Experimental Study on use of Waste Glass as Admixture in Concrete

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Abstract— Glass is utilized as a part of numerous structures in everyday life. It has restricted life and after use it is either stock heaped or sent to landfills. Since glass is non-biodegradable, landfills don't give a situation well-disposed arrangement. Thus, there is solid need to use waste glasses. Many efforts has already been made in concrete engineering as a partial replacement of cement or fine aggregate or coarse aggregate. In this experiment we use waste glass powder as a partial replacement of cement and a comparative study has been made with other admixture such as fly ash and silica fume. A series of test were conducted with partial replacement of glass by 15% and 30% to weight of cement where as we have used only 15% of partial replacement in case of fly ash and silica fume just to compare the results with glass at 15% and 30%. The present study demonstrates that waste glass, if ground finer than 100µm demonstrates a pozzolanic conduct. It responds with lime at early time phase of hydration forming extra CSH gel along these lines shaping denser bond matrix. The early utilization of alkalis by glass particles moderate alkali silica reaction consequently expands durability of cement.

Key words: Glass Concrete; Use of Waste Glass in Concrete

I. INTRODUCTION

The construction with new and waste materials now a days is on increasing demand. As in increasing demand of construction the basic needs in development of civil engineering also kept as on keen demand. The substitutions in concrete material have already studied early with different types of low weight aggregates or heavy weight aggregates or admixtures. But in this case we use glass powder as a partial replacement in cement which works out as an admixture

Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. The key factor that adds strength to concrete is cement to overcome harshest environments plays a significant role. The global warming has become the major role to be reduced in society because of various defects on health and other aspects. The major gas in global warming is carbon dioxide and concrete constitutes more than 20% of carbon dioxide in over all percentage. Mundanely glass does not harm the environment in any way because it does not give off pollutants, but it can harm humans as well as animals, if not dealt conscientiously and it is less cordial to environment because it is non-biodegradable. Thus, the development of incipient technologies has been required. The main constituent of glass is silicon sand.

The different types of glass powder have been widely used in cement and aggregate mixture as pozzolana (i.e., admixture). The use of broken or waste glass in concrete as an admixture implies in increase of alkali content in the cement.

A. Properties of glass:

The following properties have been observed in glass Broken glass has good refractive index when compare to other admixtures like surkhi or rice husk ash and also behaves like a perfectly elastic material. The following image shows the characteristic of glass under application of load

Property	English Units	SI Metric Units	Alternate Metric Units
Refractive Index		1.50-1.58	
Surface Reflectance (visible)		4% (each surface)	
Softening Point	1330°F-1345°F	993 K-1003 K	720°-730°C
Thermal Conductivity	0.52-0.57 Btu / hr.ft.F	0.9-1.0 W / m.K	0.77-0.85 kcal / hr.m.°C
Coefficient of Linear Expansion (room temp. to 350°C/660°F)	4.7-5.0 x 10^{-6} / °F	8.5-9.0 x 10^{-6} / K	4.7-5.0 x 10^{-6} / °C
Hardness (Mohs Scale)		4.5-6.0	
Density	156 lb/ft³	2500 kg/m³	2.5 g/cm³
Young's Modulus	10.4 x 10^6 psi	71.7 Gpa	7310 kg/mm²
Poisson's Ratio		0.23	
Specific Heat (0-1000C or 32°F-212°F)	0.20 Btu/lb.°F	840 J/kg.k	0.20 cal/g.°C
Weather Resistance		Excellent	

Fig. 1:

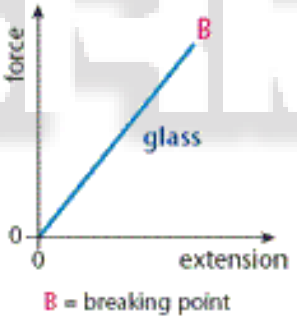

Fig. 2:

From above figure we can see that whenever the load is acted upon glass to generate stresses which are directly proportional to strain i.e., the force implied is directly proportional to the extension in glass till it reaches breaking point.

An ordinary glass consists of materials like lead, boron, barium, oxides and manganese etc. Which influence various other properties because of which it is preferred as a building material.

Substance	Property
Lead	Brilliance and weight
Boron	Thermal and Electrical resistance
Barium	Refractive index
Cerium	Absorb infrared rays
Metallic oxides	Impart Colour
Manganese	Decolorizing

Table 1:

B. Advantages of broken glass as building material:

- It helps in bricks and ceramic industries during manufacturing and preserves its raw material which in turn implies decrease in energy consumption and reduces the volume of wastage which is sent to landfill
- As an important recycled material, glass powder or glass fiber are also used in many civil engineering fields for example it is used in concrete as an admixture which influences various strength property at the same time it is also used as glass fiber in reinforced concrete which increases tensile strength
- The glass powder is used as construction material to decrease environmental problems (i.e., reduction of Co2 from concrete)

C. Scope of work:

We aim following scope of work for this research program

1) To comparative study on strength of concrete when different admixtures such as waste glass powder with fly ash and silica fume
2) To evaluate the property of recyclability of waste glass powder in concrete

D. Experimental Program:

Total 20 cubes were casted to test for 14 days and 28 days strength in concrete

Four cubes are control cubes (i.e., without any admixture)

Four cubes are casted with partial replacement of fly ash (i.e., 15% to weight of cement)

Four cubes are casted with partial replacement of silica fume (i.e., 15% to weight of cement)

Eight cubes are casted with partial replacement of broken glass powder (i.e., 2 with 15% to weight of cement and 2 with 30% to weight of cement)

E. Materials:

The materials used in this experiment are cement, admixtures (fly ash, silica fume), broken glass, and fine aggregate and coarse aggregate.

F. Cement:

Cement is used as binding material in concrete which also imparts strength in concrete. The cement used in this experiment is 53 grade which is brought from local store and specific gravity is found out to be 3.15

G. Fine aggregate:

Locally available fine aggregate which passes through 4.75 mm IS sieve is used in experiment, about 27% of sand is retained on 2.36 mm IS sieve . This also reduces shrinkage in concrete which is having a specific gravity of 2.5.

H. Coarse aggregate:

Crushed gravel is used in this experimental program. Coarse aggregates occupy more portion of any other raw material in concrete. The maximum size of aggregate used in this experiment is 20 mm which is having a specific gravity of 2.9.

I. Glass powder:

Waste glass is collected from landfills and some are brought from local market and then crushed to form powder and crystalline.

J. Silica Fume:

Silica fume is a non crystalline polymorph of silica dioxide which is also brought from local market

The following properties are observed in silica fume.

Property	**Silica Fume**	
	ASTM C618	**Actual analysis**
SiO_2 content (%)	85–97	87
CaO content (%)	< 1	0.9
Specific surface (m^2/kg)	15,000–30,000	17,275
Specific gravity	2.22	2.22
Bulk Density	550 to 700	650
General use in concrete	Property enhancer	

Table 2:

K. Fly ash:

Fly ash is also known as pulverised fuel ash, is one of the residues generated by coal combustion, and is composed of the fine particles that are driven out of the boiler with the flue gases. This is also brought from local market. Class F fly ash is used in this experiment which is having the following chemical components.

Component	**ASTM**
SiO_2 (%)	20-60
Al_2O_3 (%)	5-35
Fe_2O_3 (%)	10-40
CaO (%)	1-12
LOI (%)	0-15

Table 3:

The following properties are observed in fly ash to use in experiment

Property	**Analysis**
Bulk density	994
Specific gravity	2.88
Moisture (%)	3.14
Average particle size	6.92 μm

Table 4:

L. Standard Consistency test:

Standard consistency test is conformed to an instrument name as Vicat's apparatus. This is one of the important tests, based upon the standard consistency of cement future test such as initial setting time, workability, compressive strength of cement and mix proportions are designed.

M. Procedure:

- Firstly 300 gm of cement is taken in a pan
- A known percentage of water say 26% with weight of cement is added and mixes thoroughly to get cement slurry
- Now cement slurry is poured in vicats mould and shake the mould with hand to compact and penetrate needle.

- Repeat the experiment with different percentage of water (say 28, 30, 32 and so on) till u reach a penetration of 15mm.

Fig. 3: Vicat Apparatus

N. Compressive Strength test:

With help of consistencies and specific gravity of element the mix proportion for M20 grade concrete is obtained as 1:1.95:3.72:0.5. The mix proportions are designed based upon the method followed in IS: 10262 2009.

As already discussed total 20 cubes are casted to check compressive strength of concrete

O. Casting of cubes:

The cubes are casted with mix proportions with different percentages of admixtures (say 0%, 15% and 30%) as already discussed. The size of mould is 15x15x15 cm which is used to cast concrete cubes. While casting of cube the concrete slurry in mould is compacted properly to achieve greater strengths.

P. Curing:

After 24 hrs of casting of cubes, the cubes are removed from mould. Then they are placed in water to cure. The heat liberated during the process of hydration requires cooling down. That is why the concrete cubes are cured at a room temperature of 27 ^{o}c. The cubes are cured for 14 and 28 days.

After cuing, the concrete moulds are directly tested in universal testing machine to get compressive strength of concrete block.

Fig. 4: Hairline Cracks in Concrete Block

Q. Capillary absorption test:

Capillary absorption test is conducted to check the durability of concrete blocks after they are cured for 14 and 28 days. Same sample of two cubes are retained for capillary absorption test (i.e., 2 control concrete, 2 cubes with 15% of fly ash to weight of cement, 2 cubes with 15% of silica fume to weight of cement, 2 cubes with 15% of glass powder to weight of cement, 2 cubes with 30% of glass powder to weight of cement). The process includes

- The concrete block is boiled at a temperature of 100 ^{o}c
- The sample is cooled for half day with desiccators such that there should not be any moisture losses
- Then the sample cube is coated with paraffin and exposed to water filled in pan such that the base of sample should immersed in water about 5mm
- The weight of sample is measured at 15 and 30 min
- The capillary absorption coefficient K is given by
- $K=Q/Axt^{2}$

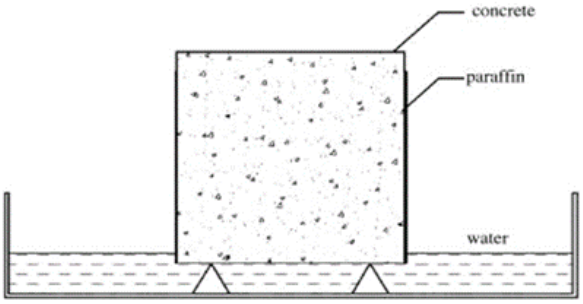

Fig. 5: Capillary Absorption Equipment Setup

R. Results:

1) Consistency of Cement:

The Normal consistency for different mixes and different weight proportions are shown below

Mix	Description	Cement (gm)	Fly Ash (gm)	Silica Fume (gm)	Glass (gm)	Consistency (%)
NC	Control Concrete	300	0	0	0	32
CF	Concrete with 15% Fly Ash	255	45	0	0	36
CS	Concrete with 15% Silica Fume	255	0	45	0	38
CG 1	Concrete with 15% Glass powder	255	0	0	45	38
CG 2	Concrete with 30% Glass powder	210	0	0	90	40

Table 5:

S. Compressive Strength:

The concrete after 14 days and 28 days curing are tested for compressive strength. Total 10 cubes are tested for compressive strength and there results are shown below

Mix	Description	14 days	28 days
NC	Control Concrete	16.22	22.12
CF	Concrete with 15% Fly Ash	14.81	21.42
CS	Concrete with 15% Silica Fume	13.38	18.06
CG 1	Concrete with 15% Glass powder	13.47	19.32
CG 2	Concrete with 30% Glass powder	12.72	18.57

Table 6:

The chart for compressive strength of concrete with different mixes is shown below

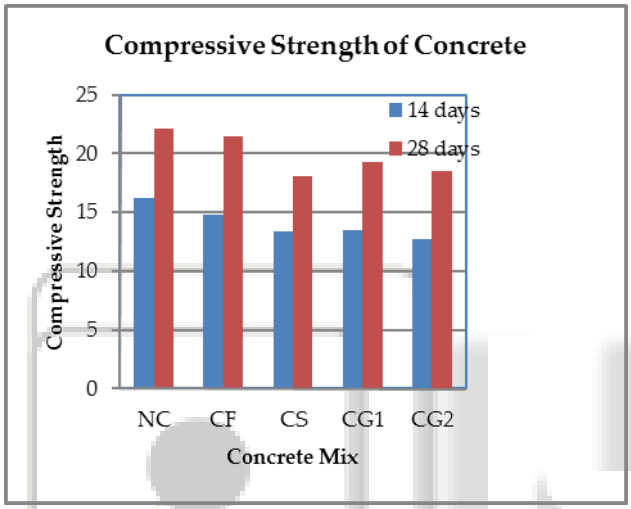

Fig. 6: Compressive Strenght of Concrete

T. Glass powder Vs Fly Ash:

The sample cube data which obtained from compressive strength of concrete for fly ash and glass powder as an partial replacement in concrete is achieved and a chart is plotted between them

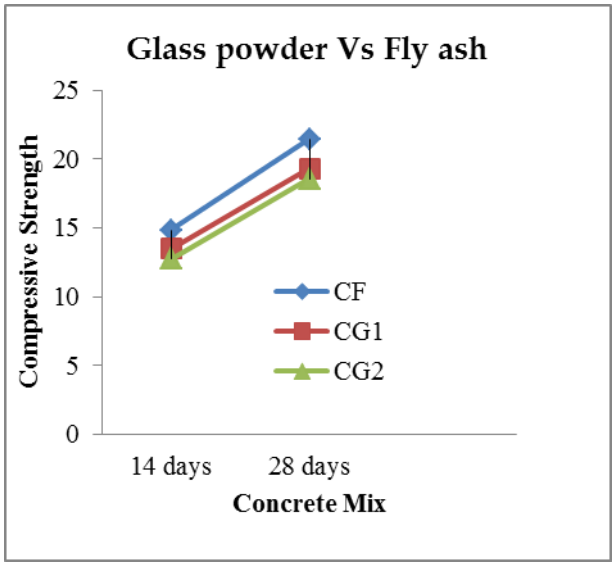

Fig. 7: Glass Powder VS Fly Ash

From above chart it can be seen that the compressive strength of concrete with fly ash attains more strength than concrete with 15% and 30 % of glass powder as an partial replacement in concrete

Glass powder Vs Silica fume:-

Similarly the values of compressive strength for silica fume and glass powder are pick up and compared

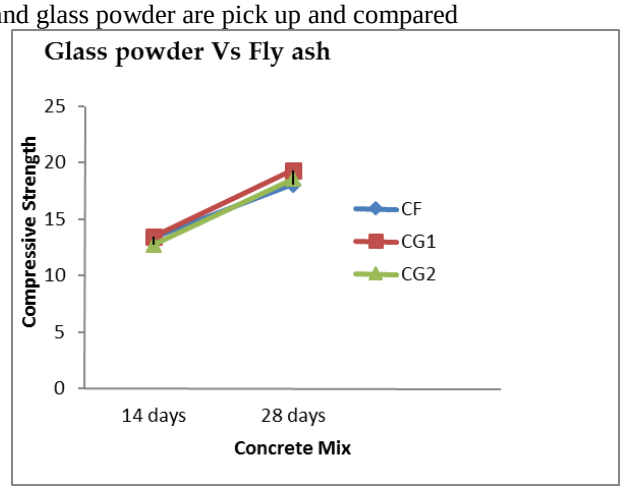

Fig. 8: Glass Powder VS Fly Ash

U. Capillary absorption test:

Mix	28 days ($k*10^{-3}$ cm/s)	28 days ($k*10^{-3}$ cm/s)
NC	3.15	2.78
CF	1.47	1.35
CS	1.32	1.16
CG 1	2.81	2.14
CG 2	1.64	1.44

The information demonstrates that fine retention lessens because of expansion of silica fume as they demonstrate like fillers and pozzolanic reactions frame an additional gel which makes bond cement framework more denser .The k quality is mostly reduced for silica fume concrete. The glass powder concrete CG2 has lower k value, indicates denser grid development. The mix CG1 has more value of k presumably because of bond failure as a result of alkali-silica reaction. The fly ash concrete shows preferable result over the control concrete NC.

II. Conclusion

The following conclusions are made during the experiment

- The waste glass powder shows pozzolonic behavior
- The fly ash admixture has more compressive strength results than silica fume and glass powder but less than normal concrete
- The replacement of cement with glass powder about 15% shows more strength than 30% replacement of glass powder and silica fume
- The coefficient of capillary shows that the glass powder concrete is durable and also shows that it is more durable than silica fume if used up to 15% partial replacement with cement
- The waste glass is used in the experiment, so the land which is used to landfill will also get reduce
- The content of cement is reduced; hence co2 liberation is also reduced
- The strength for 28 days is less than or nearly equal M20 when 15% glass powder is used, so it is preferable when there is strength is not much contributed.

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