# Research Study on Waste Glass Powder Partial Replacement with Cement Concrete

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*Abstract*— This study was conducted to investigate the effect of using waste glass powder in concrete. Laboratory work was conducted to determine the performance of control sample and concrete with used waste glass powder. The performance of these types of concrete was determined by the workability test, density test and compressive strength test. The workability of concrete is determined using slump test and compacting factor test. Meanwhile, compressive strength test is done to determine the strength of concrete. For each type of concrete, a total of six 150mm x 150mm x 150mm cubes were cast. The cubes were tested at the ages of 7, 14 and 28 days to study the development of compressive strength. The results indicate that the concrete with using waste glass powder were able to increase the workability of concrete and also the compressive strength. However, the density is reduced compare to standard mixture of concrete.

***Keywords:*** Powdered waste glass, workability, Alkalinity, split tensile, pozzolanic I

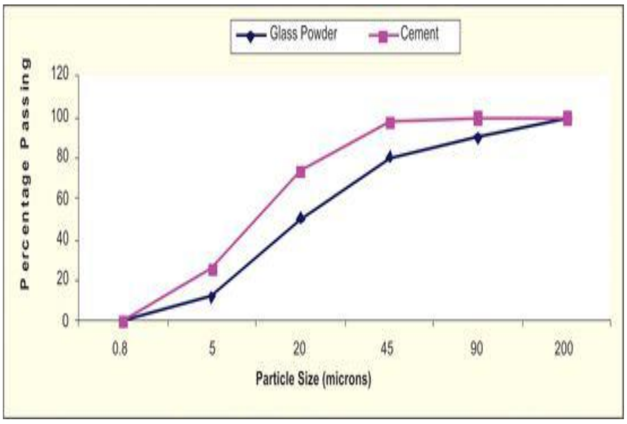
## I. Introduction

The interest of the construction community in using waste or recycled materials in concrete is increasing because of the emphasis placed on sustainable construction, the waste glass from in and around the small shops is packed as a waste and disposed as landfill. Glass is an inert material which could be recycled and used many times without changing its chemical property (Aimin Xu and Ahmad shayam,2004). Besides using waste glass as cullet in glass manufacturing, 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 (Carpenter, A.J. and Cramer, C.M,1999). 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 (Chi sing lam, chi sun poon and Dixon chan,2007).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 (Christoper cheeseman,2011) Glass is amorphous material with high silica content, thus making it potentially pozzolanic when particle size is less than 75μm(Federio.L.M and Chidiac S.E,2001, Jin.W, Meyer.C, and Baxter.S,2000). Studies have shown that finely ground glass does not contribute to alkali – silica reaction. In the recent, various attempts and research have been made to use ground glass as a replacement in conventional ingredients in concrete production as a part of greenhouse management. 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 (Christopher cheeseman, 2011, Mageswari.L.M and B.Vidivelli,2010). 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 (Malek Batayneh, Iqbal Marie, Ibrahim Asi,2007),Optimal dosage range of this glass powder is chosen based on cement paste studies.

## II. History

There has been a general perception in the concrete industry that glass aggregates should be precluded from concrete because of their potential for alkali silica reaction (ASR), even although early research did not draw definite conclusions. Recent publications, whilst not specifically supporting the use of glass in concrete, have led to a great understanding of ASR parameters and methods by which it can be suppressed and major recent research in the USA and UK has made it possible for recycled glass to be viewed as a potentially “fit-for-purpose” concrete construction material. Early researches in 1960’s, 1970s and1980s on the study of ASR of glass aggregate were conducted without definite conclusions. In parallel to these scientific advances, changes in environmental legislation are positively encouraging the use of secondary aggregates in concrete and waste glass is becoming available in larger quantities as container, end-of-life vehicle and waste electrical goods legislation take effect.

*A. Sieve analysis*




*B. Mix Design:*

The concrete mix without glass powder was proportioned as per Indian Standard Specifications IS: 10262-1982. Mix design was done for M20 grade of concrete. The mixture was prepared with water to cement ratio of 0.5. The mix proportion of materials is 1:2.35:4.47 as per IS 10262-2009. Then natural fine aggregate was used. Nine different mixes (M1, M2, M3, M4, M5, M6, M7, M8, M9) were prepared at cement replacement levels of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% in concrete. To impart workability to the mix, a superplasticiser was used with a dos age of 2% by weight of cement.

*C. Casting and Testing:*

The 150 mm concrete cubes were cast for compressive strength and 150 x150x 700 mm beams were cast for flexural strength according to the mix proportion and by replacing cement with glass powder (GP) in different proportion.

*1) Strength test:*

Using a compression testing machine (CTM) of capacity 2000KN in accordance with the provisions of the Indian Standard specification IS: 516-1959, strength of specimens were tested at 7, 28 and 90 days [2].

*2) Workability Test:*

Workability is the property of freshly mixed concrete that determines the ease with which it can be properly mixed, placed, consolidated and finished without segregation. Workability depends on water content, aggregate cementitious content and age and can be modified by adding chemical admixtures. The workability of fresh concrete was measured by means of the conventional slump test as per IS: 1199-1989. Before the fresh concrete was cast into moulds, the slump value of the fresh concrete was measured using slump cone [2].

*3) Alkalinity Test:*

For conducting the alkalinity test specimen are taken out from curing tank after 28 days of curing. Then oven dry the specimens at 105°C for 24 hours. The dry specimens are cooled to room temperature. Mortar was separated from the concrete by breaking down the dry specimen. 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 stirred it completely. Then immerse the pH meter 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 were noted

*D. Glass powder*

The initial work undertaken by ARRB on the utilisation of glass as a pozzolonic material was partially supported by Eco-Recycle Victoria in 1998, and subsequently by VISY Recycling – Glass Division. The following section summarises the results obtained during this research program using this research program.

*E. Effects of glass powder (GLP) on mortar strength*

The particle size distribution of the glass powder (GLP) used is as follows:
Particle size : <5 µm 5-10 µm 10-15 µm >15 µm %: 39.0 49.0 4.4 7.6

The specific surface area of the GLP was 800 m2/kg, which is around double that of most Australian GP cements (~ 400 m2/kg).

The effects of cement or sand replacement by GLP on the strength of mortar cubes (aggregate to cement ratio of 2.25 and water/cement ratio of 0.47) are shown in Figures 5 and 6. In the case of cement replacement, the reduction in the 28 days strength, may, to some extent, be a short-term effect because in such short periods the pozzolonic effects would not become evident. Fly ash also exhibits a similar effect when it replaces an equal mass of cement.

## III. Test Results

Test results are presented graphically and in tubular forms and have been discussed under different categories.

*A. Workability*

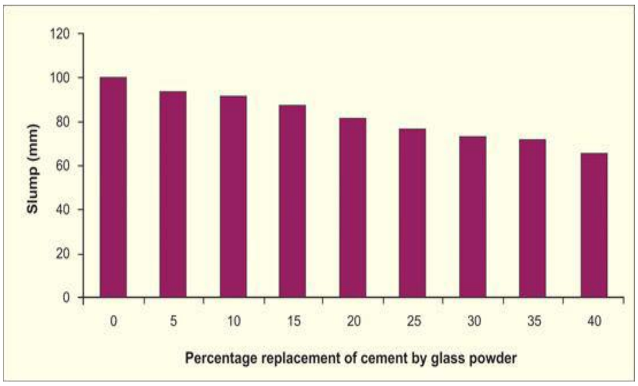
Table 2 and Figure 2 shows the results of workability of concrete with cement replacement by glass powder in various percentages ranging from 5% to 40% in increments of 5% (0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40%).

| Mix Designation | Percentage replacement of cement by Glass powder | Slump(mm) | Percentage decrease or increase with respect to reference mix |
|---|---|---|---|
| M1 | 0(Ref.mix) | 100 | - |
| M2 | 05 | 94 | -6 |
| M3 | 10 | 91 | -9 |
| M4 | 15 | 88 | -12 |
| M5 | 20 | 82 | -18 |
| M6 | 25 | 76 | -24 |
| M7 | 30 | 73 | -27 |
| M8 | 35 | 72 | -28 |
| M9 | 40 | 66 | -34 |

Table 2: Overall result of slump of concrete

From table 2 and figure 3 we can conclude that workability of concrete decreases as the glass content increases.




### B. Strength tests

#### 1) Compressive Strength

| Age, days | Compressive strength, MPa | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0% GP | 5% GP | 10 % GP | 15 % GP | 20 % GP | 25 % GP | 30 % GP | 35 % GP | 40 % GP |
| 7 | 21.05 | 22.28 | 23.27 | 24.86 | 27.30 | 23.72 | 17.62 | 16.04 | 12.93 |
| 28 | 27.05 | 28.58 | 29.77 | 31.56 | 33.50 | 30.52 | 24.22 | 22.44 | 19.03 |
| 90 | 27.33 | 28.87 | 30.08 | 31.84 | 33.86 | 30.82 | 24.44 | 22.72 | 19.25 |

Table 3: Overall results of development of compressive strength in concrete with age

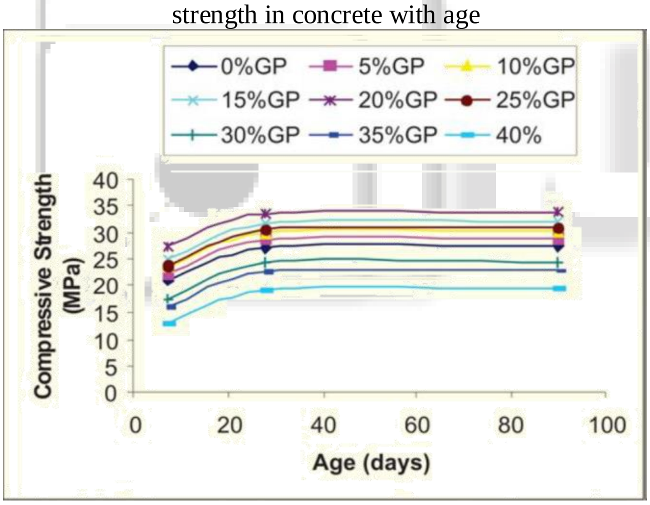



Fig. 4: Variation of compressive strength development in concrete

#### 2) Flexural Strength

| Age in days | Flexural strength, MPa | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0% GP | 5% GP | 10 % GP | 15 % GP | 20 % GP | 25 % GP | 30 % GP | 35 % GP | 40 % GP |
| 7 | 2.40 | 2.45 | 2.78 | 2.85 | 3.05 | 2.90 | 2.82 | 2.42 | 2.32 |
| 28 | 3.50 | 3.78 | 3.78 | 3.95 | 4.17 | 4.00 | 3.90 | 3.57 | 3.41 |
| 90 | 3.60 | 3.64 | 3.82 | 4.00 | 4.21 | 4.05 | 3.92 | 3.60 | 3.45 |

Table 3: Overall results of development of flexural strength in concrete with age

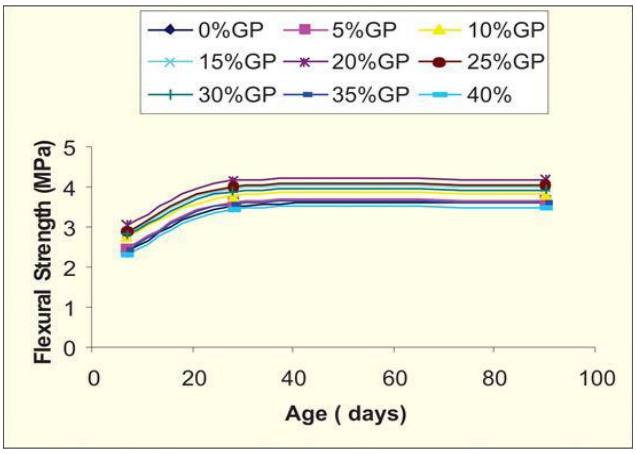



Fig. 5: Variation of flexural strength development in concrete with age

### C. Alkalinity test

Table 5.The alkalinity test values for glass powder added concrete

| % Replacement of Glass powder in concrete | pH Value |
|---|---|
| 0 | 12.6 |
| 10 | 12.7 |
| 20 | 12.46 |
| 30 | 12.67 |
| 40 | 12.98 |

The pH value observed from the alkalinity test showed that the specimen tested found to be more alkaline and hence more resistant towards corrosion.

## IV. Discussion on Test Results

### A. Workability

As the glass content increases (i.e. cement content decreased) workability decreases. As there is a reduction in fineness modulus of cementatious material, quantity of cement paste available is less for providing lubricating effect per unit surface area of aggregate. Therefore, there is a restrain on the mobility.

### B. Strength

As the percentage of replacement of cement with glass powder increases strength increases up to 20% and beyond that it decreases. The highest percentage increase in the compressive strength was about 30% and flexural strength was about 22% at 20% replacement level. The increase in strength up to 20% replacement of cement by glass powder may be due to the pozzolanic reaction of glass powder due to high silica content. Also it effectively fills the voids and gives a dense concrete microstructure. However, beyond 20%, the dilution effect takes over and the strength starts to drop. Thus it can be concluded that 20% was the optimum level for replacement of cement with glass powder [1]. The strength improvement at early curing ages was slow due to pore filling effect. Later waste glass powder on hydration liberates sufficient amount of lime for starting the secondary pozzolanic reaction leading to more quantity of C-S-H gel getting formed.

## V. 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/mm2
- Replacement of glass powder in cement by 20%, 30% and 40% increases the compressive strength by 19.6%, 25.3% and 33.7% respectively.
- Replacement of glass powder in cement by 40% increases the split tensile strength by 4.4% respectively
- Replacement of glass powder in cement by 20%, 30% and 40% 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 pozzolonic properties to serve as partial cement replacement, the effect of ASR appear to be reduced with finer glass particles, with replacement level.

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