"Comparative study of waste glass powder as the partial replacement of cement in concrete production-A Laboratory Investigation"

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Abstract: The global cement industry contributes about 7% of greenhouse gases emission 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 and Ground Granulated Blast Furnace Slag. 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. In this study Glass Powder partially replaced at varying percentage 0 to 40, at interval of 10% and tested for its Workability, Compressive Strength, Split Tensile Strength, Alkalinity test, Density Measurement, Water Absorption test, Volume of permeability test, Ultrasonic Pulse Velocity test for the age of 7, 28, 56 days and was compared with those of conventional concrete. The overall test result shows that Waste Glass Powder could be utilized in concrete as a good substitute of cement.

Keywords: *Pozzolana,Strength, SupplementaryCementitious Material, Waste glass powder*.

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1. 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. Glass is an amorphous solid that has been found in various forms for thousands of years and has been manufactured for human use since 1200 BC [1].

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 [2].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 pozzolanic 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 90µm [3]. 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 0% to 40% at interval of 10% each.

2. SIGNIFICANCE OF WORK

The present day world is witnessing the construction of very challenging and aesthetic structures. Concrete is the most important and widely used material as it possesses very high strength and sufficient workability [4]. Glass recycling is the process of turning waste glass into usable products. Disposes of waste glass possesses major problems for municipalities everywhere, and this problem can be greatly eliminated by re-using waste glass as binding material in concrete, by partial replacement of cement.

Moreover, there is a limit on the availability of natural aggregates and minerals used for making cement, and it is necessary to reduce energy consumption and emission of carbon dioxide resulting from construction processes. Solution of this problem is sought through usages of waste glass as partial replacement of Portland cement.

Replacing cement by pozzolanic material like waste glass powder in concrete, not only increases the strength and introduces economy but also enhances the durability [5].

3. DESIGN 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, total of four groups of concrete mixes were prepared in laboratory. First group was cement replacement by glass powder (GLP) having particle size less than 90 µm. The waste glass powder was replaced by 0% to 40% at interval of 10% each and mix design prepared. The used materials were confirmed by IS: 383-1972 [6]. The material details are as follows:

3.1. Cement: In this research, Ordinary Portland Cement type (43 grade) was used conforming to IS 8112throughout the work.

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

3.3. Fine Aggregate: The fine aggregate used in this experimental investigation was clean river sand which is locally available with maximum size of 4.75 mm.

3.4. Coarse Aggregate: The coarse aggregate used for this research work was 20-4.75 mm.

3.5. Waste Glass Powder: Waste glass available locally on Pusad shop was collected and crushed to fine glass powder. Before adding glass powder in the concrete it has to be powdered to required size. In this study glass powder (GLP) having particle size less than 90 µm was used.

4. EXPERIMENTAL WORK AND TEST

4.1. Mix Design: Mix design carried out for M25 grade of concrete by IS 10262:2009 [7], yielded to a mix proportion of 1:2.35:3.04 with water cement ratio of 0.50. Chemical admixtures are not used in experimental work.

4.2. Test Specimens: For each mix 45 cubes of 100mm in size were used to find out compressive strength, density, volume of permeable voids and cylinders of size 150*300mm were used for Split tensile strength and Ultrasonic Pulse Velocity.Before casting the slump test was conducted to assess the workability. Specimens werecast in steel moulds and placed in a room temperature of 20°C for 24 hours until demoulding. Test specimens were tested at 7, 28 and 56 days using compressive testing machine of capacity 2000kN as per IS 516:1959 [8].

4.3. Workability test: The behavior of green or fresh concrete from mixing up to compaction depends mainly on the property called "workability of concrete". Workability represents the amount of work which is to be done to compact the concrete in a given mould. The slump is a measure indicating the consistency or workability of cement concrete. In this experimental work, the slump value of fresh concrete was maintained in the range of 60mm to 80mm. The result shows in Table-5.1.

4.4. Compressive test: In this investigation for compressive strength test, Cube specimen of size 100 x 100 x 100 mm. was used. The concrete cubes were tested by using Compression Testing Machine having capacity of 20 tons confirmed by IS: 516-1959 [8].The results are as shown in figure5.1.

4.5. Split tensile strength test: In this investigation for split tensile strength test, Cylinder specimen of size 150 x 300 mm. were used and the test was confirmed by IS: 5816-1999 [9].The result shows in table 5.5.

4.6. Alkalinity test: After 28 and 56 days curing, the specimens were taken out from curing tank. Specimens were dried in oven at 105°C for 24 hours. Then the dry Specimens were cooled at room temperature. Dry specimen was broken and separated mortar was grinded into powder form. The powder form is sieved in 150µm sieve. From the total prepared sample 10 gm of mortar is taken and it is diluted in 50ml distilled water and completely stirred it. Then pH papers immerse into solution and pH value is noted. The general pH value of the solution and the level of inducing corrosion in the concrete were noted and the results are shown in table-5.2.

4.7. Water Absorption Test: Water absorption of concrete is an important factor in classifying its durability. Generally concrete of low water absorption will afford better protection to reinforcement within it. Glass by nature is an impermeable material, so it could be assume that the presence of glass particles can reduce the permeability of concrete mix. The results are as shown in table-5.3.

4.8. Density of concrete: The density of hardened concrete was determined from a cube at the age of 28 days and 56 days from their mass and measured volume. The measured density was generally lower than the theoretical density of concrete. The results are shown in figure-5.2.

4.9. Volume of permeable voids: The volume of some but all, of these voids can be determined by the weight of absorbed water when a dried sample immersed for a period of time. Those voids that communicate directly with the exterior surface of the sample or are connected to the surface via capillary channels via cracks formed by drying or shrinkage, absorb water upon immersion. These are called the 'permeable pores' and represent the pore space measured by drying followed by immersion. The test conducted for 28, 56 days and the results are shown in table-5.4.

4.10. Non-Destructive test: Ultrasonic Pulse Velocity method consists of measuring the time of travel of an ultrasonic pulse, passing through the concrete to be tested. The test was confirmed by IS: 13311 (Part-I)-1992 [10] and performed on cylindrical specimen for the age of 7, 28 and 56 days. The results are shown in figure-5.3.

5. TEST RESULTS

The concrete specimen prepared with various percentage of replacement of the cement with GLP, such as 0%, 10%, 20%, 30% and 40% were cured under normal conditions as per IS recommendations and were tested at 7, 28 days and 56 days for determining the workability, compressive strength, split tensile strength, density, alkalinity, water absorption, volume of permeable voids and ultrasonic pulse velocity.

Table 5.1
Workability test Results in Millimeter

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Specimen	JJ	JJ1	JJ2	JJ3	JJ4
GLP	0%	10%	20%	30%	40%
Batch-1	79	76	70	68	61
Batch-2	80	75	72	7	4
Batch-3	79	75	74	69	62

TABLE 5.2
Alkalinity test Results

Specimen	JJ	JJ1	JJ2	JJ3	JJ4
GLP	0%	10%	20%	30%	40%
pH Value @ 28Days	12.60	12.68	12.49	12.71	12.97
pH Value @ 56Days	12.62	12.70	12.56	12.73	12.94

TABLE 5.3
Water Absorption test Results

Specimen	JJ	JJ1	JJ2	JJ3	JJ4
GLP	0%	10%	20%	30%	40%
WA Value @ 28Days	4.45%	4.15%	3.47%	2.91%	2.44%
WA Value @ 56Days	3.11%	3.02%	2.59%	1.95%	1.84%

TABLE 5.4
Volume of Permeable Voids (VPV) Results

Specimen	JJ	JJ1	JJ2	JJ3	JJ4
GLP	0%	10%	20%	30 %	40%
VPV @ 28Days	11.40 %	10.53 %	8.90%	7.54 %	6.90%
VPV @ 56Days	8.44%	7.67%	6.43%	5.20 %	4.62%

Figure-5.1 shows the results of **Compressive Strength** in**N/mm^2**of concrete with glass powder replacement in cement in different proportions for **7, 28** and **56** days.

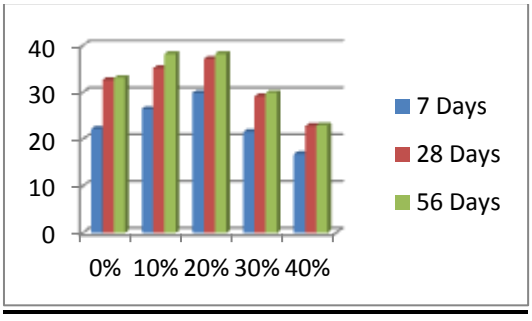


Table shows the results of **Split tensile Strength** in**N/mm^2**of concrete with glass powder replacement in cement in different proportions over**7, 28** and **56** days.

Table 5.5
Split tensile strength test Results in N/mm^2

Specimen		Test Duration

Notation	GLP	7 Days	28 Days	56 Days
JJ	0%	2.56	3.76	3.92
JJ1	10%	2.89	3.98	4.05
JJ2	20%	3.16	4.20	4.32
JJ3	30%	2.34	3.53	3.60
JJ4	40%	2.02	3.31	3.43

Figure-5.2 shows the results of **Bulk Dry Density** in**kg/mm^3**of concrete with glass powder replacement in cement in different proportions over **28** and **56** days.

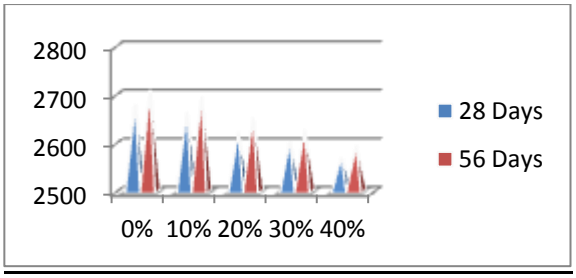
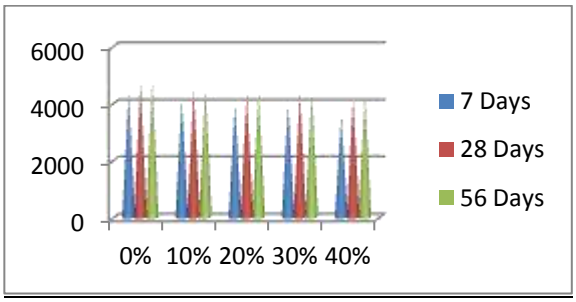


Figure-5.3 shows the results of **Ultra Sonic Pulse Velocity** in**meter/second** of concrete with glass powder replacement in cement in different proportions over**7, 28** and **56** days.



6. CONCLUSIONS & DISCUSSION

Based on experimental observations, following conclusions can be established:-

- Workability of concrete decreases as percentage of glass powder increases.
- Slump value of experiment's concrete ranges from 60 to 80 mm.
- Highest compressive strength was observed when GLP replacement is about 20%.
- Cement replaced beyond 20% by GLP shows decrement in compressive strength.
- Highest split tensile strength was observed when GLP replacement is about 20%.
- The average pH values of different samples were found to be 12.60. This shows alkaline nature of the samples, which offers resistance against corrosion.
- The bulk dry density of specimens decreases with increase in percentage of GLP.

- The water absorption decreases with increment in the amount of GLP.
- The volume of permeable voids decreases with increase in percentage of GLP.
- The ultra-sonic pulse velocity decreases with increment in GLP, which means soundness and durability reduces with increment in GLP.
- Use of waste glass in concrete can prove to be economical as it is non useful waste and available in abundance, and help in solving the problem of disposal of waste glass.

7. FUTURE SCOPE

The suggestion for future scope from this study are as follows:

- Various SCM may be used with waste glass powder as a pozzolona.
- Different sizes of GLP may be used with other pozzolona.
- Different admixtures may be used for the improvement of quality with waste glass powder as SCM.
- Waste glass aggregate may be used with GLP.

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