the tests performed on the fresh concrete it was observed that there was very little effect of NS and SF on the flowability of mix and as the percentage of NS was increased the mix has higher resistance to segregation and to bleeding and also the mix with NS has move cohesive properties then the mix without NS while addition of steel fibers improves the flexural strength of the concrete

[3] T.G USHA, R ANURADHA(2015) This research was conducted to study how change in molarity of NaOH effect the fresh properties of SCGPC and also to study the effect of different mineral admixture on fresh and hardened properties of SCGPC. To study the molarity effect four different concrete mix were prepared by changing the molarity from 8M-14M and the following tests were conducted on the fresh concrete mix 'V' funnel test, 'L' box test T50 Slump flow test, 'U' box test and compressive test were also performed on various molarity from the results it was found that as the molarity of NaOH was increased the flowability of concrete was being reduced at the same time the compressive strength was increased. Now to study the effect of mineral admixture on SCGPC seven different concrete mix were prepared by replacing flyash with GGBFC from 0% to 30% with a interval of 10% and then another three concrete mix were prepared by replacing the flyash with silica fume from 0% to 15% these samples were oven cured for 48 hours and then placed at ambient temperature till the day of testing. From the test results it was clear that when flyash was replaced with GGBFC the workability was increased as the percentage of GGBFS was increased and at the same time compressive strength was reduced. Now when flyash was replaced with silica fume workability was reduced as the percentage of silica fume was increased but strength was being increased.

[4] K. Vijai 1 , R et al(2010) This research was conducted to study the effect of curing temperature on the density and compressive strength of SCGPC. To study this effect two type of curing were done to the samples some samples were cured at ambient temperature and some were cured at 60°C for 24 hours and then kept at room temperature till the day of testing and it was found that the strength of samples cured at ambient temperature was effectively increased with increase in the age at the same time the strength of samples cured at 60°C has very minimum increase with increase in the age. The strength of ambient cured SCGPC
After 7 days and 28 days was 3.89 and 17.69 whereas samples cured at 60°C for 24 hours has a compressive strength of 28.31 and 33.22 respectively. Hence it was conclude that hear curing of samples greatly increases the strength of SCGPC.

[5] Prakash R et al(2013) This papers presents the study about the different parameters that effect the strength properties of geopolymer concrete.

1. First parameter was ratio of alkaline liquid to the flyash two different samples were casted by varying the ratio from 0.35 to 0.4 and it was found that there was very minimum effect of this ratio on the compressive strength of geopolymer concrete.
2. Second parameter was to study the effect of sodium silicate to the sodium hydroxide solution this effect was studied by comparing two mixes in which one mix ratio was 2 and another mix ratio was 2.5 and it was observed that the mix with sodium silicate to the sodium hydroxide ratio 2 has 40Mpa compressive strength whereas the mix with sodium silicate to the sodium hydroxide as 2.5 has only 30Mpa
3. Compressive strength.
4. Third parameter was to study the effect of curing time. Samples were cured for 24 hours and 28 hours and the sample which was cured for 48 hours has compressive strength 18% grater then the samples cured for 48 hours
5. To know the effect of superplastisizer on the strength of geopolymer concrete three mixes were

prepared by adding 2%, 3% and 4% of superplastisizer and it was found that SP increases the workability of the mix but at the same time the compressive strength was reduced by 0.7%.

[6] Djwantoro Hardjito at al(2004) This paper focused on the parameters that effect the fresh and hardened properties of geopolymer concrete.

- As the molarity of sodium hydroxide was increased the workability of concrete was reduced but compressive strength was increased
- To achieve higher compressive strength the curing temperature much be in between 30°C to 90°C
- The fresh geopolymer can be freely handle upto 120 min without any problem
- As the ratio of sodium silicate to sodium hydroxide was increased as a result compressive strength of geopolymer concrete also increases but also reduces the workability
- Addition of water reducing admixtures upto 2% of flyash gives a good workability with a little reduction in strength of concrete

[7] Jithendra and Elavenil(2020) This study focused on how the change in solution to binder ratio affect the various properties such as Rapid Chloride Permeability Test (RCPT), Ultrasonic Pulse Velocity (UPV) and water absorption of SCGPC these three tests were performed after 28 days of ambient curing and it was found that the water absorbtion was low for the mixture with SB ratio of 0.650 as compared with 0.68 and 0.70, when rapid chloride permiabillity test was performed it was found that as SB ratio was increased from 0.65 to 0.70 the pores in the samples was being increased this might be due to increase in the solution results in increases in the pores. Ultrasonic pulse velocity test results shows that the specimen with SB ratio 0.65 has a pulse velocity of 3.6km/s whereas the specimen with SB ratio 0.68 and 0.70 has a pulse velocity of 3.5km/sec and 3.29km/sec from these results it can be concluded that to achieve good compressive strength solution to binder ratio should be 0.65.

[8] Manjunath et al(2014) This research presents the study how change in volume of paste affect the fresh and hardened properties of SCGPC to study this four different mixes were prepared by varying the volume of paste from 0.4 to 0.52 within an interval of 0.04. mixes were prepared by using flyash obtained from a thermal power plant near Raichur city and the proportion of fine and course aggregate was 50-50 when tests were performed to check the fresh properties of SCGPC it was observed that the slump of all four mixes ranges between 600mm to 630 mm and it was also found that increase in volume of paste till 0.48 leads to increase in the slump but further increase in the volume of paste leads to slightly decrease in the slump. Now coming to the mechanical properties of SCGPC it was observed that increase in the volume of paste tends to increase in both compressive and split tensile strength of SCGPC mixes and also reduces the water absorption capacity.

III. MATERIAL USED

3.1 FLY ASH

The low calcium fly ash (Class F) used in this research work was bought from a RMC plant near to Lovely Professional University. Chemical and physical properties of Class F fly ash are as mentioned in below table

Table 3.1 chemical composition of Fly ash

CHEMICAL COMPONENTS	FLYASH FROM BATALA THERMAL POWERPLANT
Iron oxide	7.06
Alumina	30.43
Silica	58
Manganese oxide	1.91
Calcium oxide	3.6
Sulphur trioxide	1.8
LOI	2

3.2 ALKALINE ACTIVATOR

Alkaline activators plays an important in gaining the strength of geopolymer concrete. usually we can use two types of alkaline activators i.e a compound solution of sodium silicate and sodium hydroxide or a compound solution of potassium silicate and potassium hydroxide.

In this research work we as using compound solution of sodium hydroxide and sodium silicate as potassium based alkaline solution are expensive and not easily available in the market. These chemicals was bought from a local store in Jalandhar.

The alkaline solution used was prepared by the combination of sodium hydroxide and sodium silicate. Sodium hydroxide solution of 8M concentration was prepared by mixing 97% purity sodium hydroxide pellets supplied by a local store into tap water.

3.3 SUPER PLASTICIZERS

The use of super plasticizers increases the workability of concrete mix. In geopolymer as we are using alkaline solution it tends to decrease the workability of the mix hence in that case we use super plasticizer to increase the workability and also it leads to increase in the strength of the concrete.

In this research work we have used polycorboxylate ether as super plasticizer. It was supplied by a local merchant in Jalandhar.

3.4 SILICA FUMES

In the manufacture of silicon and ferrosilicon alloys, silica fume is a byproduct of the carbothermic reduction of high-purity quartz with carbonaceous materials such as steel, coke, and wood chips in electric arc furnaces.

Silica fume is a ultrafine medium containing spherical particles that are smaller than 1 m in diameter on average, with an average diameter of 0.15 m. This makes it about 100 times smaller than a typical cement particle. [number four] The bulk density of silica fume ranges from 130 kg/m3 (undensified) to 600 kg/m3 (densified) depending on the degree of densification in the silo.

3.5 MIX DESIGN OF GPC

As till time there is no definite code that guides about the mix design of geopolymer concrete. So in this research the mix was prepared on the basis of the previous. In this research different samples of geopolymer was prepared by varying the percentage of silica fumes as 0%, 3%, 6%, 9%, 12% and 15% and studied how increase in silica fumes effect fresh and hardened properties of geopolymer concrete

3.6 MIX PROPORTIONING

S.no	Mix ID	Fly ash	Silica fume(kg.m-3)	Fine agg	Course agg	Sodium silicate	Sodium hydroxide	Molarity	W/Gs ratio	SP mass fraction/ weight %	Extra water mass fraction/wt%	Curing time	Curing temperature
1	M1(Control mix)	400	0	850	950	143	57	10	0.33	6	12	48	70
2	M2(3% SF)	388	12	850	950	143	57	10	0.33	6	12	48	70
3	M3(6%SF)	376	24	850	950	143	57	10	0.33	6	12	48	70
4	M4(9%SF)	364	36	850	950	143	57	10	0.33	6	12	48	70
5	M5(12%SF)	352	48	850	950	143	57	10	0.33	6	12	48	70
6	M6(15%SF)	340	60	850	950	143	57	10	0.33	6	12	48	70

IV: TESTS ON FRESH CONCRETE

4.1 SLUMP CONE TEST

The table below shows the slump value of different geopolymer mix. It was observed that as the percentage of silica fume is increased it tends to reduce the slump value which means those mix with high amount of silica fumes are hard to handle.

Mix	Slump (mm)
M1	65
M2	58
M3	52
M4	47
M5	42
M6	35

Table 2 slump test results of GPC for all the mixes

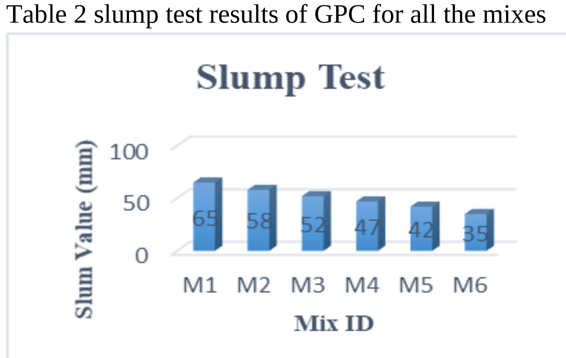

Chart 1 slump test results of SFRC with all mixss

4.2 TESTS ON HARDENED CONCRETE

4.2.1 COMPRESSIVE STRENGTH

Test results of compressive strength on geopolymer concrete with different percentage of silica fume ranging from 0% to 15% is as follows

Table 4 Compressive strength of GPC

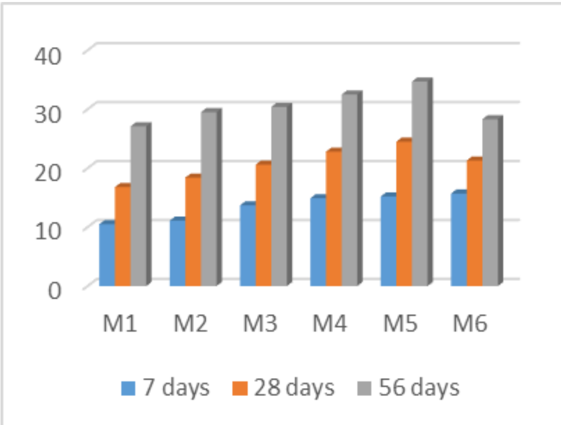

Chart 2 Compressive Strength of Different Mix Specimen

4.2.2 SPLIT TENSILE STRENGTH

The test results shows that the mix with 12% of silica attains maximum split tensile strength and as further increase in the percentage of silica it was observed that the strength was being reduced.

S.no	Mix designation	Splite tensile strength		
		7 days	28 days	56 days
1	M1	1.4	1.7	2
2	M2	1.6	1.9	2.2
3	M3	1.9	2.2	2.5
4	M4	2	2.5	2.8
5	M5	2.2	2.7	3
6	M6	1.9	2.2	2.7

Table 5 Split tensile strength of different Mix

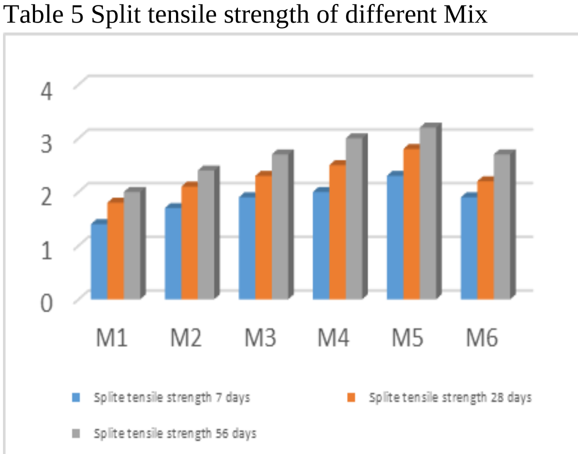

Chart 3 Split Strength Values

4.2.3 FLEXURAL STRENGTH

Flexural strength of GPC mixes with silica fume are given in table 4.3.7 from the table it absorbed that As the amount of silica fume was increased there was increase in the strength. The highest flexural strength is achieved in the M4 mixes with content of 12% of silica fume at all the ages.

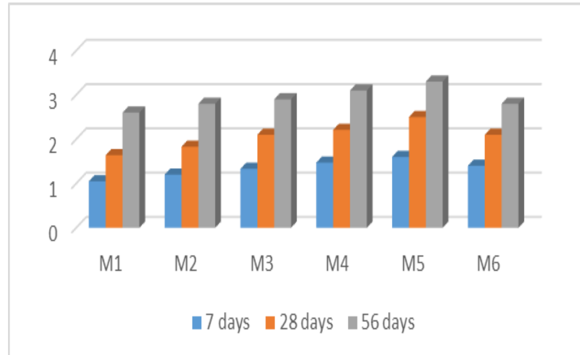

Chart 4 Flexural Strength of GPC with Silica fume

S.no	Mix designation	Flexural strength (Mpa)		
		7 days	28 days	56 days
1	M1	1.05	1.64	2.6
2	M2	1.2	1.83	2.8
3	M3	1.33	2.1	2.9
4	M4	1.47	2.21	3.1
5	M5	1.6	2.5	3.3
6	M6	1.4	2.1	2.8

Table 6 Flexural Strength

V.CONCLUSION

1. From the results of slump cone test it was observed that the workability of geopolymer concrete was being reduced as we were increasing the amount of silica fume percentage which makes the concrete tough to handle. Mix M2 and M3 with silica fume percentage as 3% and 6% has good workability and easy to handle.
2. Now coming to the compressive strength of geopolymer concrete it was also being increased as percentage of silica fume was increased till 12% further increase in silica fumes leads in the reduction of compressive strength. This indicates that 12% of silica fumes is the optimum value
3. There split tensile strength of mix with 12% silica fumes was increased by 50% compared to the mix in which silica fume was 0% and further increase

in silica fume till 15% reduces the strength by 15% so to achieve maximum split tensile strength in geopolymer concrete the percentage of silica fume should be not more the 12%

4. Flexural strength of geopolymer concrete was improved from 2.6Mpa to 3.3Mpa i.e there was a 20% increase in flexural strength (strength against bending) when silica fume were added by 12% and further increase in silica fumes leads to decrease in the strength by 15% i.e from 3.3Mpa to 2.9Mpa.
5. By observing all the test results it can be conclude that the optimum silica fume percentage to achieve maximum strength is 12% by weight of fly ash.
6. This material has the ability to replace OPC fully in future as in has the similar properties that of conventional concrete and in some cases it is much better then conventional concrete.

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