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Experimental Investigation On The Mechanical And Durability Of Concrete With Partial Replacement Of Cement By Glass Powder And Partial Replacement Of Fine Aggregate By Foundry Sand

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***Abstract*—This paper presents a laboratory investigational study on the influence of the binary blend (glass powder &foundry sand) on its mechanical and durability properties of concrete. The waste glass powder is used as a partial replacement of cement due to its pozzolonic property. The waste foundry sand is used as a partial replacement of sand. The mechanical properties are examined by the tests are compression strength and flexural strength. Water absorption and sorptivity durability aspects are examined. Replacement of cement by waste glass powder from 10%,20%,30%,40%,50% and the replacement of sand by waste foundry sand from 10%,15%,20%,25%,30%.The test were conducted at 3,7 & 28 days of concrete . The optimum mix was selected from the 3, 7 & 28 days of compressive strength, flexural strength and durability properties of different mixers.**

Keywords— Concrete, foundry sand, waste glass powder ,strength parameter and durability parameter

I. Introduction

Concrete being the most extensively used construction materials in the world, without concrete the development of construction field is not fulfilled in any other ways. The concrete is considered as a back bone of buildings. The cement, sand and aggregates are the back bone of the concrete. These materials are extracted from nature as a source. By making the concrete as a sustainable material using waste material as a part of a concrete using in terms of increasing the strength.

In recent decades the glass powder is used in concrete based on the idea of increasing the compressive strength. Moreover, waste glass is potentially a very useful material and appropriate economical applications. High consumption of natural sources, high amount production of industrial waste and environmental is some of the factors which are responsible for obtaining new solution for a sustainable development. The waste glass powder has more pozzolonic property and fineness. Thus solution of using glass powder as cement giving sustainable improvement.

Increasing the production of industries due to the increase of population, this also leads to increasing the generation of wastes. Some of the wastes having good properties .The waste foundry sand is also that kind of material. The foundry sand is the byproduct of metal casting industries. Per annum more than 100 million tons of foundry sand are produced. Foundry sand consists primarily of clean, uniformly sized, high quality silica sand that is bonded to form molds for ferrous (iron & steel) and nonferrous (copper, aluminum, brass) metal casting industries. The waste foundry sand having more amount of silica so it can be used as sand in concrete.

II. Experimemtal Investigation

A. *Material and Methods*

1) Cement: Ordinary Portland cement of 43 grade is used. The physical properties of OPC43 grade was found out by conducting experiments and the results are tabulated in table 1.T he chemical composition of cement is presented in table 2.

TABLE I. PHYSICAL PROPERTIES OF CEMENT

SI.No	Properties of cement	Results
1.	Specific gravity	3.2
2.	Initial setting time	32min
3.	Final setting time	450min
4.	Colour	Grey colour
5.	Grade	43 grade

TABLE II. CHEMICAL COMPOSITION OF CEMENT

Formula	Concentration in %
Cao	69.00
Sio_2	24.91
Fe_2O_3	5.85
Mgo	0.20
Na_2O	0.04

2) Waste glass powder: Commercially available finely ground waste powder from M/S.Aswin ceramics, Chennai was used. The physical properties of the GP are presented in table 3.The chemical properties are shown in table4.

3) Waste foundry sand: Foundry sand from Astra chemicals, Chennai was used. The physical properties of waste foundry sand are presented in table 3.The chemical properties are shown in table4.

TABLE III. PHYSICAL PROPERTIES OF FS AND GP

SI.NO	Property name	Foundry sand	GP
1.	Specific gravity	2.45	2.98
2.	Ph	-	6
3.	Particle size	75μm	70μm
4.	Appearance	Black	Off white
5.	Fineness(m^2/kg)	_	389.5

TABLE IV. CHEMICAL COMPOSITIONS OF WASTE FOUNDRY S AND GLASS POWDER

Constituents	Waste foundry sand	Glass powder
Silica(SiO_2)	78.81	72.00
Iron oxide(Fe_2O_3)	4.83	3.50
Alumina(Al_2O_3)	6.32	0.50
Calcium oxide(CaO)	1.88	10.00
Magnesium oxide(MgO)	1.95	2.50
Total sulphur(SO_3)	0.05	-
Sodium oxide(Na_2O)	-	10.20
Chloride	0.04	-
Cr_2O_3	-	1.00
Loss on ignition	2.15	-
Insoluble residue	-	0.1

4) Coarse aggregate and fine aggregate: Crushed granite aggregate of size 20 mm collected from locally available source .FA is less than 4.75 mm size which is free from clay, silt and organic impurities.

5) Water: The water used for mixing and curing purposes is of good quality portable water.

B. Methodology

1) Detailed of specimens: M20 grade of concrete was designed and used .The specimens of size 150 mm x150 mm x150mm cube where cast for control mix without replacing waste glass powder and foundry sand. The coarse aggregates in conventional mix kept as constant and replacing cement by WGP in 10%-50% and sand by waste foundry sand 10 %-30%.The designation of various mix proportions used and its percentage of various constitutions viz .cement, GP,FS are tabulated in table 5. For tensile strength test 150 mm diameter and 300mm height cylindrical specimens were cast for same mix. For durability test, 100 mm diameter and 50 mm height cylindrical specimen were cast for sorptivity test, 100 mm cube specimens were cast for water absorption test .In pull out test 150mmX150mmX150mm cube is made by inserting specially shaped 10mm diameter bar.

2) Mix design and proportion: M20 grade of concrete with OPC 43 grade cement was used. Since foundry sand was used along with GP . Which consume more water. So we use W/C ratio of 0.5.The workability of concrete is having slump value of 125mm.The mix proportion was 1:1.69:2.86.The percentage replacement of GP and FS is presented in table 5.The mix proportion of various ingredients is presented in the table 6.

TABLE V. MIX PROPORTION PERCENTAGES OF CEMENT, GP, FS,FA, CA

Mix designation	*Cement (%)*	*Waste glass powder (GP) (%)*	*Foundry sand (FS) (%)*	*Fine aggregate (FA) (%)*	*Coarse aggregate (CA) (%)*
CM	100	0	0	100	100
GF11	90	10	10	90	100
GF22	80	20	15	85	100
GF33	70	30	20	80	100
GF44	60	40	25	75	100
GF55	50	50	30	70	100

TABLE VI. MIX PROPORTION OF VARIOUS INGREDIENTS FOR 1 M^3 OF CONCRETE

Mix designation	Cement(kg)	GP(kg)	FS(kg)	FA(kg)	CA(kg)	Water(kg)
CM	406	0	0	687.42	1163.12	203
GF11	365.4	40.6	68.74	618.68	1163.12	203
GF22	324.8	81.2	103.12	584.30	1163.12	203
GF33	284.2	121.8	137.49	549.93	1163.12	203
GF44	243.6	162.4	171.56	515.86	1163.12	203
GF55	203	203	206.23	481.19	1163.12	203

C. Testing of specimen

1) Compressive strength test: The compressive strength test is more important ,because the concrete characteristic properties and the structural design are related to compressive strength .The test was conducted in compression testing machine of 3000KN capacity for different ages of concrete viz .3,7 and 28 days. The test set up is shown in Fig. 1.

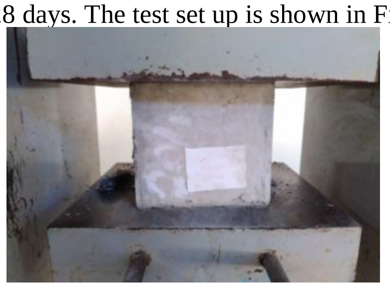

Fig. 1. Compression test.

2) Split tensile test: This is an indirect test to ascertain the tensile strength of cylindrical specimen. Split tensile strength tests were carried out at the age of 3, 7 and 28 days. The test was carried out in compression testing machine of 3000KN capacity. The test set up shown in Fig. 2.

The splitting tensile strength was estimated using the relationship.

$$f_t = \frac{2P}{\pi DL}$$

Where,

f_t=Splitting tensile strength of concrete in MPa,

P=Load at failure in Newton,

D=Diameter of cylinder,

L=Length of cylinder,

Fig. 2. Split tensile strength.

3) Sorptivity test: The durability of the blend was measured by analyzing sorptivity test. It was performed by casting cylindrical specimens of size 100 mm diameters X 50mm height. This method is most suitable to find out the susceptibility of an unsaturated concrete to the penetration of water. The specimen was kept on the air oven at 50◦C for 3 days. After the 3 days oven curing, the specimen subjected to room temperature for 15 days .The top and bottom of the specimen are sealed by keeping the bottom side of specimen open .Bottom surface was exposed to water in such a way that 1/10 th of the height of the specimen was kept in water for 28 days. Then the mass of the specimen was noted at different intervals. Mass of dried specimen was noted and the procedure as per ASTM C1 [46] was followed. The test set up was shown in Fig. 3.

Fig. 3. Sorptivity test.

a) Measurement procedure: The concrete mass was taken at the interval of 1, 2, 3..7 days. The amount of absorbed water depends on the characteristics of the concrete surface layer .The changed mass due to water absorption is calculated for defined time interval.

Finally the sorptivity was calculated by using the following equation,

$$I = \frac{\Delta m}{aXd}$$

I-Water absorption of the tested specimen in mm⁄s^(1/2)

A –contact area in 〖mm〗^2

Δm-Increase in strength of the tested specimen in grams

d-Density of water in g/mm^3

4) Water absorption test: The volumetric water absorption of concrete specimen was found as per the guide lines of ASTM C 642 [47] . After 28 days curing, the concrete specimen was taken out from the curing tank and oven dried at 105°C temperature for 24 hours. The dried specimen was cooled in room temperature and the weight of the specimen was noted.

To evaluate the water absorption of the concrete the dried specimen were submerged in water as shown in figure 4 above ,and the differences in weight of the specimen in before and after immersion was measured at a periodic interval of one hour until successive same observation obtained .The amount of water observed by the concrete was computed as the change in the weight of specimen from saturated surface dry condition to dry condition and the values were represented as percent by the volume of specimen. The tst set up was shown in Fig. 4.

Fig. 4. Water absorption test.

5) Flexural behavior test: The beam of size 100mm×150mm with 1200mm length. The beam is considered for simply supported for flexural test. The beam is designed for simply supported beam with 12mm diameter bars of 2 numbers at tension zone. For stirrups 2legged 6mm diameter bars provided at minimum spacing of 300mm centre to centre. In compression zone 2 numbers of 8mm diameter bars are used. Commonly two type of loading arrangements are used. There are central point loading and third point loading method. In this test we are using symmetrical two points loading. Because in this type the crack may appear at anywhere of the beam he type of crack developed due to applied loading is observed carefully. The two symmetrical loads are applied at L/3 distance from each support. For recording the load and axial displacement automatic data acquision system is used. The test setup for flexural test is shown in Fig. 5.

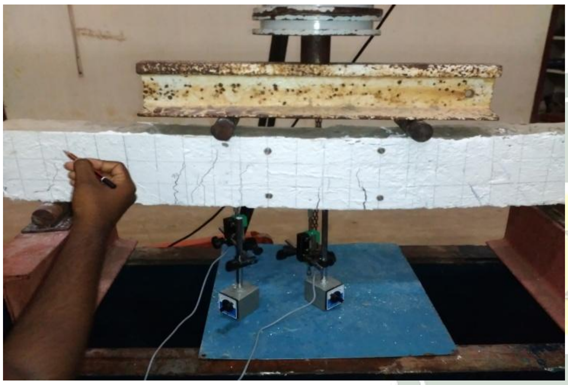

Fig. 5. Flexural behavior test.

6) Pull out test: In the pull out test 10mm dia bar is casted into the concrete cube of 150mmx150mmx150mm.A pull out test measures the force required to pull out the rod from the concrete, a specially shaped rod whose enlarged end has been cast into the concrete. The stronger concrete the more force is required to pull out. The concrete is weak the force required to pull out is less. In the strongest one means the bond strength is high. To break this bond strength more force is required to pull out the bars from the concrete.

Fig. 6. Pull out test set up.

D. Results and discussion

1) Compressive strength: The compressive strength of different mixes of various proportion at different ages were presented in table 7.The compressive strength for GF11 is low as compared to CM. After GF33 (70+30+20) the compressive strength was gradually decreased. The max strength of trial mix was obtained at GF22.So GF22 mix is preferable on the point of view of compressive strength. The maximum strength obtained by GF22 compared to conventional mix is presented in graph. The finer material of foundry zone behave as a good transition zone.Upto 20% of replacement of glass powder the pozzolonic property of GP is used by concrete. After that the GP acts as an inert material.The figure 7 shows the graph for compressive strength test result for conventional and trial mixes.

TABLE VII. COMPRESSIVE TEST RESULT

Mix designation	Cement:GP(C):FS(FA)	3 days(MPa)	7 days(MPa)	28 days(MPa)
CM	100+0 + 0	9.94	13.00	21.49
GF11	90+10+10	9.01	12.42	21.24
GF22	80+20+15	11.02	14.43	23.92
GF33	70+30+20	10.21	13.99	23.59
GF44	60+40+25	9.52	12.93	21.32
GF55	50+50+30	8.32	11.92	20.99

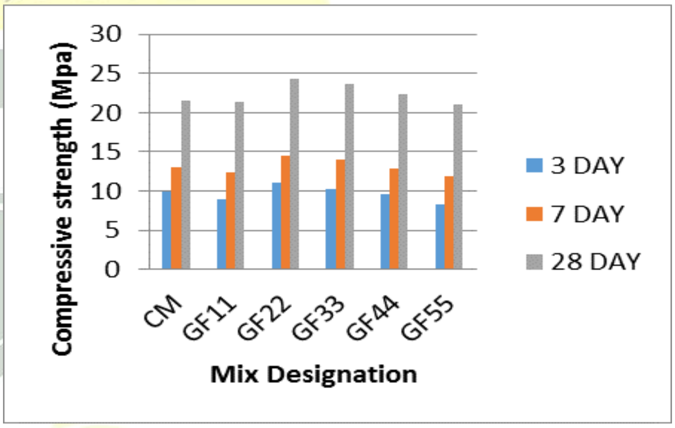

Fig. 7. Compressive strength test results for trial mixes and convensional mix.

2) Split tensile strength: The results of split tensile test for various mixes are mentioned in table 8.Every civil engineers should known concrete is weak in compression and strong in tension. At GF22 the maximum tensile strength is obtained. After that decreasing gradually. Increasing in age of concrete also increasing in the splitting tensile strength. The reduction in tensile strength of GF11 is 13.20%, 34.43% and 21.13% at 3,7and 28 days respectively. The increase in tensile strength compare to CM is 35% ,10.1% and 7.3% respectively atGF22 for 3,7,28 days curing.In figure 8 the graph showing the split tensile test result for CM and trial mixes.

TABLE VIII. SPLIT TENSILE TEST RESULT

Mix designation	3 days(MPa)	7days(MPa)	28 days (MPa)
CM	1.06	1.51	2.53

GF11	0.92	0.99	1.99
GF22	1.21	1.66	2.70
GF33	0.94	1.34	2.54
GF44	0.79	0.95	1.98
GF55	0.52	0.73	1.52

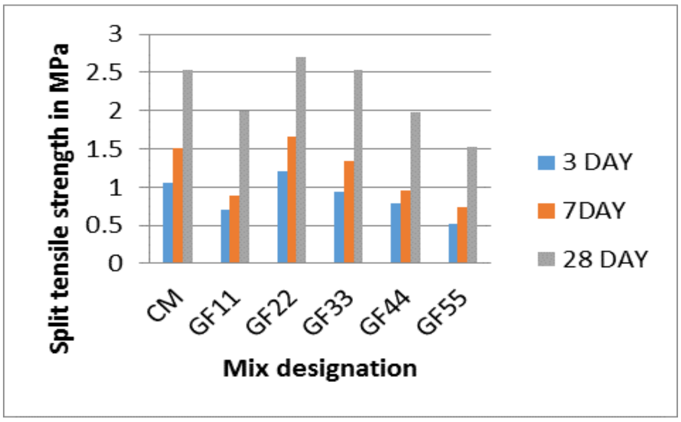

Fig. 8. Graph showing the variation in split strength for CM and various mixes.

3) Resistance to water absorption and sorptivity

a) Water absorption: The water absorption test results are presented in table 9.In GP the water absorption is increased up to 30% GP the water absorption is low as compared to CM. An increase of water absorption greatly affects the compressive strength. In our trial mixes the water absorption at GF22 is low as compared to trial mixes. After that increasing gradually. Due to the pozzolonic property of GP and pore filling capacity of foundry sand that may occur. In figure 9 and 10 the graph showing the water absorption test result and minimum absorption of water as compared to trial mixes respectively.

TABLE IX. WATER ABSORPTION TEST RESULTS

Mix designation	***Water absorption in days***						
	1(%)	***2(%)***	***3(%)***	***4(%)***	***5(%)***	***6(%)***	***7(%)***
CM	1.99	2.43	2.98	3.14	3.50	3.87	3.96
GF11	1.80	2.23	2.45	2.95	3.43	3.54	3.72
GF22	1.78	2.16	2.28	2.91	3.22	3.51	3.59
GF33	1.87	2.46	2.56	3.11	3.54	3.77	4.41
GF44	2.33	2.63	2.71	3.33	3.87	3.94	4.79
GF55	2.43	2.72	3.20	3.48	3.91	3.98	4.22

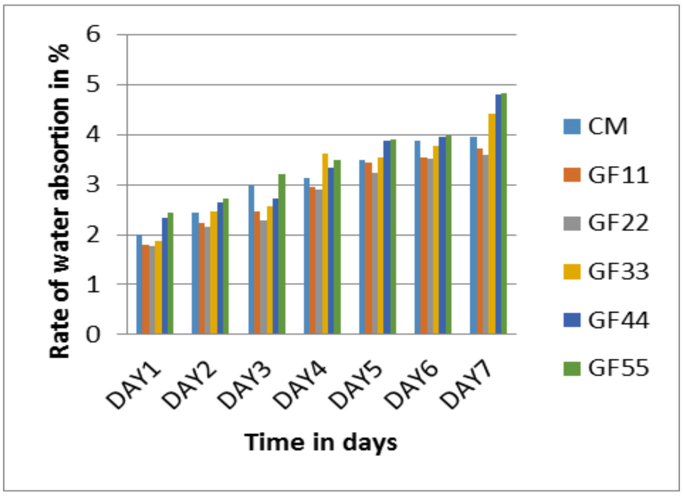

Fig. 9. Water absorption test results.

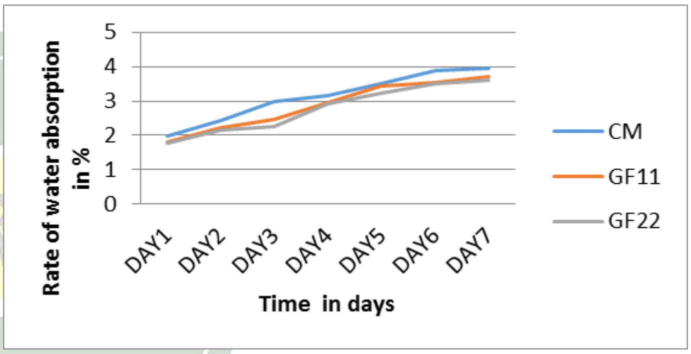

Fig. 10. Graph showing the mimimum water absortion of trial mix compared to conventional mix.

b) Sorptivity: From table 10 the absorption coefficient for GF11 is higher as compared to CM for all time intervals. The sorption coefficient after 1 day of all trial mixes does not changed or nearly equal. After GF22 the absorption coefficient is least than CM.The reason for the reduced penetration is due to filler effect of micro particle.In figure 11 the graph showing the test result for soprtivity.

TABLE X. SORPTIVITY TEST RESULTS

Mix designation	***Sorption coefficient=I=$\frac{\Delta m}{a \times d}$ in (days)***						
	Day1	***Day2***	***Day3***	***Day4***	***Day5***	***Day6***	***Day7***
CM	6.41	6.41	6.41	6.41	6.41	6.41	6.41
GF55	6.70	6.71	6.71	6.71	6.71	6.69	6.71
GF44	6.62	6.62	6.63	6.61	6.61	6.61	6.61
GF33	5.94	5.93	5.93	5.91	5.90	5.91	5.91
GF22	5.52	5.54	5.54	5.54	5.54	5.54	5.54
GF11	5.42	5.45	5.45	5.44	5.55	5.55	5.55

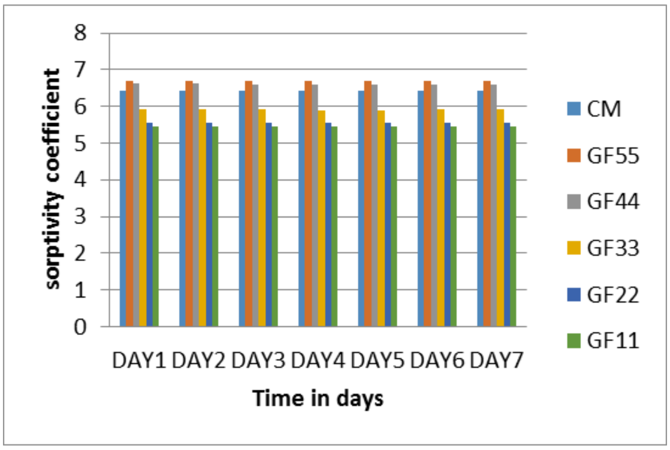

Fig. 11. Sorptivity for control mix and various mixes.

4) Flexural strength test: The optimum flexural strength obtained at GF33.Upto GF33 the flexural strength is increased. Beyond that the flexural strength is reduced. The GF22 have strength nearly equal but lower than theGF33 mix. The flexural strength of beam is calculated by using the following equation,

$$f_b = \frac{PL}{bd^2}$$

Where,

P=Ultimate load in KN,

L=Span length of the beam in m,

b=Breadth of the beam in m,

d=Depth of the beam in m.

TABLE XI. FLEXURAL STRENGTH TEST RESULTS

Description	*CM*	*GF33*	*GF22*
Peak load(KN)	51.54	54.25	52.22
First crack load(KN)	23.24	32.50	30.32
Max deflection at (L/2) span(mm)	9.98	10.32	9.54
Minimum crack width(mm)	1	2	1.5
Maximum crack width(mm)	3.5	6	4.5

a) Load carrying capacity: The load carrying capacity of the beam at first cracking stage is represented in graph. The load carrying capacity of the trial mixes is increased up to GF33.And then reduced gradually. The increase of fine material increasing the compressive strength. But it affects the flexural strength. In figure 12 the graph showing the maximum load carrying capacity of trial mixes compared to CM.

X axis as First cracking load in KN.

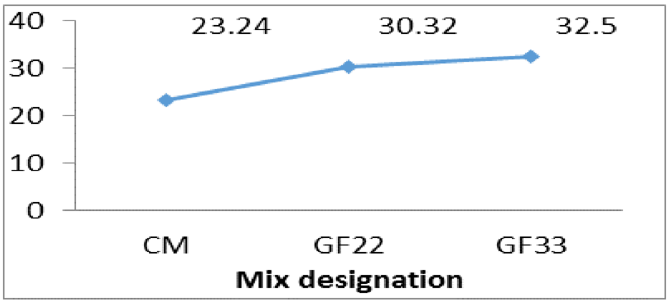

Fig. 12. Max load carrying capacity of trial mixes compared to CM.

5) Bond strength: The strength of the concrete is depending upon the bond between the steel and concrete. The bond strength value is presented in figure. The bond strength of mix GF22 is very high. Up to GF22 bond strength is increased. After GF22 the bond strength is reduced considerably. Increasing the proportion of GF and FS the bon strength is reduced. In figure 13 the graph showing the bond strength of CM and trial mixes.

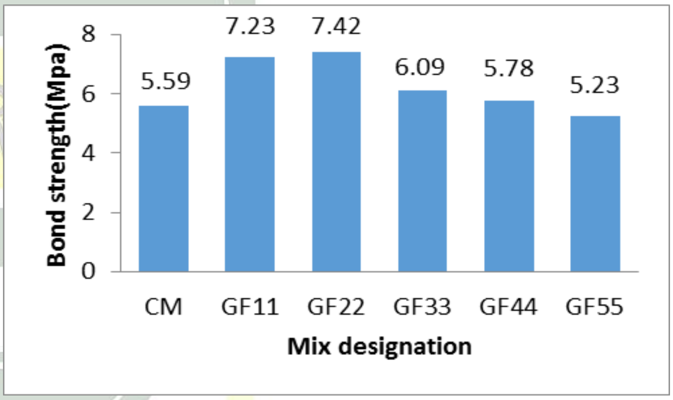

Fig. 13. Bond strength of CM and various trial mixes.

CONCLUSION

From experimental test and result the conclusion for this trial mixes are pointed below.

- The maximum compressive and tensile strength are obtained at GF22 (80(FA)+20(GP)+15(FS))mix. So that is the suitable mix for considering mechanical behavior. The compressive strength of GF22 mix is 10.15% higher than the CM.Also GF33 has maximum strength compared to CM. But 1.25% lower than the GF22.
- In flexural strength test GF22 having high load carrying capacity as compared to conventional mix of about 23.12%. The bond strength also high at GF22.GF11have nearly equal value of bond strength of GF22.
- The GF22 have good mechanical as well as durable property over other mix designation. The replacement of 20% of glass powder and 15% of foundry sand is a suitable trial mix.

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