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Effect of Using Glass Powder in Concrete

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ABSTRACT: The global warming is caused by the emission of green house gases, such as CO_2, to the atmosphere. Among the greenhouse gases, CO_2 contributes about 65% of global warming. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. Consequently efforts have been made in the concrete industry to use waste materials as partial replacement of coarse or fine aggregates and cement. Waste glass is one materials when ground to a very fine powder shows pozzolanic properties which can be used as a partial replacement for cement in concrete. In this paper, an attempt has been made to find out the strength of concrete containing waste glass powder as a partial replacement of cement for concrete. Cement replacement by glass powder in the range 5% to 40% increment of 5% has been studied. It was tested for compressive strength and flexural strength at the age of 7, 28 and 90 days and compared with those of conventional concrete. Results showed that replacement of 20% cement by glass powder was found to have higher strength. Also alkalinity test was done to find out resistance to corrosion.

KEYWORDS: Concrete, Glass Powder, Strength, Alkalinity test, Global warming.

I. INTRODUCTION

Concrete is one of the world's most used construction material due to its versatility, durability and economy. India uses about 7.3 million cubic meters of ready-mixed concrete each year. It finds application in highways, streets, bridges, high-rise buildings, dams etc. [4].Green house gas like CO_2 leads to global warming and it contributes to about 65% of global warming. The global cement industry emits about 7% of green house gas to the atmosphere. To reduce this environmental impact alternative binders are introduced to make concrete [6].

Glass is an amorphous material with high silica content making it potentially pozzolanic when particle size is less than 75µm. The main problem in using crushed glass as aggregate in Portland cement concrete are expansion and cracking caused by the glass aggregate due to alkali silica reaction. Due to its silica content ground glass is considered a pozzolanic material and as such can exhibit properties similar to other pozzolanic material. In this study, finely powdered waste glasses are used as a partial replacement of cement in concrete and compared it with conventional concrete. Concrete mixtures were prepared with different proportions of glass powder ranging from 5 to 40% with an increment of 5% and tested for compressive strength after 7, 28 and 90 days of curing [3].

II. MATERIAL AND METHODS

1. **Cement:** The cement used in this study was 43 grade Ordinary Portland Cement (OPC) confirming to IS 8112-1989.
2. **Fine aggregate:** Locally available sand confirming to zone II with specific gravity 2.62 was used. The testing of sand was done as per Indian Standard Specification IS: 383-1970.

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3. **Coarse aggregate:** Coarse aggregate used was 20mm and down size and specific gravity 2.93. Testing was done as per Indian Standard Specification IS: 383-1970.
4. **Glass:** Waste glass available locally was collected and made into glass powder. Glass waste is very hard material. Before adding glass powder in the concrete it has to be powdered to desired size.
5.

A. **Chemical composition**

Table 1. Chemical composition of cementing materials

Composition (% by mass)/ property	Cement	Glass powder
Silica (SiO_2)	20.2	72.5
Alumina (Al_2O_3)	4.7	0.4
Iron oxide (Fe_2O_3)	3.0	0.2
Calcium oxide (CaO)	61.9	9.7
Magnesium oxide (MgO)	2.6	3.3
Sodium oxide (Na_2O)	0.19	13.7
Potassium oxide (K_2O)	0.82	0.1
Sulphur trioxide (SO_3)	3.9	-
Loss of ignition	1.9	0.36
Fineness % passing (sieve size)	97.4(45 µm)	80 (45 µm)
Unit weight,Kg/m^3	3150	2579
Specific gravity	3.15	2.58

The particle size distribution of the glass powder and cement are shown in figure 1.

B. **Sieve analysis**

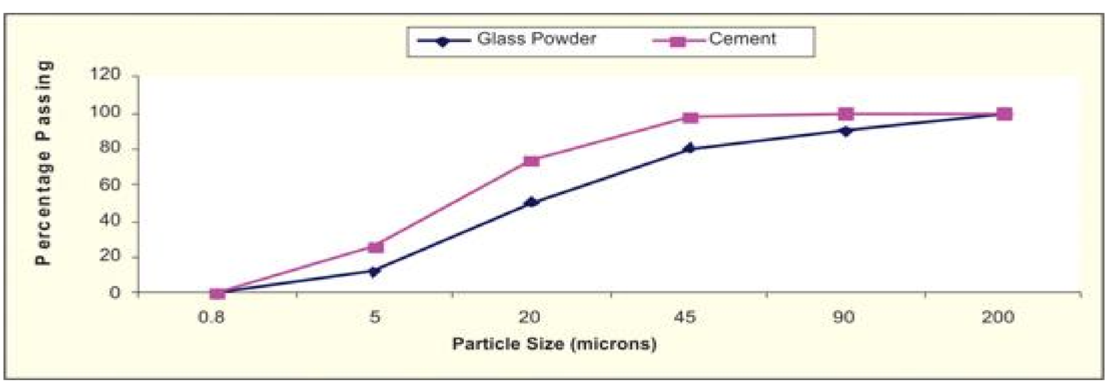

Fig.1. Particle Size Distributions of Cementitious Materials

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C. 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.

D. 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 [6].

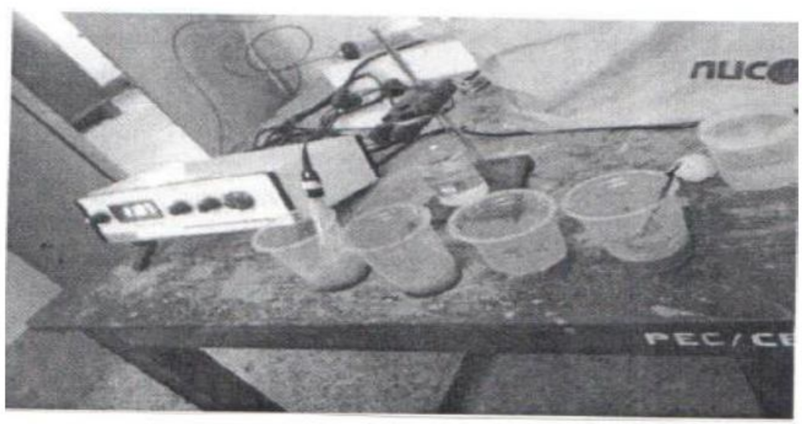

Fig.2. Alkalinity test on glass powder added concrete

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%).

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Table 2. Overall result of slump of concrete

Mix Designation	Percentage replacement of cement by glass powder	Slump (mm)	Percentage increase or decrease 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

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

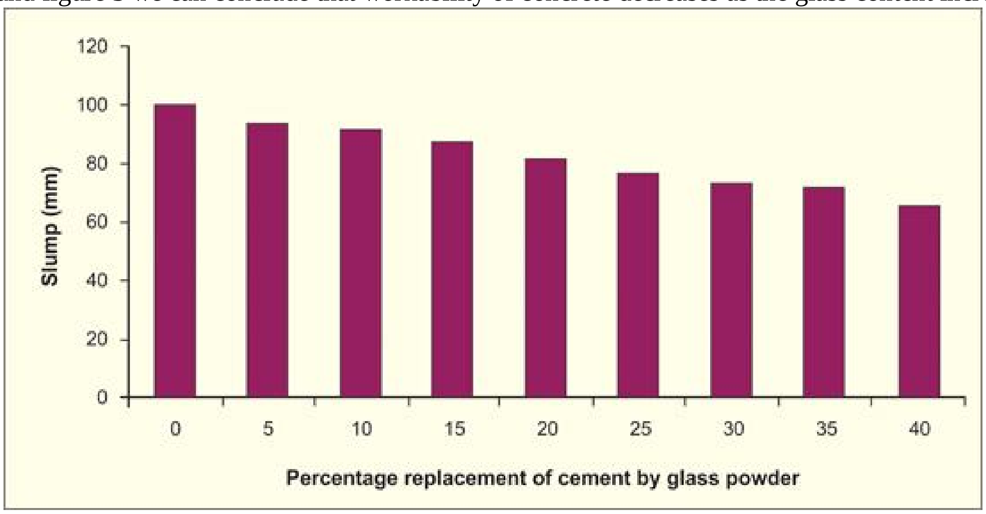

Fig.3. Variation of slump of concrete with cement replacement by glass powder

C. **Strength tests**

1. Compressive Strength

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

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	31.85	33.86	30.82	24.44	22.72	19.25

The table gives the results of test conducted on hardened concrete with 0-40% glass powder for 7, 28 and 90 days. From table 4 and figure 4, the results shows that the compressive strength increases with increasing curing time. It seems the compressive strength obtained for concrete with 20% replacement by glass powder showed a higher value by 30%, 24%, 24% compared to control concrete for 7 days, 28 days and 90 days respectively.

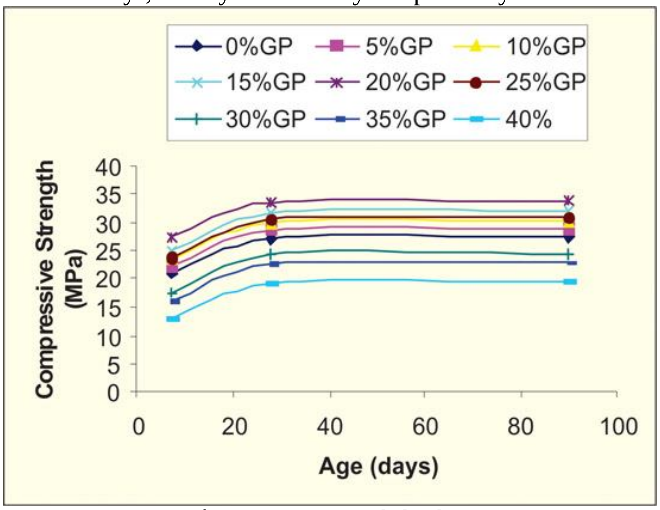

Fig.4. Variation of compressive strength development in concrete

2. Flexural Strength

Table 4. Overall results of development of flexural strength in concrete with age.

Age, 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	3.62	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 4 and figure 5 shows the result of variation of flexural strength of concrete with cement replacement by glass powder for 7, 28 and 90 days. It seems flexural strength of concrete with 20% cement replacement by glass powder showed a higher value by 27%, 20%, 17% compared to control concrete for 7 days, 28 days and 90 days respectively.

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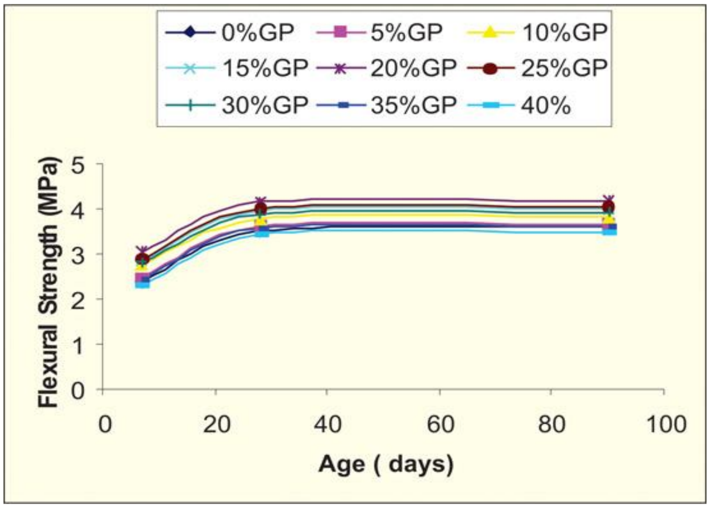

Fig.5. Variation of flexural strength development in concrete with age

D. **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.

III. Discussion on Test Results

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.

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

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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 [5].

IV. CONCLUSIONS

Based on experimental observations, the following conclusions are drawn:

- As the percentage of glass powder increases the workability decreases. Use of super plasticizer was found to be necessary to maintain workability with restricted water cement ratio.
- Compressive strength increases with increase in percentage of glass powder upto 20% replacement and beyond 20% strength decreases.
- Flexural strength also increases with increase in percentage of glass powder upto 20% replacement and beyond 20% strength drops down.
- Considering the strength criteria, the replacement of cement by glass powder is feasible. Therefore we can conclude that the utilization of waste glass powder in concrete as cement replacement is possible.
- 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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