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Strength and Fire resistant properties of the partial replacement of Cement by using glass powder & fly ash in concrete

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ABSTRACT

The sheet glass cutting industries producing waste glass material, which are not recycled at current and usually deliver to landfills for disposal. By using glass powder in concrete as a partial replacement is an interesting possibility for economy on waste disposal sites and conservation of natural resources. The aim of this project work is to use glass powder in the range of 5% to 20% as replacement of cement and concrete cube, cylinder and beam strength compared with conventional concrete cubes, cylinder and beam respectively. In these types of work waste glasses is to be used so the cost will be relatively low when compared with normal concrete. The project work was emphasizing on use of glass materials as partially replacement of cement.

Keywords: Glass powder, fly ash, Fire resistant characteristics.

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INTRODUCTION

Glass is one of the oldest man-made materials. It is produced in many forms such as packaging or container glass, flat glass, and bulb glass, all of which have a limited life in their manufactured forms and therefore need to be recycled so as to be reusable in order to avoid environmental problems that would be created if they were to be stockpiled or sent to landfills. The construction industry has shown great gains in the recycling of industrial by-products and waste, including waste glass materials. Quantities of waste glass, fly ash have been rising rapidly during the recent decades due to the high increase in industrialization and the considerable improvement in the standards of living, but unfortunately, the majority of these waste quantities are not being recycled but rather abandoned causing certain serious problems such as the waste of natural resources and environmental pollution. Recycling of this waste by converting it to aggregate and cement components could save landfill space and also reduce the demand for extraction of natural raw material for construction activities. The ultimate aim of this effort is to ascertain the performance of concrete containing glass powder and fly ash and compare it with the performance of the conventional concretes.

Since the demand in the concrete manufacturing is increasing day by day, the utilization of river sand as fine aggregate leads to exploitation of natural resources, lowering

of water table, sinking of the bridge piers, etc as a common treat. Attempts has been made in using crushed glass as fine aggregate in the replacement of river sand. The crushed glass was also used as coarse aggregate in concrete production but due to its flat and elongated nature which enhances the decrease in the workability and attributed the drop in compressive strength.

A major concern regarding the use of glass in concrete is the chemical reaction that takes place between the silca – rich glass particle and the alkali in pore solution of concrete, which is called Alkali – Silicate reaction can be very detrimental to the stability of concrete, unless appropriate precautions are taken to minimize its effects. ASR can be prevented or reduced by adding mineral admixtures in the concrete mixture, common mineral admixtures used to minimize ASR are pulverized fuel ash (PFA), silica fume(SF) and metkaolin (MK).A number of studies have proven the suppressing ability of these materials on ASR. A high amount of waste glass as aggregate is known to decrease the concrete unit weight. The fact that glass has a high silica content has led to laboratory studies on its feasibility as a raw material in cement manufacture. The use of finely divided glass powder as a cement replacement material has yielded positive results, Optimal dosage range of this glass powder is chosen based on cement paste studies.

SIGNIFICANCE OF THE WORK

The use of recycled glass as aggregate greatly enhances the aesthetic appeal of the concrete. Recent research findings have shown that concrete made with recycled glass aggregate have shown better long term strength and better thermal insulation due to its better thermal properties of the glass aggregates. When tested for the compressive strength values at the 10 %, 40%, and 60 % aggregate replacement by waste glass with 0 – 10mm particle size were 3%, 8% and 5% above the value of conventional concrete. It has been concluded that 30%glass powder could be incorporated as cement replacement in concrete without any long-term detrimental effects. Upto 50% of both fine and coarse aggregate could also be replaced in concrete of 32 MPa strength grade with acceptable strength development properties. Better results are achieved when the waste glass powder replaced either 30 % or 70% of the sand with particles sizes ranging between 50 μm and 100 μm. Used glass waste, which is cylindrical in shape prevents crack propagation in concrete structures. From the research carried out on glass powder by the authors, it was found that glass of particle size 1.18 to 2.36 mm produced the highest expansion where as low expansion was observed at smaller particle sizes. It was observed that with a 30% replacement of cement by amber waste glass content of particle size 75μm along with fly ash, the compressive strength of concrete increase 25% at 7 days and 35% when tested for 28 days strength. This effect provide ample evidence that both fly ash and waste glass sand can be used together to produce concretes with relative high strength without any adverse reaction. Particle sizes under that threshold had no effect on length variations. Glass was ground to a particle size of 300 or smaller, the alkali reaction (ASR) induced expansion could be reduced.

The tensile and flexural strength are adversely affected by the addition on waste to replace the virgin aggregate, at a replacement level of 30 % for the fine aggregate, the tensile strength decreased by 3%, in comparison to the control conventional concrete.

EXPERIMENTAL INVESTIGATION

Experiment were conducted on concrete prepared bypartial replacement of cement by waste glass powder of particle size 75µm.The the waste glass powder was replaced by 10%, 20%, 30% and 40% of the binder and the mix design was prepared. The physical and chemical characteristic was studied and the chemical components of the glass powder used in the concrete were also determined.

Conventional concrete of M25 grade was used in this investigation using glass fiber as reinforcement with varying percentages of 0 to 1.5. The basic materials were tested to evaluate their properties. The rheological properties such as slump (Fig. 1) and compaction factor were studied. Control specimens such as cubes, cylinders, prisms were cast and tested at 7 and 28 days to determine the mechanical properties.

MATERIALS USED

Cement, water and Aggregates: Concrete is prepared by mixing various constituents like cement, aggregates, water etc. which are economically available. Ordinary Portland cement of 43 grade conforming to IS 8112 was used throughout the work. The fine aggregate used in this investigation was clean river sand, whose maximum size is 4.75 mm, conforming to grading zone II. Machine crushed blue granite stone angular in shape was used as coarse aggregate. Two size of coarse is used; one 16 mm passing through 12.5 mm retained and other 25 mm passing through 20mm retained. As per IS: 2386 – 1963 recommendations the following properties of coarse aggregates were determined.

Glass powder: Waste glass available locally in Pondicherry shops is been collected and made into glass powder. Glass waste is very hard material. Before adding glass powder in the concrete it has to be powdered to desired size. In this studies glass powder ground in ball/ pulverizer for a period of 30 to 6o minutes resulted in particle sizes less than size 150 µm and sieved in 75 µm.

TABLE 1: Physical properties of glass powder

S.No	Properties	VALUES
1	Specific gravity	2.6
2	Fineness Passing 150µm	99.5
3	Fineness Passing 90µm	98

Issue 6, Vol. 6 (November 2016)
ISSN 2249-6149

TABLE 2: Chemical properties of glass powder

S.No	Properties	VALUES
1	ph	10.25
2	Colour	Grayish white

TABLE 3: Chemical Composition of glass powder

S.No	Properties	Values
1	SiO2	67.330
2	Al2O3	2.620
3	Fe2O3	1.420
4	TiO2	0.157
5	CaO	12.450
6	MgO	2.738
7	Na2O	12.050
8	K2O	0.638
9	ZrO2	0.019
10	ZnO	0.008
11	SrO	0.016
12	P2O5	0.051
13	NiO	0.014
14	CuO	0.009
15	Cr2O3	0.022

Issue 6, Vol. 6 (November 2016)
ISSN 2249-6149

TABLE 4: Physical properties of Fly ash

S.No	Characteristics	Requirements
1	Fineness	320 m^2 /Kg
2	Soundness	0.8mm
3	Colour	Grey

TABLE 5: Chemical Composition of Fly ash

S.No.	Characteristics	Requirements	
		Siliceous	Calcareous
1	SiO2+Al2O3+Fe2O3	70	50
2	MgO	5.0	5.0
3	SO3	3.0	3.0
4	Na2O	1.5	1.5
5	Total Chloride	0.05	0.05
6	Loss on Ignition	5.0	5.0
7	Reactive Silica	20	20

SPECIMENS TESTING:

Mix Proportion:

M-25 grade is taken for the 3 testing specimen having cement content 355.7 kg/m and w/c ratio 0.47. As per IS code 10262-2009, the mix proportion of testing specimen was found

Issue 6, Vol. 6 (November 2016)
ISSN 2249-6149

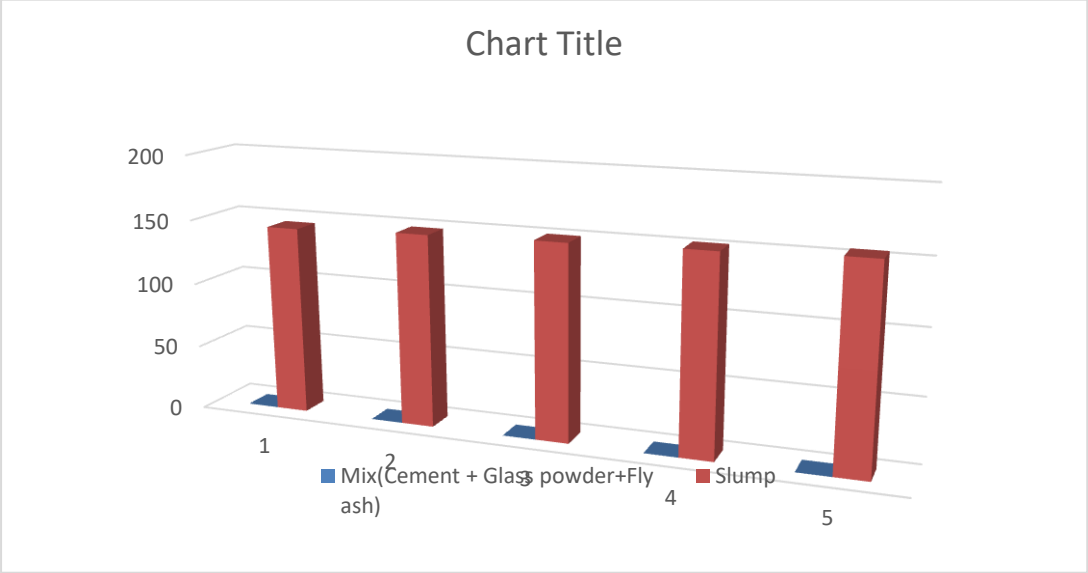
out as 1:2.48:3.04(cement: FA: CA). The amount of cement replaced by the glass powder was 10%, 15% & 20% and the amount of fly ash was maintained constant,that is, 15%.

Workability Test:

Workability indicates theease with which a concrete can be mixed, transported, placed and finished without segregation. The workability of green concrete was measured by means of slump test as per IS Code 1199-1989. In the work, at different proportion of glass powder replacement different values of slump was obtained.

TABLE 6:

S.No	Mix (Cement + Glass powder+Fly ash)	Slump (mm)
1	(100+0+0)	145
2	(80+5+15)	148
3	(75+10+15)	150
4	(70+15+15)	152
5	(65+20+15)	155



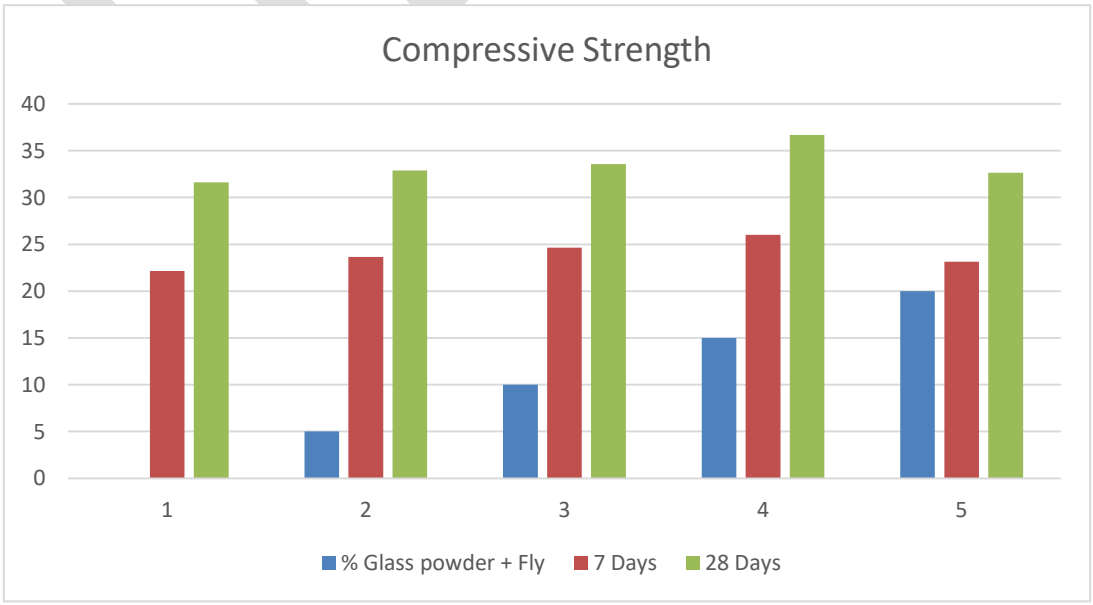
Issue 6, Vol. 6 (November 2016)
ISSN 2249-6149

Compressive Strength Test:

Compressive strength test is done to ensure the strength of the concrete specimen. The strength ofconcrete indicates its load bearing capacity without failure. In our work, we have calculated strength of M-25 grade of concrete after 3, 7, and 28 days.

TABLE 7: Compressive Strength Test

S.No.	% Glass powder + Fly ash	Compressive strength	
		7 Days	28 Days
1	0	22.15	31.63
2	5+15	23.65	32.89
3	10+15	24.65	33.58
4	15+15	26.01	36.69
5	20+15	23.15	32.65

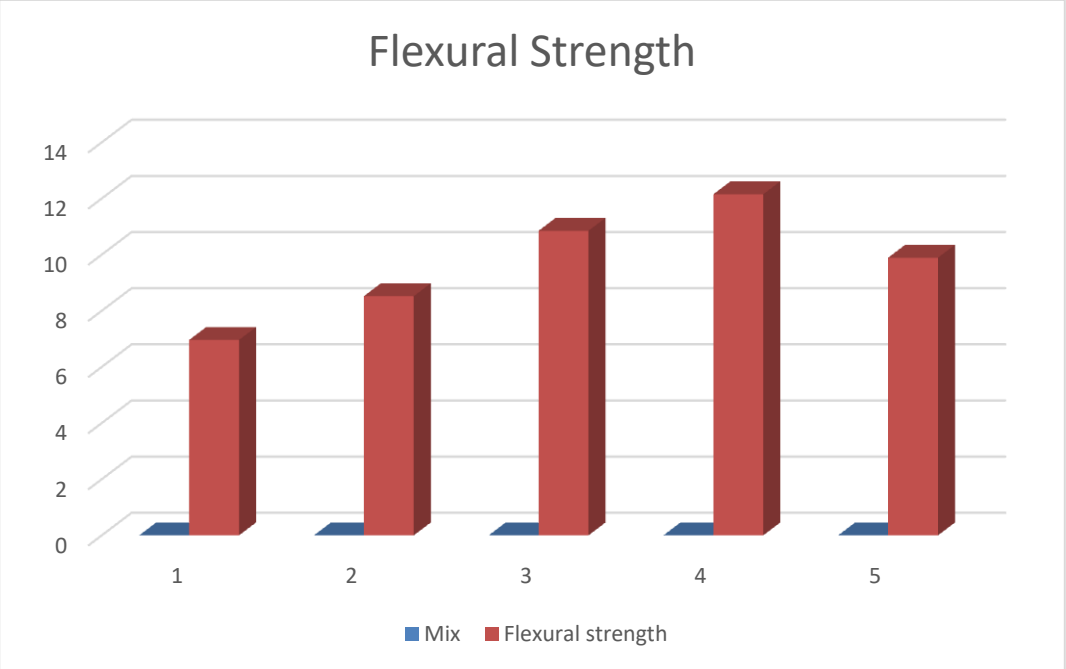


Issue 6, Vol. 6 (November 2016)
ISSN 2249-6149

Flexural Strength

TABLE 8: Flexural Strength

S.No	Mix (Cement+Glass Powder+Flyash)	Flexural strength (N/mm^2)
1	(100+0+0)	6.96
2	(80+5+15)	8.52
3	(75+10+15)	10.85
4	(70+15+15)	12.15
5	(65+20+15)	9.89



Issue 6, Vol. 6 (November 2016)
ISSN 2249-6149

Split Tensile Strength

Table 9: Split Tensile Strength

S.No	Mix (Cement+Glass Powder+Flyash)	Split tensile strength (N/mm^2)
1	(100+0+0)	3.58
2	(80+5+15)	4.01
3	(75+10+15)	4.53
4	(70+15+15)	4.26
5	(65+20+15)	4.05

Issue 6, Vol. 6 (November 2016)
ISSN 2249-6149

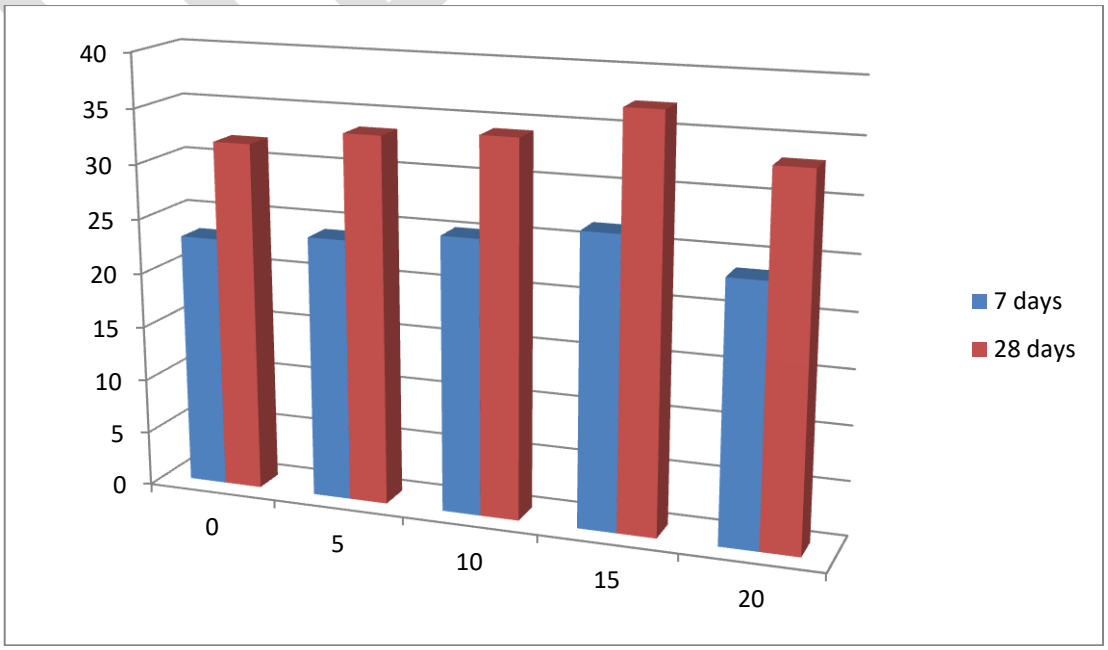
FIRE RESISTANT TEST

The concrete cubes were subjected to elevated temperature of 300□C for two hours duration. Afterwards they were tested under Compression Testing Machine to determine their residual strength as, generally, the compressive strength of the concrete will be reduced afterit is heated. The objective of this study here is to determine whether the glass fibre concrete is highly resistant to fire as compared to conventional concrete.

TABLE 8: Results of strength testing of concrete

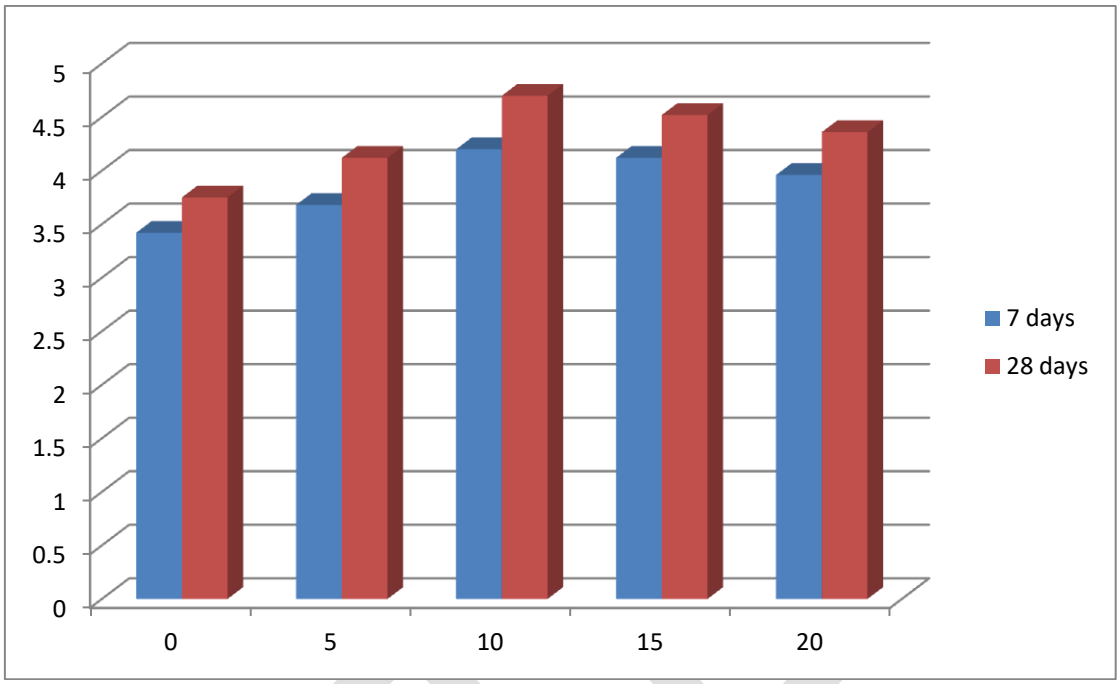
Percentage addition of powder	Strength (MPa)					
	7 days			28 days		
	Compressive	Split tensile	Flexural	Compressive	Split tensile	Flexural
0	23.10	3.42	6.68	31.98	3.75	7.26
5	24.01	3.68	8.54	33.52	4.12	8.94
10	25.15	4.2	10.35	34.15	4.7	11.23
15	26.57	4.12	11.85	37.25	4.52	12.37
20	23.65	3.96	9.25	33.24	4.36	10.15

Compressive Strength

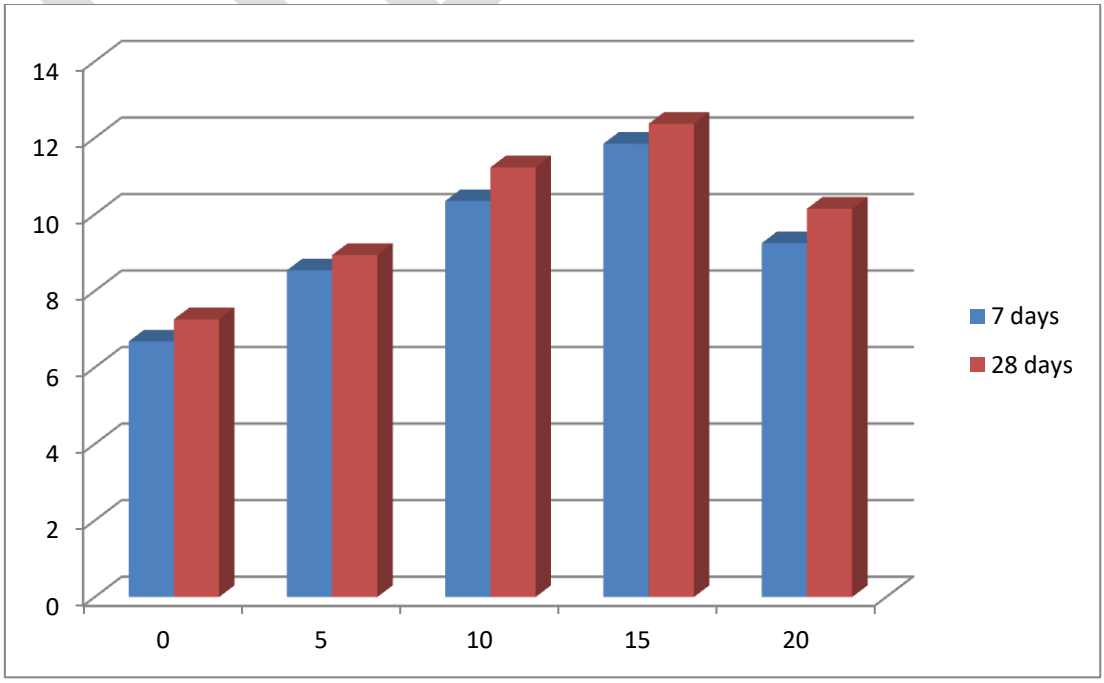


Issue 6, Vol. 6 (November 2016)
ISSN 2249-6149

Split Tensile Strength



Flexural Strength



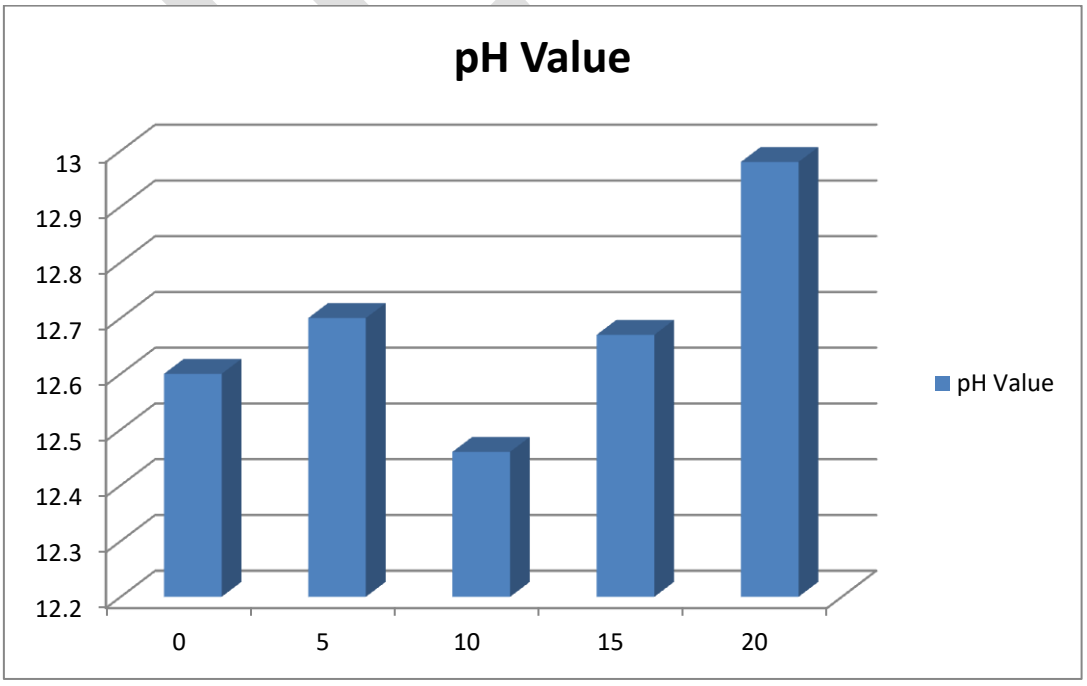
Issue 6, Vol. 6 (November 2016)
ISSN 2249-6149

Alkalinity test:

After 28 days curing the specimen are taken out from curing tank. Specimens are dried in oven at 105°C for 24 hours the dry specimens are cooled to room temperature. Dry specimens are broken and separated the mortar from the concrete. Then the mortar is grinded into powder form. The powdered mortar is sieved in 150µ. 10 gm of mortar is taken and it is diluted in 50ml distilled water and completely stirred it. Then the pH meter immerse into the solution and pH value of the solution is noted. The general pH value of the solution and the level of inducing corrosion in the concrete was noted.

TABLE 9: The Alkalinity test values for glass powder added concrete

% Replacement of Glass powder in concrete	pH Value
0	12.6
5	12.7
10	12.46
15	12.67
20	12.98



RESULT AND DISCUSSION

The compressive strength test on both conventional and glass added concrete was performed on standard compression testing machine of 3000kN capacity. Totally 30 numbers of cubical specimens of size 100mm X100mmX100mm, and 30 number of cylinder was casted and tested for the compressive strength at the age of 28 days and 60 days. Each of the compressive strength test data corresponds to the mean value of the compressive strength of three cubes. At 28 days the glass powder shows a strength of 41.96N/mm2, strength at 30% cement replacement, at 28 days but mean while in 60 days it shows strength at 40% 0f 3.55N/mm2. The flexural strength of glass powder added concrete at the age of 28 days and 60 days. At 28 days, in 10% replacement the strength has been increased to 6.5N/mm2, which is gained at 30% at 60 days itself and goes higher to 7.01N/mm2 in 40 %.The pH value observed from the alkalinity test showed that the specimen tested found to be more alkaline and hence more resistant towards corrosion.

CONCLUSION

Conventional concrete shows at 28 days compressive strength as 31.1 N/mm2, split tensile strength of 2.27N/mm2 and flexural strength of 3.25N/mm^2

- ✓ Replacement of glass powder in cement by 0%, 5%, 10%, 15% and 20% increases the compressive strength by 19.6%, 25.3% and 33.7% respectively.
- ✓ Replacement of glass powder in cement by 20% increases the split tensile strength by 4.4% respectively
- ✓ Replacement of glass powder in cement by 5%, 10% and 15% increases the flexural strength by 83.07%, 99.07% and 100% respectively.
- ✓ Glass powder concrete increases the compressive, tensile and flexural strength effectively, when compared with conventional concrete.
- ✓ Very finely ground glass has been shown to be excellent filler and may have sufficient pozzolanic properties to serve as partial cement replacement, the effect of ASR appear to be reduced with finer glass particles, with replacement level.
- ✓ The percentage decrease in 28 days strength of concrete by replacement of cement with 5% glass powder is only about 9%.
- ✓ The percentage decrease in 28 days strength of concrete by replacement of cement with 10% glass powder is only about 2.33%.
- ✓ It is clear that about 15% of cement replacement by fine glass powder provide the most optimal strength results because with this replacement the decrease in strength is less than 1.78%.

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