

EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH GLASS POWDER AND FLY ASH ON COMPRESSION STRENGTH OF STEEL FIBER REINFORCED CONCRETE

*Suram. S¹, Wayal. A²

¹P.G. Student, Construction Management, Department of Civil & Environmental Engineering, Veermata Jijabai Technological Institute (VJTI), Mumbai-400019, India.

²Associate Professor, Department of Civil & Environmental Engineering, Veermata Jijabai Technological Institute (VJTI), Mumbai-400019, India.

Abstract: Cost of Cement in a concrete is highly expensive so there is a need to find its alternative and the material used as an alternative should exhibit the pozzolanic property when mixed in concrete as well as should be sustainable in nature and should be available at low cost as compared to the cement. Glass powder and Fly Ash powder are one of the sustainable materials which are also available at low manufacturing cost and can be used as cement alternative because they exhibit the pozzolanic reaction when mixed in concrete. It is often used as a pozzolan to form hydraulic cement. This Research focuses on the improvement of early compressive strength of the concrete and not on the alkali silicate reaction. The Compressive strength are calculated of the casted cubes as per IS: 516-1969. The mix design used is M25 as per IS: 10262-2009. Proportion of glass powder used is 0%, 10%, 15%, 20% of total cementitious content in concrete and proportions of Fly ash powder in a concrete are 30%, 15%, 10%, 0% of total cementitious content in a concrete. The constant steel fiber proportion of 1% by the weight of cementitious materials was maintained. This proportions are concluded with the help of study conducted from previous literatures. The use of fly ash reduces the early compressive strength whereas the use of GP improves the early compressive strength of concrete.

Keywords: Glass powder (GP), Steel fibers (SF), Steel fiber reinforced concrete (SFRC), Universal Testing Machine (UTM), Ready Mixed Concrete (RMC), Supplementary cementitious material (SCM).

1. INTRODUCTION

The production of cement causes high global CO₂ emissions in an environment [3]. The use of waste materials such as Glass powder and fly ash as partial replacement for cement in concrete is a viable strategy for reducing the use of Portland cement, and thus reducing the environmental and energy impacts of concrete production [3]. This promising approach is considered as an innovative means to promote the use of sustainable materials in construction.

Steel fiber reinforced concrete (SFRC) is formed by the uniformly and disorderly distributed steel fiber in concrete matrix. The addition of steel fibers in a concrete reduces the crack propagation and also improves the bonding between different constituents of the concrete. The addition of steel fibers in high performance concrete (HPC) can improve the brittle behavior and the energy absorption capacity [6]. Effect of steel fibers in combination with coarse aggregate was investigated on the compressive and flexural toughness of high strength concrete. The mechanical properties of high strength fiber reinforced concrete are volume fraction of aggregate and both compressive strength and flexural toughness are significantly influenced with increase in fiber content [6]. The workability of concrete significantly

reduced as the fibre dosage rate increases [11].

Glass is principally composed of silica. Use of finely grounded waste glass in Steel Fiber Reinforced concrete (SFRC) as partial replacement of cement could be an important step toward development of sustainable (environmentally friendly, energy-efficient and economical) infrastructure systems. When waste glass is milled down to micro size particles less than 75 microns, it is expected to undergo pozzolanic reactions with cement hydrates, forming secondary Calcium Silicate Hydrate (C–S–H) [4]. Dali et al. (2012), studied the effect of glass powder sieved through 600 mm sieve and observed that the compressive strength increment is observed up to 25% replacement of cement, but the peak of increment is at 20% replacement [12]. The test results of Vasudevan et al. (2013), showed that the use of glass powder up to 20.0% enhanced the concrete compressive strength [13].

2. MATERIALS AND METHODOLOGY

2.1 Materials used

2.1.1 Cement: Cement used for the casting cubes is Ordinary Portland Cement (OPC) 53 grade confirming to IS 8112 (ASTM Type-1). The Physical properties of cement are available by manufacturer directly. The cement used was of brand UltraTech OPC 53 grade cement. Cement used was free from lumps and was recently manufactured (less than a month).

2.1.2 Glass Powder: Glass powder is obtained from waste glass fiber like structures which are then crushed in the ball mill to a size less than 75 microns so that they exhibit pozzolanic properties. These crushed glass has a final product whitish in color in a powder form which can be used as cement substitute up to 25% of cementitious material which is maximum limit. Glass powder's composition and physical properties are shown in the Table 1 and Table 2. Waste glass can be cost-effectively collected in mixed colors.



Fig. 1. Shows the Source through Which GP is Obtained

Table 1. Chemical Composition and Physical Properties of GP

Elements	GP	Property Name	GP
CaO	18.55	Specific Gravity	2.7
SiO ₂	64.94	pH	6
Al ₂ O ₃	1.81	Particle size	<75 micro meter
Fe ₂ O ₃	1.97	Appearance	White

SO ₃	0
P ₂ O ₅	0
MgO	3.12
KO ₂	0.44
Na ₂ O	9.16

2.1.3 Steel fibers: Steel fibers made of stainless steel and free from corrosion is used. Locally available crimped steel fibers were used in concrete mix of 5 cm length. As per literatures studied the steel fibers with 1% quantity of cementitious material in concrete yields a good mechanical property so steel fiber quantity is maintained to 1% of cementitious material in a concrete casted.



Fig. 2. Crimped Steel Fibers

2.1.4 Fly Ash: Class F are being utilized in making building materials such as concrete, lightweight aggregate, bricks etc. Fly ash used in the research work is of class F designated in ASTM C 618 and originates from anthracite and bituminous coals. It consists mainly of alumina and silica and has a higher LOI than Class C fly ash. When used in Portland cement, Class F fly ash can be used as a Portland cement replacement ranging from 20-30% of the mass of cementitious material. Color of class F fly ash is light greyish. It is to be seen that it should not contain any impurities in it.

Table 2. Class F Fly ash properties

Properties	SiO ₂ +Al ₂ O ₃ +Fe ₂ O ₃	SO ₃	Moisture Content	Loss on Ignition
Content	70	5	3	6

2.1.5 Coarse Aggregates and fine aggregates: Crushed Granite of Metal 1 and Metal 2 were used as course aggregate in a concrete mix to be prepared. The Metal 1 coarse aggregates are passing through 10 mm and retained on 4.75 mm sieve whereas Metal 2 aggregates are passing through 20 mm and retained on 12.5 mm. They are mixed at certain proportion in the concrete mix based on trial and error. The locally available river sand will be used as a fine aggregate to prepare the concrete mix. It should be seen that the fine aggregates used should be free from silt, clay, and other impurities. The sand used is passed from 4.75 mm sieve and retained on 75 micron sieve. The sand used follow IS code 383-1970.

Table 3. Particle Size Distribution in Concrete of Different Materials:

Coarse Aggregates	20mm & 10mm
Fine Aggregates	<4.75mm
Glass Powder	<75μ
Cement	As obtained
Fly ash	As obtained (8-14 μ meter)

2.1.6 Water: The water used for mixing purpose is potable water of good quality. It should be free from an Impurities.

Mix Design M25 Some Basic Assumptions and Calculations:

- Water to cement Ratio adopted based on trial and error – 0.369 (0.55 max)
- Water content for 50mm slump based on w/c ratio – 186 Kg for 20 mm aggregates
- Water content for 150mm slump based on w/c ratio – 213.9 Kg for 20 mm aggregates
- Maximum Cement content – 450 Kg/ m³
- Water to cement ratio is calculated by assuming the exposure condition as ‘Mild’.
- Water to cement ratio is calculated by assuming the maximum size of the aggregate as ‘20 mm’.
- Degree of quality control was also assumed as ‘good’ condition.

2.2 Methodology

Different tests are conducted so as to find mechanical properties of casted concrete. The tests are conducted according to IS 516:1959. Cubes of 150*150*150 mm are casted for finding compressive strength of concrete. Cylinders of diameter 150 mm and height 300 mm are casted to find the split tensile strength of the concrete. Prisms of size 150*150*700 mm are casted so as to find the flexural strength of the concrete. The mix design implemented is M25 with OPC 53 grade cement which follows IS: 10262-2009. As per literatures studied the mechanical properties of concrete are improved only at the Glass powder content of 15-20% in a concrete so glass powder to be used in research work will be 0%,10%, 15%, 20% (Islam et al., 2016). It is to be seen that the Materials are properly sieved to the size needed and the materials should not contain any impurity with in it at the time of casting. The materials to be used are of good quality with proper certifications and should not be the expired one.

Table 4. Shows the Total Amount of Concrete to be Casted and Tested.

Mix	Day	Total no of cubes	Qty of concrete (m ³)	Cement	GP	Fly ash	Steel fibers
CM	Day 1	3	0.010125	100%	0%	0%	0%
GP0	Day 2	3	0.010125	70%	0%	30%	1%
GP10	Day 3	3	0.010125	70%	10%	20%	1%
GP15	Day 4	3	0.010125	70%	15%	15%	1%
GP20	Day 5	3	0.010125	70%	20%	10%	1%
	Total	15	0.050625				

Table 5. Shows the Quantity of all the Materials in a Particular Mix for 1m³ of each mix

All quantities in Kg									
Sr no	Mix	Cement	Fly ash	GP	River Sand	Aggregates		Steel fiber (0.1% by wt of Cement+GP+Fly ash)	Water
						10mm	20mm		
1	C.M	450	0	0	578.91	522.76	589.08	4.498	213.87
2	GP0	315	135	0	578.91	522.76	589.08	4.498	213.87
3	GP10	315	90	45	578.91	522.76	589.08	4.498	213.87
4	GP15	315	67.5	67.5	578.91	522.76	589.08	4.498	213.87
5	GP20	315	45	90	578.91	522.76	589.08	4.498	213.87
Total		1710	337.5	202.5	2894.5	2613.8	2990.4	22.49	1069.3

2.2.1 Compression Test

It is to be seen that the materials are properly batched and mixed by use of mixer or hand mix. The cubes casted of size 150*150*150 mm are placed in UTM (Universal Testing Machine) under a constant certain load. The Load at which concrete cube is cracked is noted and by using formula (P/A) we can find the ultimate compressive strength of the concrete cubes which are casted. The strength of samples are checked at 7 days respectively. For each day of testing 3 cubes are kept in UTM and average strength of 3 cubes are noted as actual compressive strength of concrete. It is calculated as load taken by the concrete specimen per cross-sectional area of the specimen. The Load applied on the Cubes is 140 Kg/cm²/min.

2.2.2 Cost Analysis:-

Table 6. The Cost of Materials

Materials	Cost per Kg
Cement	7
River Sand	2
Aggregates	0.7
Fly ash	1.8
Glass Powder	7
Steel Fibers	50

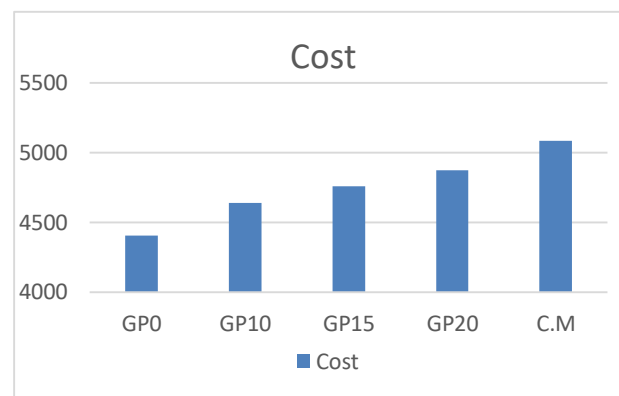


Fig. 3. Graph Showing Variation in Cost of Different Proportions of Concrete based on Cost of Materials

The above graph shows the difference in the cost of different GP proportional concrete. As the GP in a concrete increases the cost of concrete is increased at the same time increase in fly ash content in a concrete decreases the overall cost of concrete.

3. RESULTS AND DISCUSSIONS

Table 7. Shows the Compressive Strength of Concrete

Grade of concrete-M25							
Size of Cubes-0.15*0.15*0.15 m ³							
Mix	Cube No	Weight (Kg)	Crushing Load	7d Strength (N/mm ²)	Average strength (N/mm ²)	Standard Deviation	Coefficient of Variation
GP0	1	8.013	251.5	11.177	11.624	0.4615	0.0397
	2	8.201	262.3	11.657			
	3	8.117	270.9	12.04			
GP10	1	8.059	248.5	11.044	12.002	0.911	0.0759
	2	8.353	289.4	12.862			
	3	8.259	272.3	12.102			
GP15	1	8.468	407.3	18.102	15.619	2.26	0.1446
	2	8.221	305.6	13.582			
	3	8.319	341.4	15.173			
GP20	1	8.383	431.5	19.177	17.53	1.3775	0.0785
	2	8.175	382.3	16.991			
	3	8.223	369.5	16.422			
C.M	1	8.089	321.5	14.288	14.725	1.118	0.0805
	2	8.001	361.4	16.062			
	3	8.163	311.1	13.826			

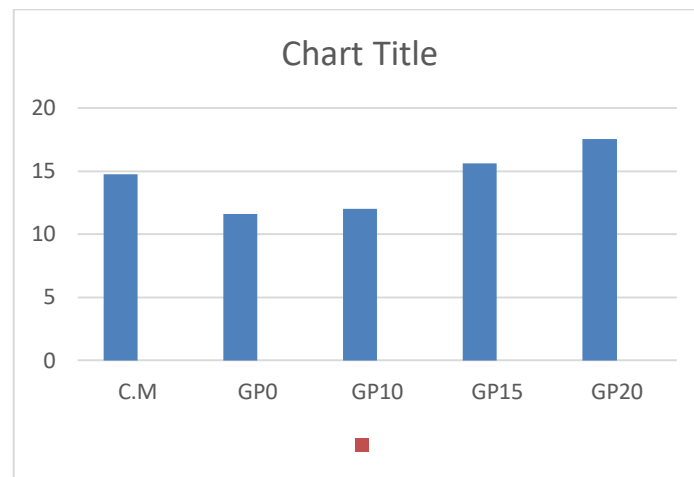


Fig 4. Graph showing Compressive Strength Variation for Different Mixes

As we can see that as we increase the glass powder content in a concrete mix there is increase in compressive strength of concrete. The above graph shows the difference in compressive strength obtained by the different mix proportional concrete. As the GP in concrete is increased the early compressive strength of the concrete is increased. The compressive strength of GP15 and GP20 is estimated to be higher than the control mix as well as we have seen that the cost of GP15 and GP20 is lower as compared to control mix.

4. CONCLUSIONS

Increase in early compressive strength of GP20 concrete mix is due to high glass powder content when compared to other concrete mixes. As the GP in the concrete mix is increased the CS of the concrete is increased. Decrease in early compressive strength of concrete GP10 and GP0 concrete mix is due to high Fly ash content and low GP content. The pozzolanic reaction in fly ash starts slowly, Small FA particles with higher specific surface area and high silica content compared to OPC induces pozzolanic reaction even after few days of casting the concrete which causes an increase in compressive strength even after 7 days. Reduced cost of GP0 concrete is observed due to high fly ash content in concrete. As we can see that the weight of concrete samples is increased per same volume of the sample. The concrete CS is improved with help of GP and SF in it due to proper bonding with the help of steel fibers in it. The use of crimped steel fibers improves bonding and reduces the cracks in concrete.

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