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A STUDY OF VARIOUS STRENGTH PARAMETERS OF FIBER REINFORCED GEOPOLYMER CONCRETE

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Abstract - Geopolymer concrete is an inventive construction material which is an replacement to Ordinary Portland Cement Concrete & also its environmental friendly. In this concrete, cement is totally replaced by pozzolonic material like fly ash & when it is activated by alkaline liquids it acts as a binder in concrete. The addition of fibers in Geopolymer Concrete (GPC) have been found to improve in its several properties like cracking resistance, ductility, etc. This paper describes the comparative study of its various strengths by considering various cases from previous studies. It is very important to do this comparison so as to find out which mix proportion is suitable for manufacturing of GPC. We studied various research papers & consider its results in the form of cases & observed the variations in the results as per the materials used & mix proportion taken. Due to this, we can able to overcome the problem of taking mix proportioning by trial & error methods. In this study, firstly we consider eight cases in which we was identified the material used, mix design process & the tests conducted & its results obtained. Based on these cases, we were compared the tests results then plot its graph & observed it. As the fibre content increases its strength parameters also increases.

***Key Words*:** Fly ash, alkaline solution, fibers, super plasticizer, geopolymer concrete.

1. INTRODUCTION

Day-by-day, the demand of concrete is increasing for fulfilling the needs of infrastructure faciliities. It is well introduce fact that production of Ordinary Portland Cement (OPC) absorbs significant amount of natural resources and energy as well as releases huge amount of carbon dioxide in the atmosphere. Hence, to make the concrete environment friendly it is necessary to find replacement of it. In 1978, Daidovits named Geopolymer & is an original and compostable construction material which are identified by chains or system. Waste materials such as fly ash and ground granulated blast furnace slab (GGBS) are being used in this concrete. Both fly ash and Ground granulated blast furnace slab are fixed by relevant technology and utilisation for concrete work in the form of geopolymer concrete. Geopolymer concrete was produce by fly ash such as base material and reinforced with fiber is called as Fiber reinforced geoploymer concrete. The construction geopolymer concrete will be strength various mix proportioning by trial and error occurred methodology. It has been found that addition of fibers improves several properties. slab are fixed by relevant technology and utilisation for concrete work in the form of geopolymer concrete. Geopolymer concrete was produce by fly ash such as base material and reinforced with fiber is called as Fiber reinforced geoploymer concrete. The construction geopolymer concrete will be strength various mix proportioning by trial and error occurred methodology. It has been found that addition of fibers improves several properties of concrete like cracking & fatigue resistance ductility, etc. The main benefit of geopolymer concrete is the reductions of carbon emission due to reduction of OPC use. It is also reduce global warming.

2. LITERATURE REVIEW:-

It is an innovative method and the mentioned paper clarifies that the fibre reinforced geopolymer concrete improves the workability, durability, setting time of cement better than Ordinary Portland Cement (OPC) concrete. The material like fly ash, GGBS, alkaline liquids, glass fibres, fine aggregate and course aggregate increase compressive strength, tensile strength of the concrete under ambient curing. Fibre reinforced geopolymer concrete is very eco-friendly and conserve concrete as it is made by the waste material like fly ash and must be curable in reasonable. Various tests were applied on fibre reinforced geopolymer concrete and it gave the higher value as compared to the OPC. Parametric study of various factors affecting the compressive strength of geopolymer concrete is strongly recommended nowadays in order to get the desirable benefits from the investigation.

3. WORK DONE:-

In this study based project we consider total eight cases & here we are showing the three most important cases.

3.1 CASE-1:-

1. Material - Fly ash, Quarry dust, Coarse aggregate, Alkaline activator i.e. sodium silicate and Sodium hydroxide solution, Super plasticizer.

2. Mix design :-

2.1 Preparing of alkaline liquid - Sodium hydroxide flakes weighed and they dissolve in distilled water and form 1 liter solution. Sodium hydroxide and Sodium silicate solution mix together at least 24 hours to make alkaline liquid. The alkaline liquid mix with super plasticizer and the extra water to prepare the liquid mixture

2.2 Casting and Curing - Fly ash, Quarry dust, Coarse aggregate are mixed dry condition for 4-5 minutes and then the alkaline liquid is added to the dry mix .The mixing is done in 8-10 minutes for proper binding of all material. The cubes are casted with mixes GP1 to GP3 after with mixing to giving proper compaction. The sizes of the cube is150mm×150mm×150mm. After the curing of geopolymer concrete cubes. The cubes are placed at in direct sunlight. After the sunlight curing the cube are demoulded after 1 day of casting and they are placed in the direct sun light for 7 days.

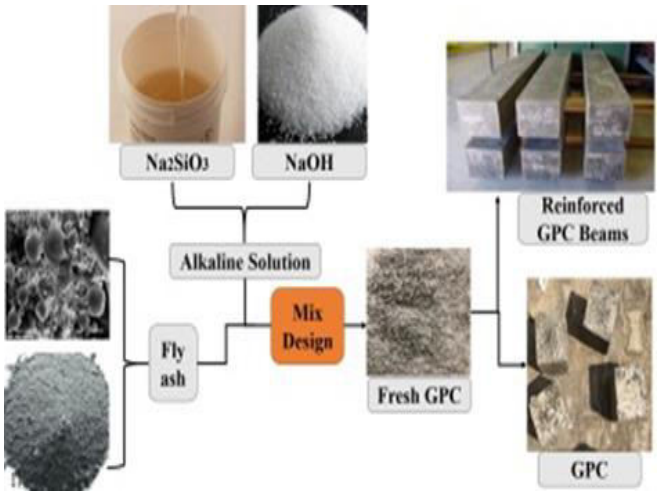

Fig.1 Flow chart of Geopolymer concrete

3. Tests Conducted:-

3.1 Compressive Strength:- Cube 150mm×150mm×150mm were casted and compressive strength test was conducted on specimenat 7 days ,14 days, 28 days.The result shown in below.

Table-1:- Compressive strength

Name of the mix	Compressive strength in N/mm2 of specimens Cured by		
	7 days	14 days	28 days
CC	18.6	23.4	27
GPC1	19.23	23.6	27.5
GPC2	20.26	24.2	28.2
GPC3	21	25.2	29.4

Chart-1:- Compressive strength of specimens at the age of 7 days

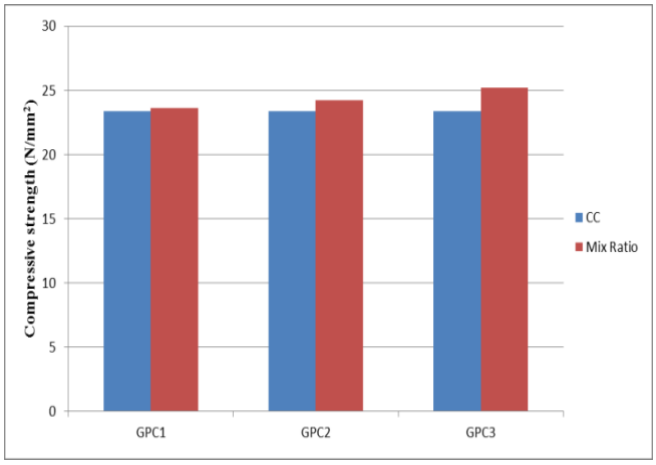

Chart-2:- Compressive strength of specimens at the age of 14 days

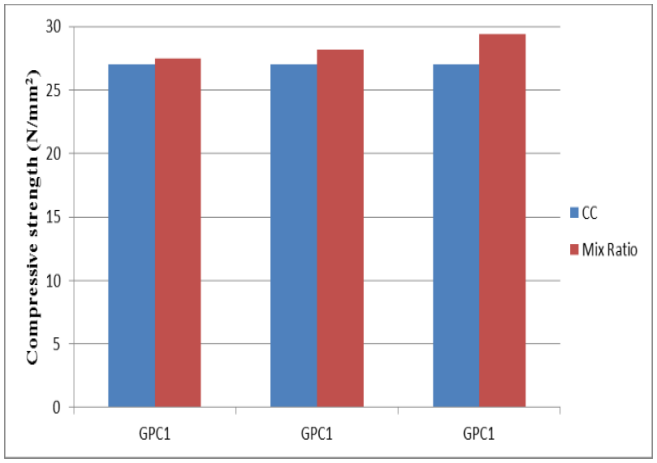

Chart-3:- Compressive strength of specimens at the age of 28 days

Observation - In the above graph the compressive strength increases the strength by 40% in 7days . The other one shows the strength increases by 60% in 14 days. The last one show the strength increases by 75% in 28 days .

3.2 Split Tensile Strength:- Split tensile strength test conducted on the cylindrical samples of concrete. In this study it was performed on cubes .This test was conducted for 7 days ,14 days ,28 days having mixes such as CC ,GPC1, GPC2, GPC3.

Table 2:- Split tensile srength

Name of the mix	Split Tensile Test in N/mm2 of specimens Cured by		
	7 days	14 days	28 days
CC	1.7	2.25	2.87
GPC1	1.9	2.34	2.74
GPC2	2.2	2.47	2.85
GPC3	2.3	2.52	2.96

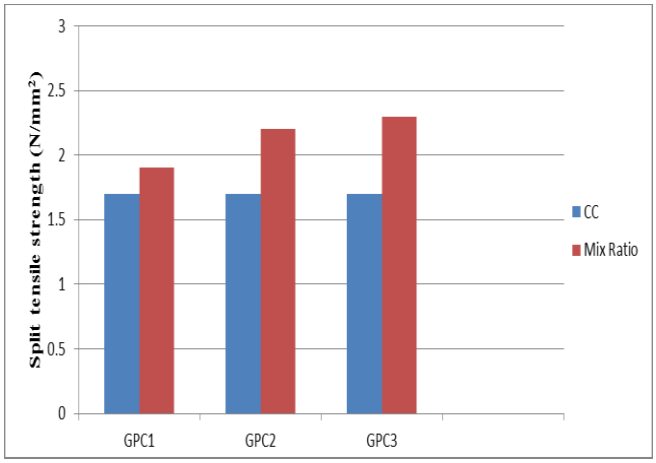

Chart-4:- Split Tensile Test of specimens at the age of 7 days

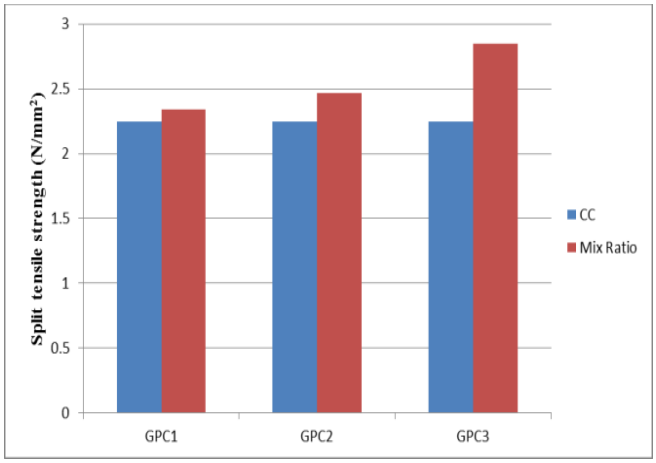

Chart-5:- Split Tensile Test of specimens at the age of 14 days

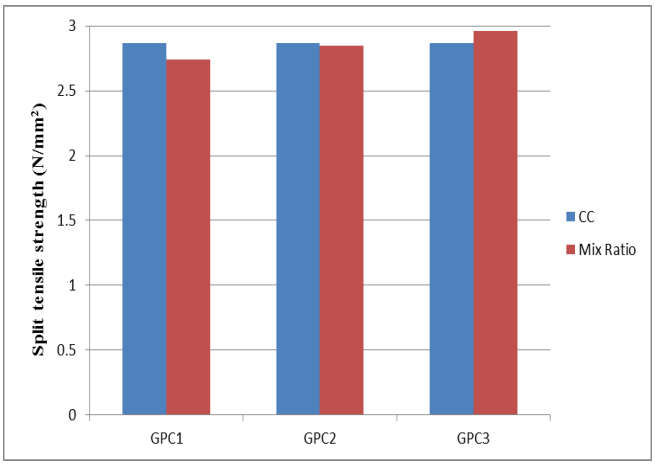

Chart-6:- Split Tensile Test of specimens at the age of 28 days

Observation- In above graphs the split tensile test can be varies as it compare with compressive strength. The only difference can use observe is Ratio of mixing of the quantity. In above graph shows the increase of compaction by 40% to 80%.

3.3 Workability test:-To find the workability of concrete, a slump test is commonly used. No additional water was added. Only a superplasticizer was added to get the required workability of the geopolymer concrete. Geopolymer concrete mixes with different slump values are represented in the below table& graphically.

Table 3:- Workability

Sr. No.	Name of the Mix	Workability in mm
1	CC	65
2	GPC1	75
3	GPC2	82
4	GPC3	92

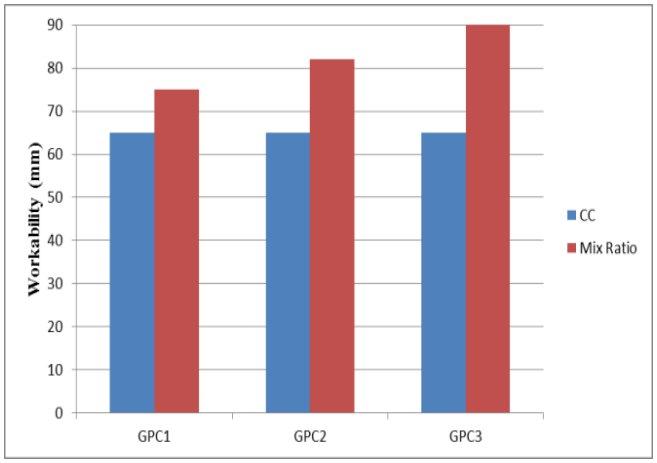

Chart-7:- Workbility Test of specimen

Observation:- In above graph, the slump value increases with the mix ratio. The highest workability is obtained in GPC3 i.e. 92 mm.

3.2 CASE-2:-

1. Material:- Low lime fly ash, Fine aggregate, coarse aggregate, GGBS, the alkaline solution (AS) is prepared by mixing sodium silicate and sodium hydroxide solution in ratio by mass of 2.5 is used.

2. Mix Design Process:-

2.1 Mixing of concrete:- The M 25 design mix of OPC is used as a reference to prepare FRGPC. arrived from IS: 10262-2009 and the mix ratio is 1:1.55:2.74. The constituents of geopolymer concrete of 12 M concentration for M 25 grade concrete are given Mix design for M 25 grade of OPC is in Table 1. The length and diameter of fibers are 30 mm and 1mm respectively. The aspect ratio (l/d) of the steel fiber is 50. NOVOCON 1050 crimped end steel fibers 1.0% by volume of concrete are used.

2.2 Casting and Curing:- Cubes and Prisms are casted and compacted using vibrating table in the laboratory as shown in fig. The specimens are cured under ambient condition at 25°C - 35°C.

Table-4 : - Constituents of Geopolymer Concrete

Description	Quantity (kg/m^3)
Fly ash	408.31
GGBS	45.36
NaOH	27.99
Water (added NaOH)	30.33
Na_2SiO_3 Solution	145.82
Fine aggregate	703.20
Coarse aggregate	1243.08

Fig. 2 Casting of specimens

Fig. 3 Curing at ambient temperature

3. Tests Conducted:-

3.1 Compressive strength:-

The FRGPC cubes are cured for 7 and 28 days and tested, using compression testing machine of 1000kN capacity. The compressive load is gradually applied until the failure occurs. The results of testing of cubes at 7 days and 28 days are shown in Figure.

Table- 5:- Compressive strength of FRGPC in 7 and 28 days

Sr. No.	Ultimate Load in (kN)		Compressive strength (N/mm^2)		Avg. compressive Strength (N/mm^2)	
	7 days	28 days	7 days	28 days	7 days	28 days
1	246	316	24.60	31.60	24.96	31.60
2	254	298	25.40	29.80		
3	249	334	24.90	33.40		

Observation:- By showing the above table the compressive strength increases its strength at 7 days having 24.96 in N/mm2 compressive strength and at 28 days 31.60 N/mm2.

3.2 Tensile Strength:-

The concrete is not usually expected to resist the direct tension because of its low strength and fragile in nature, the determination of tensile strength of concrete is necessary but all the concrete structure will crack on some extent due to shrinkage and tension in concrete. The testing of cubes are shown in Figure.4 and given in Table. 2

Table-6:- Tensile strength of FRGPC in 7 and 28 days

Sr. No.	Breaking Load in (kN)		Tensile strength (N/mm^2)		Avg. Tensile Strength (N/mm^2)	
	7 days	28 days	7 days	28 days	7 days	28 days
1	63	75	4.01	4.77	4.03	4.70
2	58	69	3.69	4.39		
3	69	78	4.39	4.96		

Observation:- From the above graph, it is shown that the Avg. Tensile strength at 7 days is 4.03 N/mm^2& that of at 28 days is 4.70 N/mm^2.

3.3 Flexural Test:-

The prism of size 100x100x500 mm are cast and tested as per IS: 516 - 1959. The specimens are tested under two point load application as shown in Figure. 7 and given in Table. 4.

Table-7:- Flexural strength of FRGPC in 28 days

Sr. No.	Ultimate load (N)	Flexural Strength of prism (N/mm^2)	Avg. Flexural strength of prism (N/mm^2)
1	11000	4.4	4.53
2	10000	4.0	
3	13000	5.2	

Observation:- From the above graph, it is shown that the Avg. Flexural strength is 4.53 N/mm^2.

3.3 CASE-3:-

1. Raw Material :-
The materials used in this study is fly ash , fine aggregate, coarse aggregate , hooked steel fiber , sodium hydroxide , and sodium silicate as alkaline solution.

1.1 Fly ash :- Low calcium (class F) fly ash are used which are taken from manjung power plant , limit.

1.2 Hooked steel fiber:- Hooked steel bar which has good mechanical properties and high tensile strength are used .

1.3 Description of hooked steel fiber:-

Diameter -0.5 to 1 mm

Length- 25 to 60 mm

Aspect ratio - > 50

Tensile strength - > 1000 MPa or N/ mm2

Coating – non , bright

Packaging – 1000 kg / plastic bag.

2. Mix Design & Process :-

960 grams(gm) sodium hydroxide pallets are diffused in distilled water .The solution is rest to setting for time 24 hours (hrs) .After 24 hrs 250 gram of NaOH solution and100 gm of Na2SiO3 solution are mixes together .When both the solutions are mixed properly and the exothermic reaction happens at that place and large quantity of heat get liberate or evolved .The solution mixture is setting down upto 1 hour for safety of others with use of hand gloves. For making geopolymer concrete samples fly ash and both aggregate are dry mix together. After that alkaline activator are mixes to dry mix and they become wet mixture after 3 to 4 minutes mixing. Finally hooked steel fiber is attached to wet mix with different weight like 28 g , 84 g , 140 g , and 196 g . Table no.1 shows the mix proportion of geopolymer concrete and hooked steel fiber.

Table-8:- Mix proportions of geopolymer concrete reinforced with hooked steel fibers

Ingredients	Fly ash	Fine aggregates	Coarse aggregates	Hooked steel fibers	NaOH	Na_2SiO_3
Quantity (g)	700	700	1050	28	250	100
				84		
				140		
				196		

3. Curing & Moulding Process :-

In this process fresh geopolymer concrete with or without hooked steel fiber are poured to (100×100×100)mm size cubes and (100×100×500) mm sized beam steel moulds to make sample of steel fiber geopolymer concrete .And all those samples are kept in room for 24 hours for setting at room temperature and after 24 hours they are demoulded after demoulding samples are store in testing laboratory at ambient condition till the day of testing. After 14 days the weight of cubes and beam samples are taken to understand that density , water absorption and those sample is tested in compressive strength test machine.

4. Tests Conducted:-

4.1 Workability :-

From graph the geopolymer concrete without steel fiber (GPC0) has the workability value 100 mm and the geopolymer concrete with mix 1% of steel fiber (GPC1) has 60 mm workability value .GPC3 i.e. geopolymer concrete with steel hooked mixes 3% has 49 mm workability value. While noticing result geopolymer concrete with mix of steel5% & 7% i.e. (GPC5 &GPC7) has 39.5 mm and 30 mm workability value.

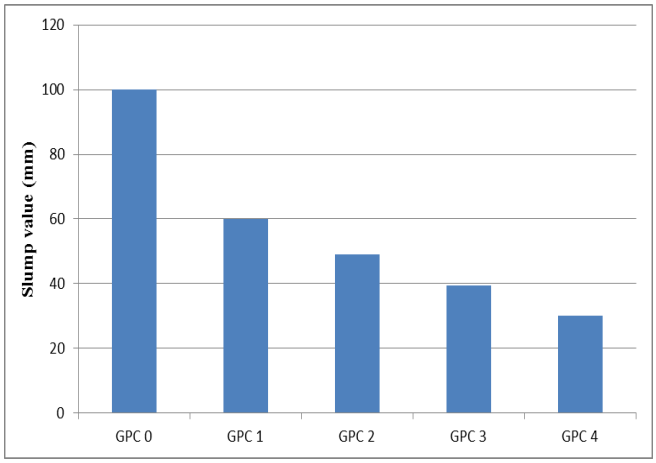

Chart-8:- Workability graph for different mix of geopolymer concrete

Observation:-When we see the graph we noticed that workability value decreases as we added steel fiber in geopolymer concrete .It conclude that addition or increase the amount of steel fiber in geopolymer concrete decrease the value of workability.

4.2 Compressive strength:-From fig. 4 We noticed that 7 days and 14 days compressive strength of geopolymer concrete.

From fig., 7 days compressive strength values for GPC0 , GPC1 , GPC3 , GPC5 and GPC7 are 12.45 MPa , 18.25 MPa , 20.87 MPa , 22.35 MPa and 26.55 MPa .And 14 days compressive strength values as GPC0 , GPC1 , GPC3, GPC5 and GPC7 are 51.30 MPa , 59.47 MPa , 63.17 MPa , 70.23 MPa and 87.83 MPa respectively.

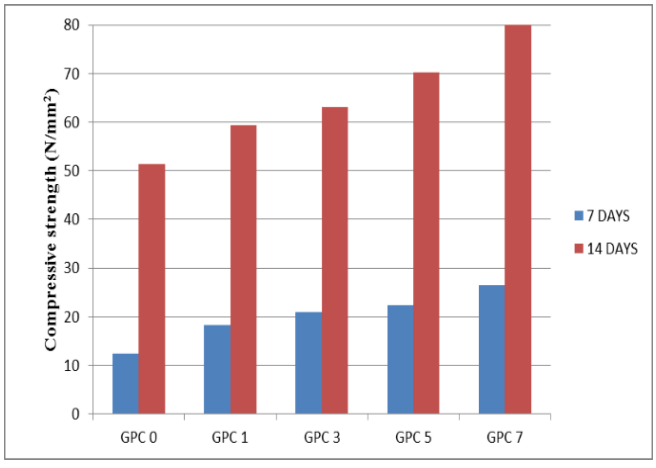

Chart-9:- Effect of inclusion of hooked steel fibers on compressive strength

Observation:-From this fig we know that the when we increase the amount of steel fiber in geopolymer concrete it

increase the compressive strength .So GPC0 has without steel fiber has less compressive value and GPC7 has more compressive value because it has more amount of steel fiber.

4. RESULT & ANALYSIS

Table-8:- Results & analysis of all cases

Sr. No.	TEST CONDUCTED	TESTS CONDUCTED							
		Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**	**Case 8**
1.	Compressive Strength (N/mm^2)	29.40	31.60	87.83	40.73	32.30	28.74	51.78	53.10
2.	Split Tensile Strength (N/mm^2)	2.96	4.70	-	-	3.11	-	5.17	3.3
3.	Flexural Strength (N/mm^2)	-	4.53	-	6.9	6.5	-	-	5.5
4.	Workability Test (mm)	92	-	100	-	-	100	-	-
5.	Water Absorption (%)	-	-	29.4	-	-	-	-	-
6.	Density (kg/m^3)	-	-	2501	-	-	-	-	-
7.	Impact Loading (N/mm^2)	-	-	-	-	-	-	23	-
8.	Rebound Hammer Test (km/sec)	-	-	-	-	-	36.4	-	-
9.	Ultrasonic Pulse Velocity Test (km/sec)	-	-	-	-	-	4.15	-	-

Based on our study, in the above table no. 8 we have shown the best value of every test performed in that particular cases & note down its value in the table. Based on this table, we have plotted graph of suitable tests conducted in that particular case.

4.1 Compressive Strength Test:

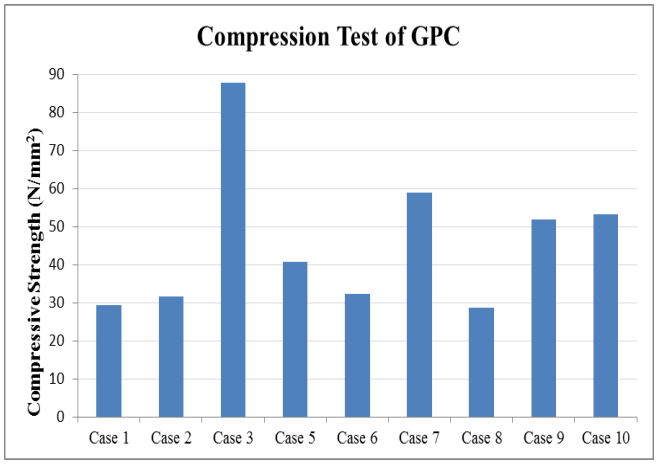

Chart 10:- Comparison of Compressive strength test

In the above graph, it is clearly observed that the compressive strength of Case-3 gives highest value which is found to be 87.83 N/mm^2. This is because of using 7% hooked steel in fibre in the GPC mix.

4.2 Split Tensile Test: -

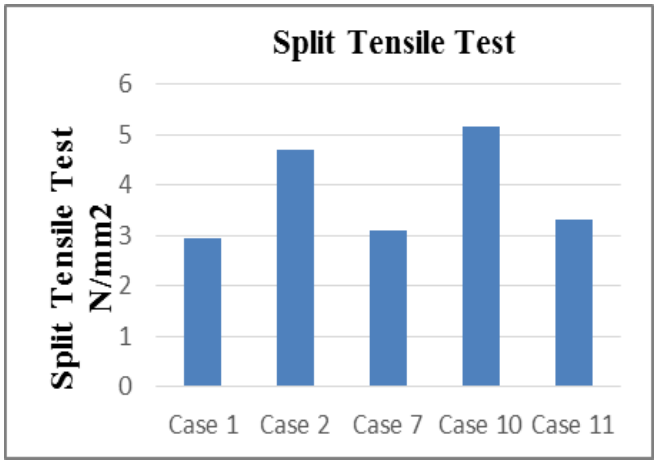

Chart-11:- Comparison of Split tensile strength test

In the above graph, the highest value of split tensile test obtained in Case-9 & it was found to be 5.17 N/mm^2 . This is due to geopolymer mix was reinforced with 0.75% crimped stainless steel fibers.

4.3 Flexural Test:-

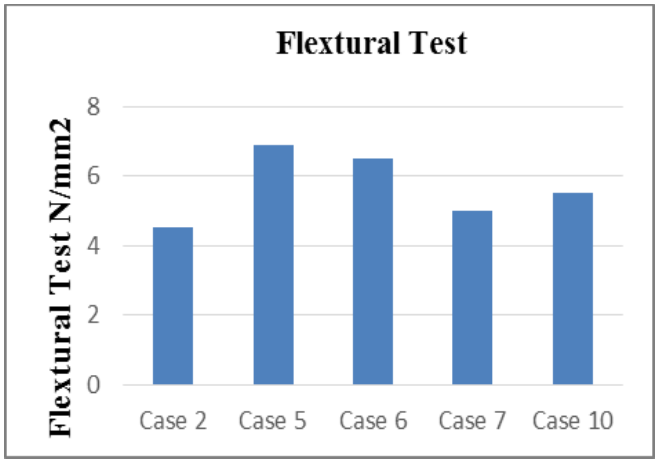

Chart-12:- Comparison of Flexural strength test

In the above graph, the highest flexural strength was obtained in Case-5 which found to be 6.9 N/mm^2. This is due to the addition of 0.03% volume fraction of glass fibers in the concrete mix.

4.4 Workability Test :-

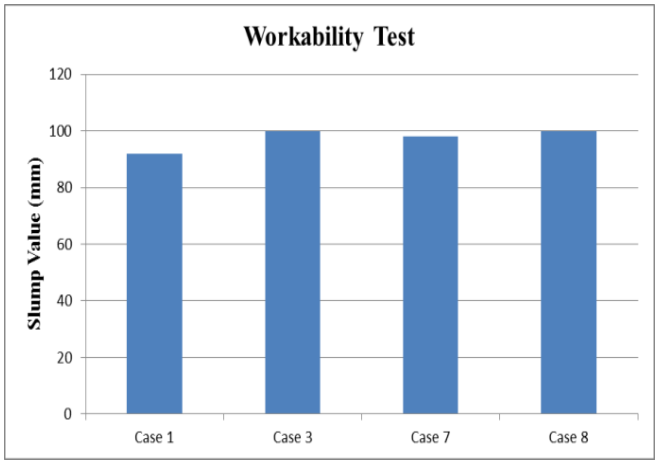

Chart-13:- Comparison of Workability test

In the above graph, the maximum slump value of workability test was found to be 100 mm which is same in Case-3 as well as Case-8. As we all know that increase in the fibre content will decreases its workability hence both the cases is without any fibre content in the mix which results in higher workability.

5. CONCLUSIONS

Workability of the geopolymer concrete is increased when concrete is made without steel fiber. If we increased steel fiber in concrete workability has decreased. If the fiber content in geopolymer concrete is increased the compressive strength is also increased so the geopolymer concrete with maximum amount of steel fiber in it has maximum compressive strength. As the volume of fraction of concrete is increases the flexural strength of concrete is also increases. The concrete have maximum water absorption having minimum compressive

strength. If the loading of steel fiber is increased in geopolymer concrete the density of geopolymer concrete is also increased. Geopolymer concrete without glass fiber has high workability value than all mixes which made with some amount of glass fiber. As the ages and amount of glass fiber increases the compressive strength also increases.

ACKNOWLEDGEMENT

Concrete is the world's most durable, reliable and flexible construction material next to the water. It is the growing field in the construction industry. The study involves investigation of the mechanical properties of fly ash replaced with OPC & also properties of fibres of geopolymer concrete. The increase of fibres results in increase the workability and enhance the setting property of geopolymer concrete. It also very much helpful for the environment as it is does not release the CO_2 in the atmosphere.

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