

# Behavior of Concrete by using Waste Glass Powder and Fly Ash as a Partial Replacement of Cement

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**Abstract:** Using glass in concrete is an interesting possibility for economy on wastage disposals. Glass is an inert material which could be recycled and used many times without changing its chemical property. Glass is an amorphous material with high silica content thus making it potentially pozzolanic when particle size is less than 75  $\mu\text{m}$ . A major concern regarding the use of glass in concrete is the chemical reaction that take place between the silica 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. The inclusion of fly ash in glass concrete reduces the alkali silica reaction and improves the workability and durability properties of concrete waste glass powder used in concrete making leads to green environment.

The objective of present work is to find out effectiveness on durability of waste glass powder and fly ash based concrete. In this investigation it was proposed that the use of glass powder with fly ash as cement replacement material partially in concrete. Cement was partially replaced (10%, 20%, 30%, 40%) with combination of fly ash and glass powder. Compressive strength of cubes and flexural strength of beams at 7 days and 28 days of duration were studied and compared with the conventional concrete. Capillary absorption test on cubes at 28 days of duration were studied and compared with the conventional concrete. The results showed that the possibility of using glass powder with fly ash as a partial replacement of cement in concrete has a considerable amount of increase in durability with increase in percentage.

**Keywords:** Fly Ash, Glass powder, Fly Ash + Glass Powder, Capillary Absorption, Compressive strength, Flexure strength

## I. INTRODUCTION

Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of green house gases, such as  $\text{CO}_2$ , to the atmosphere. Among the greenhouse gases,  $\text{CO}_2$  contributes about 65% of global warming. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to address environmental effects associated with cement manufacturing, there is a need to develop alternative binders to make concrete. Consequently extensive research is on going into the use of cement replacements, using many waste materials and industrial by products [1].

Glass could be used in concrete in three forms; as coarse and fine aggregate, and in powder form. The coarse and fine glass aggregates could cause ASR in concrete, but the glass powder could suppress their ASR tendency, an effect similar to supplementary cementitious materials (SCMs). On a market price basis, it would be much more profitable to use the glass in powder form as a cement replacement material (i.e., as an SCM), than as aggregate. This would be a value-added material, produced from contaminated, mixed-colour glass chips which are not useable for packaging purposes. Although such material could also be used as abrasive grit, although the volume used for this application is not very high compared to that of SCMs.

The susceptibility of glass to alkali implies that coarse glass or glass fibers could undergo ASR in concrete, possibly with deleterious effects. However, it would be expected that fine ground glass (i.e. glass powder), would exhibit pozzolonic properties such as those of the materials named above, and would be an effective ASR-suppressant, preventing ASR damage to concrete in the presence of reactive aggregates.

A major concern regarding the use of glass in concrete is the chemical reaction that takes place between the silica-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 metakaolin(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 [1].

Design professionals often specify prescriptive requirements such as quantities of Class F fly ash, slag, low-alkali cement, the use of a non-reactive aggregate, etc., to avoid ASR-related distress in structures.

Efforts have been made in the concrete industry to use waste glass and fly ash as partial replacement of cement. In this study, finely powdered waste glasses, fly ash and their combination are used as a partial replacement of cement in concrete and compared it with conventional concrete. This work examines the possibility of using Glass powder as a partial replacement of cement for new concrete. Glass powder was partially replaced as 10%, 20%, 30% and 40% and tested for its compressive and flexural strength up to 28 days of age and were compared with those of conventional concrete; from the results obtained, it is found that glass powder can be used as cement replacement material up to particle size less than 75 $\mu$ m to prevent alkali silica reaction.

## II. MATERIALS AND METHODS

### A) Concrete Composition

The main objective of this study is to investigate the effect on the mechanical properties of concrete when OPC is partially replaced by 10%, 20%, 30% and 40% of glass powder, fly-ash and their combinations. Different material and experimental tests are performed to check the quality of concrete. The materials should be suitable for the intended use in concrete and not contain harmful ingredients in such quantities that may be detrimental to the quality or the durability of the concrete.

### B) Cement

The Portland Cement used in present study is Rockstrong Cement of 43 Grade. Portland cement (often referred to as

OPC, from ordinary portland cement) is the most common type of cement in general use around the world because it is a basic ingredient of concrete, mortar, stucco and most non-specialty grout.

### C) Fly Ash

Mineral admixtures like fly ash are usually added to concrete in larger amounts to enhance the workability of fresh concrete; to improve resistance of concrete to thermal cracking, alkali-aggregate expansion, and sulphate attack; and to enable a reduction in cement content.

Class F Fly ash obtained from Century pulp and paper mill, Lalkuan (Uttarakhand state) was used in the present study. Chemical analysis of fly ash is given in Table: 3.5. The fly ash had a relatively low specific gravity and fineness modulus of 1.975 and 1.195 respectively.

### D) Waste Glass Powder

The glass powder (less than 90 micron) used in the present study is brought from Kolkata market. This material replaces the cement in mix proportion. Theoretically, glass is a fully recyclable material; it can be recycled without any loss of quality. There are many examples of successful recycling of waste glass: as a cullet in glass production, as raw material for the production of abrasives, in sand-blasting, as a pozzolanic additive, in road beds, pavement and parking lots, as raw materials to produce glass pellets or beads used in reflective paint for highways, to produce fibre glass, and as fractionators for lighting matches and firing ammunition.

## III. TESTING METHODOLOGY

### A) Capillary Absorption test

This test is conducted to measure the capillary absorption which indirectly measures the durability. This test method is under the jurisdiction of ASTM Committee C09



Fig. 1 Capillary Absorption Test

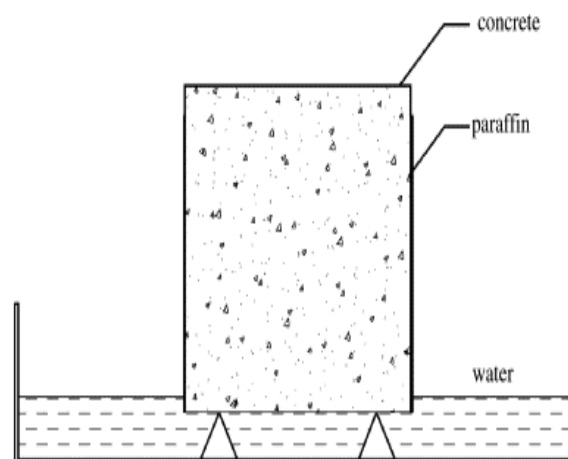


Fig. 2 Capillary Absorption Test

### Procedure:

- The sample was dried in oven at 105°C until constant mass was obtained.
- Sample was cool down to room temperature for 6hr.
- The side of the sample was coated with paraffin to attain unidirectional flow.
- The sample was exposed to water on one side by placing it on a pan filled with the water.

- The water in the pan was kept about 5mm above the base of the specimen as shown in the figure below.
- The weight of the sample was measured at 1, 5, 10, 20, 30, 60 minutes and 2, 3, 4, 5, 6 hour intervals.
- The capillary absorption coefficient (S) was calculated by using formula:

$$S = I/t^{1/2} \quad \text{in mm/s}^{1/2}$$

Where, I= ( $\Delta$  Mass/A) x Density of water, mm

$\Delta$  Mass = amount of water absorbed

A = cross sectional area in contact with water

t = time

#### COMPRESSIVE STRENGTH OF CONCRETE

It is well known that concrete is weak in tension and strong in compression. As a result, the compressive strength of concrete is often considered the most important property of concrete as per IS: 516-1959, and is the most common measure used to evaluate the quality of hardened concrete. Compressive strength can be defined as the load, which causes the failure of a standard specimen (ex 150 mm cube according to ISI) divided by the area of cross-section in uniaxial compression under a given rate of loading. The test of compressive strength should be made on 150 mm size cubes.

#### FLEXURAL STRENGTH

The flexural test measures the force required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material's stiffness when flexed. This test method follows the IS: 516-1959 procedure where the 10x10x50 cm hardened concrete specimen lies on two 40 cm apart supporting spans and the load is applied to the centered by the loading nose producing three points bending at a specified rate till failure.

The formulae used for finding flexural strength is

$$R = 3PL/2BD^2$$

Where

R= modulus of rupture MPa

P= Maximum Applied Load N

L= Span length mm

B= Average Width mm

D= Average Depth mm

#### IV. Results and Discussion

TABLE 1.DIFFERENT TYPES OF MIX USED:

	Mix
	Limit value
M1	Cement
M2	Cement+ 10% fly ash
M3	Cement 10% glass powder
M4	Cement + 5% fly ash+ 5% glass powder
M5	Cement + 20% fly ash
M6	Cement + 20% glass powder
M7	Cement + 10% fly ash+ 10% glass powder
M8	Cement + 30% fly ash
M9	Cement + 30% glass powder
M10	Cement + 15% fly ash+ 15% glass powder
M11	Cement + 40% fly ash
M12	Cement + 40% glass powder
M13	Cement + 20% fly ash+ 20% glass powder

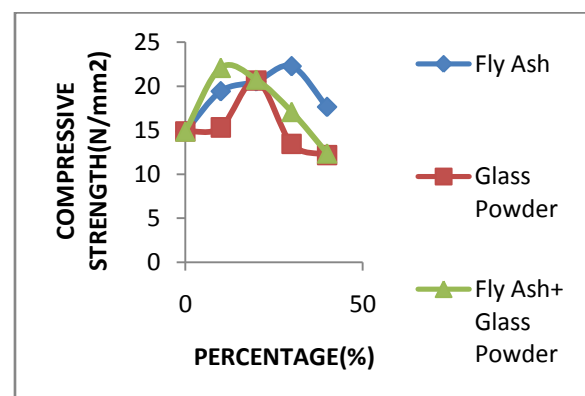


Fig.3 7 Days Compressive Strength

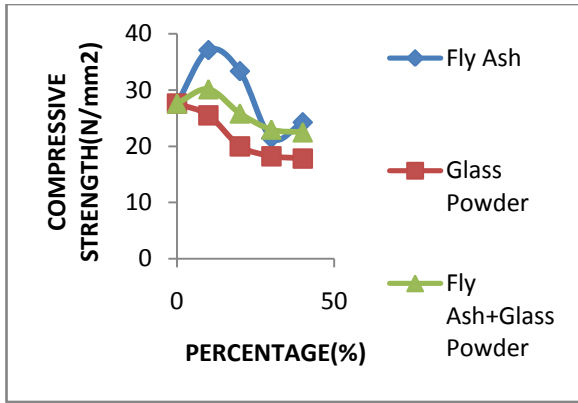


Fig.4 28 Days Compressive Strength

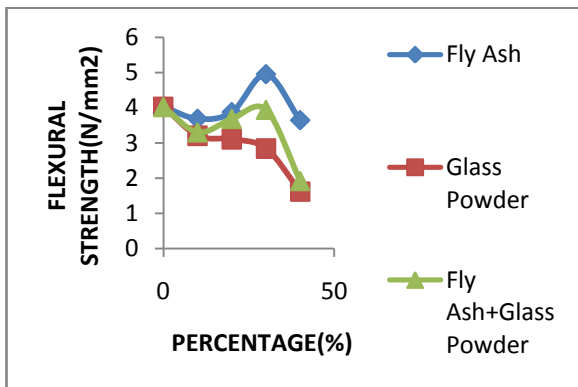


Fig.5. 7 Days Flexural Strength

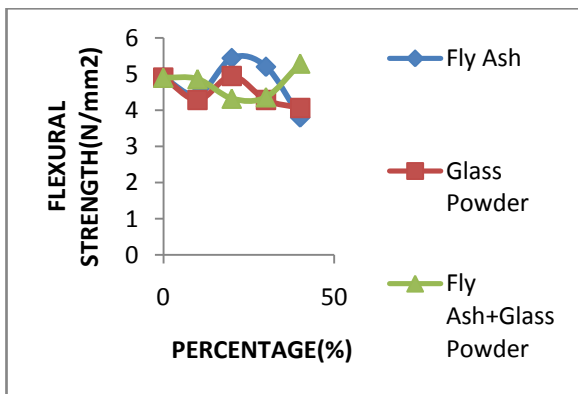


Fig.6. 28 Days Flexural Strength

A) Capillary Absorption Test on Cube

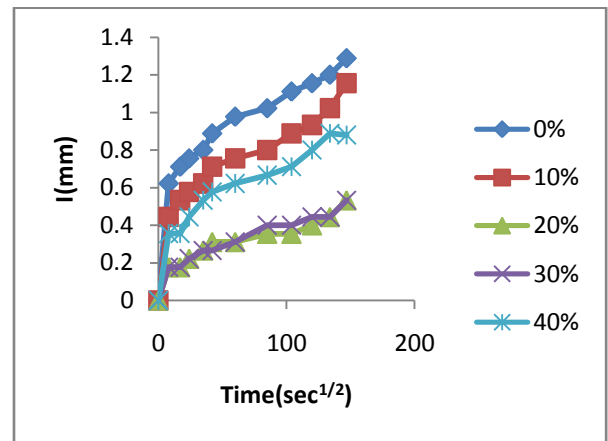


Fig.7 Capillary Absorption of cube after 28 days in which cement is partially replaced with different percentage of Fly Ash

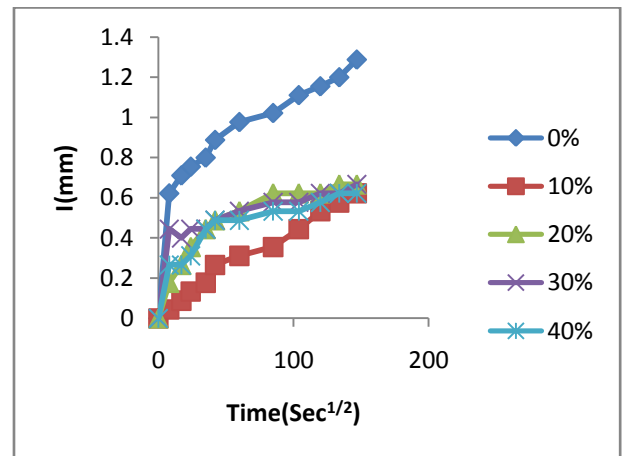


Fig.8 Capillary Absorption of cube after 28 days in which cement is partially replaced with different percentage of Glass Powder

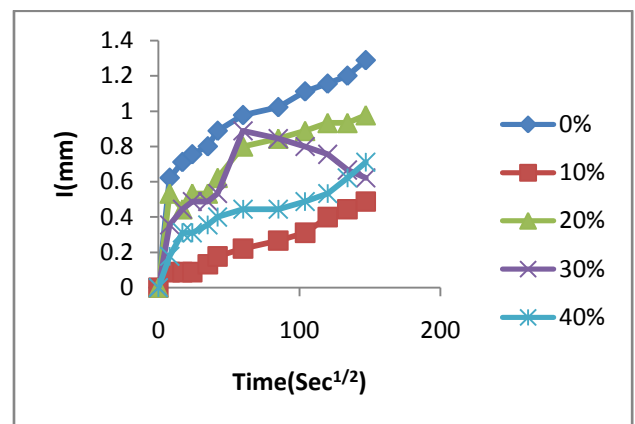


Fig.9 Capillary Absorption of cube after 28 days in which cement is partially replaced with different percentage of Fly Ash + Glass Powder

Fig.7 shows the values of Capillary absorption test results of 10%,20%,30% and 40% replacement of fly ash in concrete after 28 days curing. The absorption vs  $t^{1/2}$  graph is plotted.

From Fig.7, for 10% replacement by Fly Ash it is found that during 1 hour there is increase in absorption rate up to 20 to 70% and after 6 hour there is an increase of 6 to 53%.The coefficient of capillary absorption decrease to a value of 0.78 after 6 hour. For 20% replacement by Fly Ash, it is found that during 1 hour there is increase in absorption rate up to 25 to 75% and after 6 hour there is an increase of 14 to 72%.The coefficient of capillary absorption decrease to a value of 0.36 after 6 hour. For 30% replacement by Fly Ash, it is found that during 1 hour there is increase in absorption rate up to 25 to 75% and after 6 hour there is an increase of 29 to 72%.The coefficient of capillary absorption decrease to a value of 0.36 after 6 hour. For 40% replacement by Fly Ash, it is found that during 1 hour there is increase in absorption rate up to 25 to 75% and after 6 hour there is an increase of 7 to 39%.The coefficient of capillary absorption decrease to a value of 0.60 after 6 hour.

Fig.8 shows the values of Capillary absorption test results of 10%, 20%,30% and 40% replacement of Glass Powder in concrete after 28 days curing. The absorption vs  $t^{1/2}$  graph is plotted.

From Fig.8, for 10% replacement by glass powder it is found that during 1 hour there is increase in absorption rate up to 100 to 500% and after 6 hour there is an increase of 14 to 100%.The coefficient of capillary absorption decrease to a value of 0.42 after 6 hour. For 20% replacement by glass powder, it is found that during 1 hour there is increase in absorption rate up to 50 to 200% and after 6 hour there is an increase of 17to 25%.The coefficient of capillary absorption decrease to a value of 0.45 after 6 hour. For 30% replacement by glass powder, it is found that during 1 hour there is increase in absorption rate up to 10 to 20% and after 6 hour there is an increase of 8 to 25%.The coefficient of capillary absorption decrease to a value of 0.45 after 6 hour. For 40% replacement by glass powder, it is found that during 1 hour there is increase in absorption rate up to 17 to 84% and after 6 hour there is an increase of 9 to 28%.The coefficient of capillary absorption decrease to a value of 0.42 after 6 hour.

Fig.9 shows the values of Capillary absorption test results of 10%,20%,30% and 40% replacement of Fly Ash+ Glass Powder in concrete after 28 days curing. The absorption vs  $t^{1/2}$  graph is plotted.

For 10% replacement by Fly Ash+ Glass Powder, it is found that during 1 hour there is increase in absorption rate up to 52 to 152% and after 6 hour there is an increase of 20 to 120%.The coefficient of capillary absorption decrease to a value of 0.33 after 6 hour. For 20% replacement by Fly Ash+ Glass Powder, it is found that during 1 hour there is increase in absorption rate up to 17 to 50% and after 6 hour there is an increase of 6 to 22%.The coefficient of capillary

absorption decrease to a value of 0.66 after 6 hour. For 30% replacement by Fly Ash+ Glass Powder, it is found that during 1 hour there is increase in absorption rate up to 25 to 150% and after 6 hour there is an decrease of 30 to 5%.The coefficient of capillary absorption decrease to a value of 0.42 after 6 hour. For 30% replacement by Fly Ash+ Glass Powder, it is found that during 1 hour there is increase in absorption rate up to 15 to 43% and after 6 hour there is an increase of 10 to 60%.The coefficient of capillary absorption decrease to a value of 0.48 after 6 hour.

## V. CONCLUSIONS

The cube compressive strength, flexural strength and capillary absorption of NC at room temperature were 14.85 and 4.02 MPa after 7 days respectively. Similarly, the above values for 28 days were 27.58 and 4.90 MPa Respectively. The following conclusion may be drawn based on experimental results obtained in the present investigation.

1. The properties of concrete with different percentages of fly ash, glass powder and fly ash + glass powder as a partial replacement of cement has been varying different for different percentages for each mix. On the basis of experimental results it may also conclude that we can use fly ash + glass powder up to 40% of cement replacement as it is showing desired compressive, flexural strength after 28 days of curing and good workability and a lower coefficient of capillary absorption hence better durability.
2. After 7 days compressive strength increases from 30 to 50% when cement is replaced by 10%, 20% and 30% of fly ash percentage and thereafter decreases with increase in flash.
3. After 7 days compressive strength increases from 3 to 38% when cement is replaced from 10% to 20% of glass powder and thereafter decreases with increase in glass powder.
4. After 7 days an increase of 48% in compressive strength upto 10% of cement replacement and thereafter decreases with the increase in percentage of mix when cement is replaced by fly ash + glass powder.
5. After 28 days compressive strength increases by 35% with the addition of fly ash Up to 10% when compare to the compressive strength of Normal Concrete(NC) at Room temperature and thereafter it starts decreases in fly ash percentages up to 30% then there is a slight increase with increase in fly ash.
6. After 28 days compressive strength values of glass powder decreases from 7 to 35% with increase in percentage of glass powder when compare to the compressive strength of Normal Concrete(NC) at room temperature.
7. After 28 days compressive strength increases by 10% with increase in percentage upto 10% addition and

thereafter it starts decreases gradually when cement is replaced by fly ash + glass powder.

8. After 7 days the flexural strength of concrete with fly ash decreases by 9% up to 10% of fly ash then it start increases gradually at 30% of fly ash it increases by 23% and thereafter it decreases.
9. After 7 days flexural strength reduction between 10 to 40% of glass powder. The flexural strength decreases by 20 to 60% for the different percentage of glass powder.
10. After 7 days small flexural strength reduction at 10% of fly ash + glass powder then flexural strength starts increases up to 30% of fly ash + glass powder thereafter decreases by 52% with the increase in fly ash + glass powder.
11. After 28 days flexural strength decreases first for the 10% fly ash then there was a increase in flexural strength from 6 to 11% with the addition of fly ash. At 40% of fly ash strength decreases by 22%
12. After 28 days flexural strength of glass powder increases by 1% at 20% of glass powder percentage and thereafter it decreases with increase in glass powder.
13. After 28 days flexural strength of fly ash + glass powder decreases by 1% at 11% of glass powder percentage and thereafter it increases by 8% after 30% of increase in glass powder.
14. The coefficient of capillary absorption when fly ash is replaced by 10, 20, 30 and 40% are 0.78, 0.36, 0.36 and 0.60 respectively which is less from the coefficient of capillary absorption of NC.
15. The coefficient of capillary absorption when glass powder is replaced by 10, 20, 30 and 40% are 0.42, 0.45, 0.45 and 0.60 respectively which is less from the coefficient of capillary absorption of NC.
16. The coefficient of capillary absorption when fly ash + glass powder is replaced by 10, 20, 30 and 40% are 0.33, 0.66, 0.42 and 0.42 respectively which is less from the coefficient of capillary absorption of NC.
17. On the basis of experimental results it may also conclude that we can use fly ash + glass powder up to 40% of cement replacement as it is showing a lower coefficient of capillary absorption hence better durability.

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