Utilization of Bottle Cap and E-Glass Powder on Partial Coarse and Fine Aggregate Replacement

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Abstract - *Concrete industry is one of the largest consumers of natural resources and now sustainability of concrete industry is under threat. The environmental and economic concern is the biggest challenge concrete industry is now facing. In this research, the issues of environmental and economic concern are addressed by the use of bottle cap and waste e- glass as partial replacement of coarse and fine aggregates in concrete. The acceptance of this waste product by the construction industry is decided depending on the application, keeping in view of the limitations on the mechanical strength. Waste e-glass particles were obtained from electronic grade glass yarn scrap by grinding to small particle size. In general, e-glass mainly consists of SiO_2, Al_2O_3, CaO and MgO. E-glass can be used in concrete as cementitious as well as inert filler depending upon particle size. Due to the strong reaction between the alkali content in cement and the reactive silica in glass, fly ash was incorporated into the glass concrete to control the expansion. Trial mix was conducted to determine the optimum percentage of e-glass and flyash. Then bottle cap was partially replaced by coarse aggregate at 1, 2, 3 and 4%.*

Key Words: **Partial replacement, E-glass, Bottle cap, Flyash**

1. INTRODUCTION

In order to make the concrete industry sustainable, the use of waste materials instead of natural resources is one of the best approaches. Researchers all over the world today are focusing on ways of utilizing all wastes either industrial or agricultural as a source of raw materials for their respective industry. These wastes utilization should not only be economical, but also control the environmental pollution. Over the years, in construction industry, many industrial waste materials and various agricultural wastes have been tried as pozzolan or alternate cementitious materials in cement based products. Addition of different types of materials to concrete in specific percentage improves the mechanical properties, durability and serviceability of the structure. Hence an attempt is made to study the influence of cut bottle caps and e-glass as partial replacement for coarse aggregates and fine aggregates respectively. The major challenge in using glass aggregates as fine aggregate in concrete is the deleterious alkali-silica reaction (ASR). Due to high concentrations of silica these aggregates may react with cement alkalies and produce an ASR gel which, in the presence of moisture, expands and causes cracking and deterioration of concrete [1], [2], [3], [4].

2. RESEARCH SIGNIFICANCE

1. To compare the mechanical properties of partially replaced concrete with that of the conventional concrete.

2. To determine the optimum percentage of e-glass and fly ash by replacing fine aggregate and cement.

3. To improve the strength of concrete by varying percentages of bottle cap

3. METHODOLOGY

1. Mix proportioning of M25 grade mix design with w/c ratio of 0.45

2. Reference specimens like natural aggregate concrete are casted

3. Specimens are casted to determine the optimum percentage of flyash and e-glass by partially replacing cement and fine aggregate at varying percentages as shown in table 1

Table-1: List of mix specimens

Fly ash (%)	E-glass (%)
5	10
	20
	30
10	10
	20
	30
15	10
	20
	30

4. Now replacing the coarse aggregate by bottle cap at 1, 2, 3 and 4 percentages.

4. EXPERIMENTAL INVESTIGATIONS

4.1 Preliminary test on materials

The properties of each materials used in a concrete mix were studied by relevant IS codes as given in table 2. OPC, fine aggregate, coarse aggregate, bottle cap, E-glass and flyash were used in concrete [9], [10], [11], [12], [13],[14].

Table-2: Properties of materials

Sl. No.	Materials	Property details	
1	Cement	Grade Consistency Specific gravity Initial setting time	OPC 53 30% 3.125 30min
2	Fine aggregate	Specific gravity Water absorption Fineness modulus	2.85 2 3.6%
3	Coarse aggregate	Size Specific gravity Water absorption	20mm 2.85 0.25
4	E-glass	Size Specific gravity Fineness modulus	0-1.18mm 3.2 3.71

4.2Test on fresh concrete

1. Workability

Workability of concrete was determined by slump test. The slump test was conducted in accordance with IS 1199-1959 [15]. Slump test is carried out on varying percentage of replacement of coarse aggregate by bottle cap.

2. Fresh density

Fresh density of concrete is calculated as per IS 1199- 1959 [15].

4.3 Test on hardened concrete

1. Compressive Strength Test

As per IS 516-1959 [7], compression test is carried out on specimens cubical or cylindrical in shape. In the test, the compression was carried out on cubes of size 150mmx150mmx150mm. Load is applied gradually at the rate of 14N/mm^2/minute. Values of compressive strength of different varying mixes at 28 days and compressive strength of conventional concrete are given in table 3.Table 4 tabulates compressive strength of cubes at 7,28 and 56 days.

Fig-1: Interface transition zone failure

Table-3: Compressive strength of cube specimens with varying mix proportions

Mix	Avg. Compressive strength(N/mm^2)
NC	44.4
5F-10G	**45.40**
5F-20G	43.5
5F-30G	42.44
10F-10G	43.98
10F-20G	42.29
10F-30G	39.18
15F-10G	40.59
15F-20G	38.8
15F-30G	35

*F- flyash, G- E-glass, number indicates percentage of replacement

Table-4: Compressive strength of cube at the age of 7, 28 and 56 days

Mix	Avg. compressive strength (N/mm²)		
	7days	28days	56 days
NC	24.4	44.4	51.11
FG-1BC	31.11	47.18	55.5
FG-2BC	26.66	44.59	48.88
FG-3BC	23.11	42.29	44.44
FG-4BC	18.66	39.85	40.44

*F- flyash, G- E-glass, BC- Bottle cap, number indicates percentage of replacement.

2. Split Tensile Strength

The test procedure of IS 5816-1959 [8] is followed to determine the split tensile strength on cylindrical specimens of 150mm diameter and 300mm length. It is measured in the compression testing machine by gradually applying load at the rate of 1.4N/mm^2/minute. Cracks formed on cylinder after split tensile test is shown in fig.2. Tensile strength at age of 7, 28 and 56 days is tabulated in table 5.

Fig-2: Cracks formed on cylinder after split tensile test

Table -5: Tensile strength at age of 7, 28 and 56 days

Mix	Avg. tensile strength(N/mm²)		
	7day	28day	56 days
NC	2.19	3.53	3.7
FG-1BC	2.40	3.74	3.85
FG-2BC	2.26	3.67	3.73
FG-3BC	2.05	3.46	3.54
FG-4BC	1.83	3.11	3.20

3. Flexural strength

Test is carried out as per IS 516-1959 [7] on beams of size 100mm x 100mm x 500mm. The bed of testing machine is provided with 2 steel rollers 38mm diameter, on which the specimen is to be supported and these rollers are so mounted that the distance from centre is 40cm.The load is applied at the rate of 0.7N/mm^2/minute until the specimen fails. The three point loading applied on beam is represented in fig 3. Flexural strength at the age of 7, 28 and56 days is represented in table 6.

Fig-3: Application of three point loading on beam

Table-6: Flexural strength at age of 7, 28 and 56 days

Mix	Avg. flexural strength (N/mm²)		
	7day	28day	56 days
NC	2.8	4.6	10.5
FG-1BC	3.4	5.2	12.5
FG-2BC	4.2	5.8	13
FG-3BC	5	7	13.5
FG-4BC	5.8	7.6	14.5

5. RESULTS AND DISCUSSIONS

1. Workability

Workability of concrete mix is given in table 10. Slump variations are shown in chart 1.

Table-10: Slump value (mm)

Mix	Slump(mm)
NC	90
FG-1BC	83.3
FG-2BC	70
FG-3BC	55
FG-4BC	40

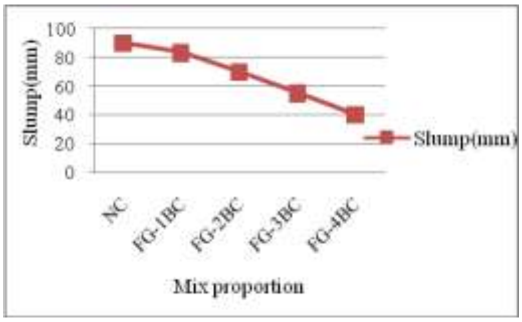

Chart-1: Slump variations (mm)

2. Fresh Density

Fresh density of concrete increases due to the presence of bottle cap and e-glass. Fresh density indicates strength and durability parameters of concrete. Fresh density of concrete mix with various percentage of bottle cap is shown in table 11 and chart 2.

Table- 11: Fresh density (kg/m^3)

Mix	Fresh density(kg/m^3)
NC	2474.07
FG-1BC	2477.037
FG-2BC	2482.96
FG-3BC	2494.81
FG-4BC	2506.66

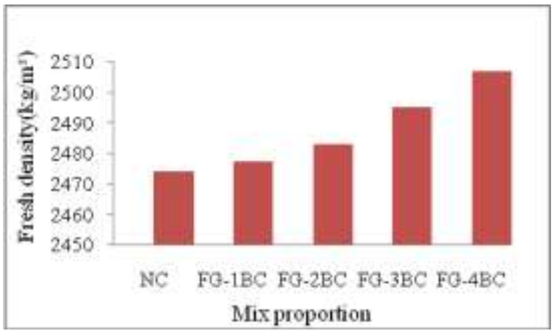

Chart-2: .Fresh density of concrete (kg/m^3)

3. Compressive strength test

From these observations, trial mix with 5% flyash replacing cement and 10% e-glass replacing fine aggregate gives higher strength compared to normal mix. Compressive strength for various mixes at 28th day is shown in chart 3.

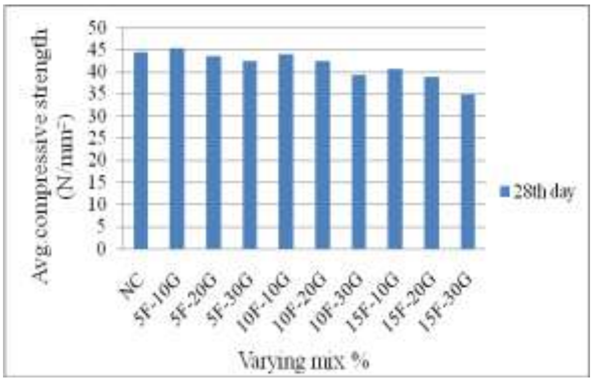

Chart-3: Compressive strength for trial mixes at 28th day

Variation of compressive strength for actual mix proportion at 7th, 28th and 56th day is given in chart 4.

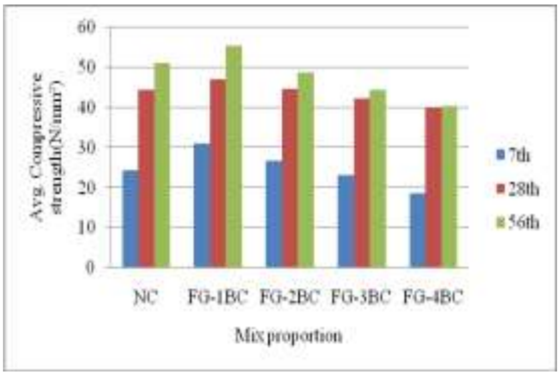

Chart 4: Compressive strength for actual mix proportion

4. Split tensile strength test

The result of split tensile strength is illustrated in chart 5.

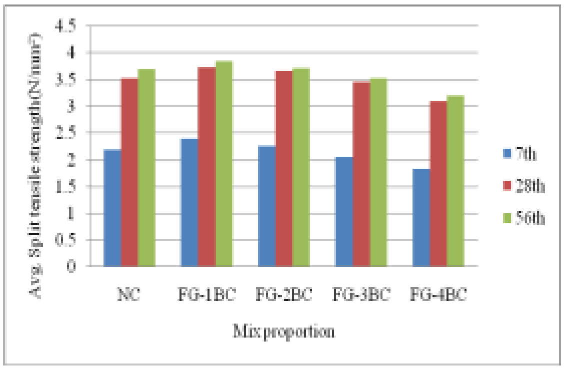

Chart-5: Split tensile strength of cylindrical specimen

5. Flexural strength test

The inclusion of bottle caps increases the resistance to crack propagation. Flexural strength results at 7, 28 and 56 days is shown in chart 6.

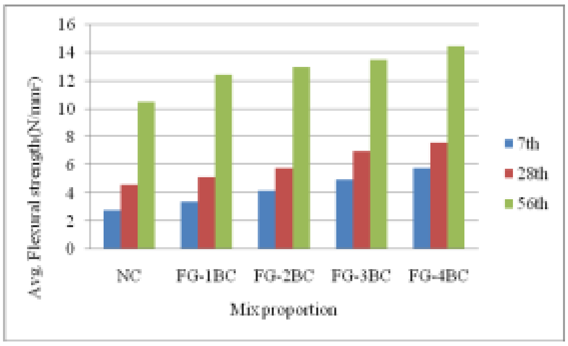

Chart-6: Flexural strength of beam at 7th, 28th and 56th day

5. CONCLUSIONS

1. Addition of e-glass and bottle cap to the concrete decreases the consistency of mix which causes decrease in workability. The reduction in workability is due to reduction in fineness modulus of glass particles and due to poor geometry of glass particles.

2. Fresh density of concrete increases with the addition of bottle cap and e-glass. Fresh density of concrete increases due to reduction of void and better particle packing.

3. During trial mix it is observed that there is an increase in strength with addition of e-glass waste of 10% and fly ash of 5% and beyond which there appears to be no specific enhancement in strength. Replacing fine aggregate by waste e-glass more than 10% reduces the bonding strength between glass aggregates and cement paste.

4. The compressive and split tensile strength of concrete with 10% replacement of fine aggregate by e-glass and 1% replacement of coarse aggregate by bottle cap is higher than control concrete. Only upto1% the mix shows considerable increase in strength as it is a flaky and elongated material. It causes less bonding capacity between the aggregates and paste.

5. Maximum flexural strength is obtained at 4% replacement of coarse aggregate by bottle cap.

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