# Incorporation of Waste Glass Powder as Partial Replacement of Fine Aggregate in Cement Concrete

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**Abstract**- Concrete industry is one of the largest consumers of natural resources due to which sustainability of concrete industry is under threat. The environmental and economic concern is the biggest challenge concrete industry is facing. In this paper, the issues of environmental and economic concern are addressed by the use of waste glass as partial replacement of fine aggregates in concrete. Fine aggregates were replaced by waste glass powder (GP) as 10%, 20%, and 30% by weight for M20mix. The concrete specimens were tested for compressive strength at seven and 28 days of age and the results obtained were compared with those of normal concrete. Waste glass when grounded to a very fine powder shows some pozzolanic properties as it contains high $SiO_2$ and therefore to some extent it replaces the cement and contributes for strength development. The results concluded the permissibility of using waste glass powder as partial replacement of fine aggregates up to 30% by weight for particle size of range 0-1.18mm. Glass is widely used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. Glass is an ideal material for recycling. The use of recycled glass helps in energy saving. The increasing awareness of glass recycling speeds up inspections on the use of waste glass with different forms in various fields. One of its significant contributions is to the construction field where the waste glass was reused for concrete production. The application of glass in architectural concrete still needs improvement.. The study indicated that waste glass can effectively be used as fine aggregate replacement (up to 20%) without substantial change in strength.

**Index Terms:** - Compressive Strength, Concrete, Glass powder and Workability.

## 1 INTRODUCTION

In order to make concrete industry sustainable, the use of waste materials in place of natural resources is one of the best approaches. An enormous quantity of waste glass is generated all around the world. In India, 0.7% of total urban waste generated comprises of glass [1]. UK produces over three million tons of waste glass annually [2] Waste glass is crushed into specified sizes for use as aggregate in various applications such as water filtration, grit plastering, sand cover for sport turf and sand replacement in concrete [3]. Concrete is most widely used man made construction material and its demand is increasing day by day. The use of river sand as fine aggregate leads to exploitation of natural resources, lowering of water table, sinking of bridge piers and erosion of river bed. If fine aggregate is replaced by waste glass by specific percentage and in specific size range, it will decrease fine aggregate content and thereby reducing the ill effects of river dredging and thus making concrete manufacturing industry sustainable.


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The amount of waste glass produced has gradually increased over the recent years due to an ever growing use of glass products. Most of the waste glass is being dumped into landfill sites. The land filling of waste glass is undesirable because waste glass is non biodegradable which makes them environmentally less friendly. Utilization of this waste is the need of the hour. There is huge potential for using waste glass in the concrete construction sector. When waste glasses are reused in making concrete products, the production cost of concrete will go down [4].

This move will serve two purposes; first, it will be environment friendly, second, it will utilize waste in place of precious and relatively costlier natural resources. The using of waste glass as fine aggregate in concrete creates a problem in concrete due to ASR (Alkali Silica Reaction). The reaction between alkalis in Portland cement and silica in aggregates forms silica gel. This gel is prone to swelling. It absorbs water and the volume of the gel increases. Under confinement by cement matrix and aggregate, the swelling of the ASR gel generates hydrostatic pressure. If the reaction continues and internal pressure exceeds the tensile strength of the matrix, cracks will form around the reactive aggregate particles [5]. Ground waste glass was used as fine aggregate in concrete and no reaction was detected with fine particle size, thus indicating the feasibility of the waste glass reuse as fine aggregate in concrete. In

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addition, waste glass seemed to positively contribute to the mortar micro-structural properties resulting in an evident improvement of its mechanical performance [6].

Larger the particle size of waste glass more is the chance of ASR occurrence. Shayan and Xu reported fine glass powder for incorporation into concrete up to 30% as a pozzolanic material suppressed the ASR [7]. Using waste glass in the concrete construction sector is advantageous, as the production cost of concrete will go down. The amount of waste glass is gradually increased over the years due to an ever-growing use of glass products. Most of the waste glasses have been dumped into landfill sites. The land filling of waste glasses is undesirable because they are not biodegradable, which makes them environmentally less friendly. There is huge potential for using waste glass in the concrete construction sector. When waste glasses are reused in making concrete products, the production cost of concrete will go down [8].

Hence the size of waste glass used was in the range 0-1.18mm. In this research, fine aggregates were partially replaced by waste glass as 10%, 20% and 30% by weight. Concrete specimens were tested for workability and compressive strength for different waste glass percentages. The results obtained were compared with results of controlled concrete mix and it was found that maximum increase in compressive strength occurred for the concrete mix containing 20% waste glass as fine aggregate.

## 2 MATERIALS USED IN THE PRESENT STUDY

### 2.1 Cement

Ordinary Portland cement Zuari-53 grade conforming to IS: 12269-1987 [9] was used in concrete.
The physical properties of the cement are listed in Table 1.

Table 1

Physical Properties of Zuari-53 Grade Cement.

| Sno | 1 | 2 | 3 | 4 | 5 | | |
|---|---|---|---|---|---|---|---|
| Properties | Sp. Gr | Normal consistency | Initial setting time | Final setting time | Compressive strength (Mpa) | | |
| Values | 3.15 | 32% | 60 min | 320 min | 3 days | 7 days | 28 days |
| | | | | | 29.4 | 44.8 | 56.5 |

### 2.2 Aggregates

A crushed granite rock with a maximum size of 20mm was used as coarse aggregate. Natural sand from Swarnamukhi River in Srikalahasti was used as fine aggregate. The fineness modulus is 5.77 for fine aggregate and for coarse aggregate is 7.18 conforming to zone- II of IS 383-1970 [10]. The specific gravity of aggregates is presented in Table. 2. The sieve analysis results of aggregates were represented in Tables. 3 & 4.

Table 2

Specific Gravity of Aggregates

| | |
|---|---|
| Specific gravity of coarse aggregate | 2.74 |
| Specific gravity of fine aggregate | 2.62 |

Table 3

Sieve Analysis of Fine Aggregate

| IS Sieve size (mm) | Weight retained in (gm) | % of weight retained | Cumulative weight retained in(gm) | % cumulative weight retained | % of finer |
|---|---|---|---|---|---|
| 4.75 | 12 | 2.4 | 12 | 2.4 | 97.6 |
| 2.36 | 85 | 17 | 97 | 19.4 | 80.6 |
| 1.18 | 135 | 27 | 232 | 46.4 | 53.6 |
| 0.600 | 47 | 9.4 | 279 | 55.8 | 44.2 |
| 0.425 | 50 | 10 | 329 | 65.8 | 34.2 |
| 0.300 | 132 | 26.4 | 461 | 92.2 | 92.2 |
| 0.150 | 19 | 3.8 | 480 | 96 | 96 |
| 0.075 | 18 | 3.6 | 498 | 99.6 | 0.4 |
| Pan | 2 | 0.4 | 500 | 100 | 0 |
| Total Cumulative % Of Weight Retained | | | | 577.6 | |
| Fineness modulus | | | | 577.6/100 =5.77 | |

Table 4

Sieve Analysis of Coarse Aggregate

| IS sieve size (mm) | Weight retained(gm) | % weight retained | Cumulative % weight retained | % passing |
|---|---|---|---|---|
| 80 | 0 | 0 | 0 | 100 |
| 40 | 0 | 0 | 0 | 100 |
| 20 | 956 | 19.12 | 19.12 | 80.88 |
| 10 | 4024 | 80.48 | 99.6 | 0.4 |
| 4.75 | 20 | 0.4 | 100 | 0 |
| 2.36 | 0 | 0 | 100 | 0 |
| 1.18 | 0 | 0 | 100 | 0 |
| 600 | 0 | 0 | 100 | 0 |
| 300 | 0 | 0 | 100 | 0 |
| 150 | 0 | 0 | 100 | 0 |

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| | | |
|---|---|---|
| Total Cumulative % Of Weight Retained | 718.72 | |
| Fineness modulus | 718.72/100 =7.18 | |

Table 4

Sieve Analysis of Glass Powder

| S. No. | Sieve No. | Mass Retained (gms) | Retained, % | Passing, % | Cumulative % retained |
|---|---|---|---|---|---|
| 1 | 4.75 | 0 | 0 | 100 | 0 |
| 2 | 2.36 | 1.7 | 0.17 | 99.83 | 0.17 |
| 3 | 1.18 | 357.7 | 35.77 | 64.04 | 35.94 |
| 4 | 0.30 | 200.2 | 20.02 | 20.95 | 79.05 |
| 5 | 0.15 | 113.2 | 11.32 | 9.63 | 90.37 |
| 6 | Pan | 96.3 | 9.63 | 0 | 0 |

Fineness Modulus of glass aggregate = ΣF/100 = 264.56/100 = 2.64

### 2.3 Water

Potable water was used for mixing and curing of concrete cubes.

### 2.4 Glass Powder

Here glass powder is used as partial sand replacement for making the concrete specimens. The glass powder is obtained from M/S. Anand Chemicals Morbi Gujarat. The specific gravity of glass powder is **2.4.**The following Table-5 gives the chemical composition of glass powder:

Table 5

Chemical Composition of the Glass Powder

| Composition (% by mass)/property | Glass powder |
|---|---|
| Silica (Si02) | 72.5 |
| Alumina (Al2O3) | 0.4 |
| Iron oxide (Fe2O3) | 0.2 |
| Calcium oxide (Cao) | 9.7 |
| Magnesium oxide (Mgo) | 3.3 |
| Sodium oxide | 13.7 |
| Potassium oxide | 0.1 |
| Sulfur trioxide (So3) | - |
| Loss on ignition | 0.36 |
| Fineness,% passing (sieve size) | 80 (45 microns) |

Fig.1 Glass Powder Being Mixed With Sand

## 3 MIX PROPORTIONING

The tests are carried out on water-cement ratio of 0.5. The control mix (M20) is designed in accordance with IS: 10262-2009 guidelines [11] . For making the mixes containing glass powder, the amount of powder is calculated by using the weight of powder, in place of the weight of sand. The resultant mix proportions of all the mixes are tabulated in Table 6

Table 6

Mix proportions for M20 Concrete

| PARAMETERS | Percentage replacement of glass powder in fine aggregate | | | |
|---|---|---|---|---|
| | CONTROL MIX | MIX 1 (10%GP) | MIX 2 (20%GP) | MIX 3 (30%GP) |
| W/C Ratio | 0.5 | 0.5 | 0.5 | 0.5 |
| Water kg/cu.m | 191.6 | 191.6 | 191.6 | 191.6 |
| Cement kg/cu.m | 383 | 383 | 383 | 383 |
| Fine aggregates kg/cu.m | 727 | 654 | 581.6 | 508.9 |
| Coarseaggregates kg/cu.m | 1103 | 1103 | 1103 | 1103 |
| Glass powder kg/cu.m | 0 | 72.7 | 145.4 | 218.1 |

## 4 RESULTS AND DISCUSSIONS

Table 6

Workability Test (Slump Cone Test)

| Replacement of Glass powder with fine aggregate (%) | WORKABILITY (SLUMP IN CM) |
|---|---|
| Control Mix | 25 |
| Mix 1 | 27 |
| Mix 2 | 29 |
| Mix 3 | 26 |

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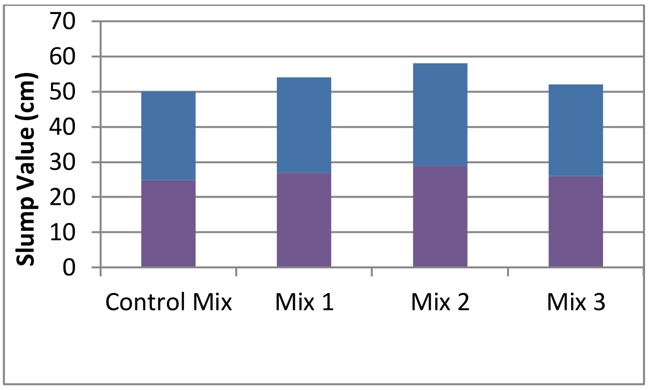


Fig.2 Variation of Slump Value with Waste Glass for Different Trail Mixes

## 4.1 MECHANICAL PROPERTIES

### 4.1.1 Compressive Strength

The compression tests were carried out as per IS: 516-1959 [12]. The compressive strength for same water cement ratios of glass powder added concrete and control concrete were tested at the end of seven days and 28 days using compressive strength testing machine as shown in Table 7and Fig 3.



Table 7

Compressive Strength Results for DifferentTrail Mixes

| Percentage of replacement of Glass powder with fine aggregate | Compressive Strength N/mm$^2$ | |
|---|---|---|
| | 7 Days | 28 Days |
| Control Mix | 13.43 | 22.77 |
| Mix 1 | 16.34 | 25.88 |
| Mix 2 | 18.32 | 29.84 |
| Mix 3 | 15.55 | 24.66 |

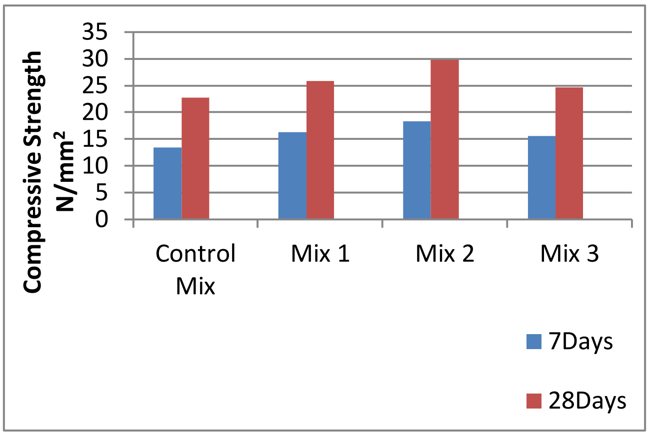


Fig.3 Variation of Compressive Strength for Different Trail Mixes

## 5 CONCLUSIONS

20% replacement of fine aggregates by waste glass showed 35% increase in compressive strength at 7 days and 30% increase in compressive strength at 28 days.

Fine aggregates can be replaced by waste glass up to 30% by weight showing 8.5% increase in compressive strength at 28 days.

With increase in waste glass content, percentage water absorption decreases.

With increase in waste glass content, average weight decreases by 5% for mixture with 30% waste glass content thus making waste glass concrete light weight.

Workability of concrete mix increases with increase in waste glass content.

Laboratory experiments were conducted to further explore the use of waste glass as coarse and fine aggregates for both ASR (Alkali-Silica-Reaction) alleviation as well as the decorative purpose in concrete.

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