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Experimental investigation of waste glass powder as the partial replacement of cement in concrete production

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ABSTRACT: *Concrete is a mixture of Portland cement or any other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without admixtures. The concrete industry is one of the largest consumers of natural resources due to which sustainability of concrete industry is under threat. The environmental and economics concern is the biggest challenge the concrete industry is facing. The global cement industry contributes about 7% of greenhouse gases emission in to the earth's atmosphere. Today many researchers are ongoing in the use of supplementary cementitious materials using many waste materials like Pulverized Fly Ash (PFA) and Ground Granulated Blast Furnace Slag (GGBS). Like PFA & GGBS a waste glass powder also act as a filler material in partial replacement of cement which takes some part of reaction at the time of hydration. Waste glass when ground to a very fine powder shows pozzolanic prosperities as it contains high SiO_2 and therefore to some extent can replaced cement in concrete and contribute strength development. In this study Glass Powder partially replaced at varying percentage 0 to 40, at interval of 5% and tested for its Compressive, Tensile, and Flexural strength up to 60 days of age and were compared with those of conventional concrete. The overall test results shows that Waste Glass Powder could be utilized in concrete as a good substitute of cement.*

Keywords: *Pozzolana, Strength, Supplementary cementitious material, Workability, Waste glass powder*

I. INTRODUCTION

The environmental impact of concrete, its manufacture and applications, is complex. Some effects are harmful; others welcome. Many depend on circumstances. A major component of concrete is cement, which has its own environmental and social impacts and contributes largely to those of concrete. The cement industry is one of the primary industrial producers of carbon dioxide (CO_2), creating up to 5% of worldwide man-made emissions of this gas, of which 50% is from the chemical process and 40% from burning fuel. Glass is an amorphous solid that has been found in various forms for thousands of years and has been manufactured for human use since 12,000 BC. Glass is one the most versatile substances on Earth, used in many applications and in a wide variety of forms, from plain clears glass to tempered and tinted varieties, and so forth. The interest of the construction community in using waste or recycled materials in concrete is increasing because of the emphasis placed on sustainable construction. Glass is an inert material which could be recycled and used many times without changing its chemical property (Aimin Xu and Ahmad shayam, 2004).

Efforts have been made in the concrete industry to use waste glass powder as partial replacement of cement. Waste glass when ground to a very fine powder shows pozzolnic prosperities as it contains SiO_2 and therefore to some extent can replace cement in concrete and contribute in strength development. Glass is amorphous material with high silica content, thus making it potentially pozzolanic when particle size is less than 75μm. Studies have shown that finely ground glass does not contribute to alkali –silica reaction. This paper reports the results of an experimental investigation on the use of glass powder in partially replacement cement in concrete applications and summarized the behavior of concrete involving partial replacement of cement by waste glass powder 5% to 40% at interval of 5% each.

II. SIGNIFICANCE OF WORK

Present day, world is witnessing the construction of very challenging and aesthetic structures. Concrete being the most important and widely used material is called upon to possess very high strength and sufficient workability. In the recent, various attempts and research have been made to use ground glass as a replacement in conventional ingredients in concrete productions as a part of green house management. Glass recycling is the process of turning waste glass into usable products. Recycling of waste glass possesses major problems for municipalities everywhere, and this problem can be greatly eliminated by re-using waste glass as cement replacement in concrete.

III. MIX MATERIALS

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. In this experimental investigation, cement was replacement by glass powder (GLP) having particle size less than 90 µm. The waste glass powder was replaced by 5% to 40% at interval of 5% each and mix design prepared. For this study M30 grade of concrete was used. Mix design was carried out for M30 grade of concrete as per IS 10262:2009. The material details are as follows:

Cement

In this research, locally available cement which is of the ordinary Portland cement type (43 grade) was used conforming to IS 8112was used throughout the work.

Water

The water used was potable, fresh, colourless, odourless, and tasteless water that is free from organic matter of any type.

Sand

The fine aggregates were used for the experiment in with maximum size 4.75 mm diameter.

Waste Glass Powder

Waste glass locally available and it has been collected and made in to glass powder. Before adding glass powder in the concrete it has to be powdered to required size. In this experiments glass powder (GLP) having particle size less than 90 µm was used.

Fig: 1 Waste Glass Powder

TABLE I
Properties of Glass Powder (Physical and Chemical)

Sr. No.	Physical properties of glass powder		Chemical properties of glass powder	
1	Specific Gravity	2.6	pH	10.25

2	Fineness passing 90 µm	99	Colour	Grayish White

TABLE II
Chemical Composition of Cementing Material (Cement and GLP)

Composition (% by mass)/Property	Cement	Waste 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)

IV. EXPERIMENTAL WORK AND TEST

1. **Mix Design:** Mix design carried out for M30 grade of concrete by IS 10262:2009, yielded to a mix proportation of 1:1:2 with water cement ratio of 0.48. The replacement of cement by 5% to 40% at interval of 5% each. Chemical admixtures are not used in experimental work.

2. **Compressive and Flexure test:** Concrete prepared with different percentage replacement of cement by 5% to 40% at interval of 5% each was cured under normal condition as per IS recommendation and were tested at 28 days and 60 days for determining the compressive and flexural strengthened and compared with the test results of conventional concrete.

3. **Workability test**: The behavior of green or fresh concrete from mixing up to compaction depends mainly on the property called "workability of concrete". The slump is a measure indicating the consistency or workability of cement concrete. The conventional slump test as per IS: 1199(1989). In this experimental work, the slump value of fresh concrete was in the range of 80mm to 100mm.

V. TEST RESULTS

Figures 2, 3, 4 and table-iii show the various results of tested concrete specimen with glass powder in cement in different proportions over 28 and 60 days.

TABLE III
Experimental Test Results

Mix	%	Compressive Strength (N/mm^2)	Flexure Strength (N/mm^2)

Notation	replacement of GLP by cement	28 days	60 days	28 days	60 days
C1	**0**	27.01	27.29	-	-
C2	**5**	28.62	28.89	3.49	3.59
C3	**10**	29.81	30.09	3.63	3.65
C4	**15**	31.66	31.90	3.80	3.84
C5	**20**	33.42	33.89	3.98	4.03
C6	**25**	30.51	30.81	4.21	4.25
C7	**30**	24.20	24.41	4.00	4.05
C8	**35**	24.21	22.76	3.59	3.62
C9	**40**	19.01	19.26	3.43	3.47

Figure: 2 Results of Slump Value of Concrete from cement replacement by waste glass powder in %

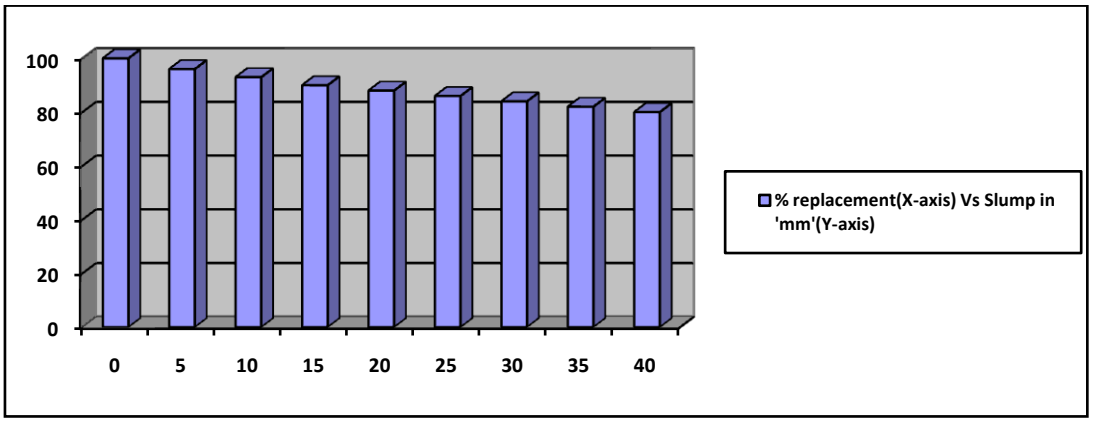


Figure 3: Comparative Compressive strength of Concrete with Cement replacement with Glass Powder for 28 days and 60 days.

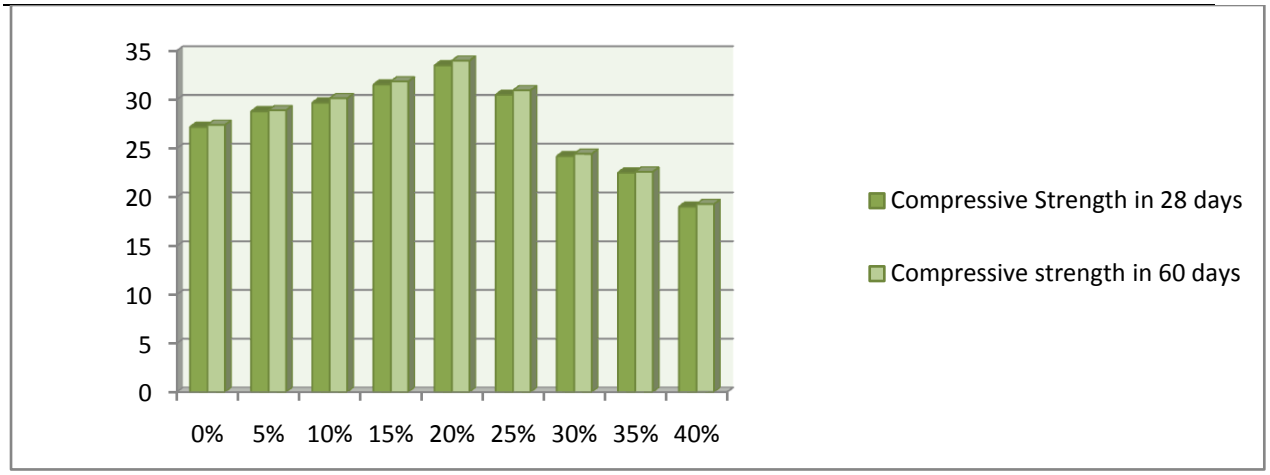
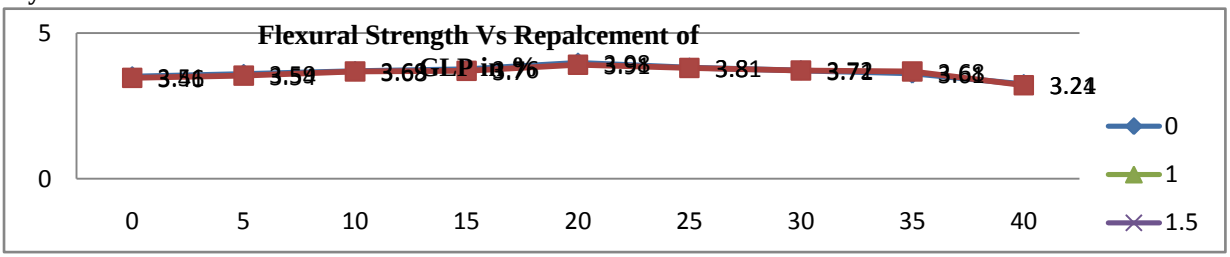


Figure 4: Flexure strength of Concrete with Cement replacement with Glass Powder for 28 days and 60 days.



VI. TEST RESULT DISCUSSION

- Increment in strength was observed with rise in percentage if glass powder up to 20%.
- Highest percentage increases was about 30% in compressive strength.
- Peak percentage increases was about 22% at 20% replacement by GLP in flexure strength.
- Cement replaced beyond 20% by GLP shows decrement in compressive strength.
- Workability of concrete decreases as percentage of glass powder increases.
- Slump value of experiment's concrete ranges from 80 to 100 mm.
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VII. CONCLUSIONS

Based on experimental observations, following conclusions can be established:

- Higher strength was obtained when 20% cement was replaced by waste glass powder.
- Workability decreases as percentage of glass powder increases.
- From strength point of view, replacement of glass powder shows positive results.

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