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Research Paper

EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH WASTE GLASS POWDER ON THE PROPERTIES OF CONCRETE

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Storage and safe disposal of waste glass is a huge problem for municipalities everywhere. Reuse of waste glass eliminates/reduces this problem. In this experimental work, the effect of partially replacing cement in concrete by glass powder is studied. The cement in concrete is replaced by waste glass powder in steps of 5% from 0% to 40% by volume and its effects on compressive strength, split tensile strength, workability and weight density are determined. It is found that the compressive and split tensile strengths of concrete increase initially as the replacement percentage of cement by glass powder increases, become maximum at about 20% and later decrease. The workability and weight density of concrete reduce monotonically as the replacement percentage of cement by glass powder increases. The replacement of cement up to about 30% by glass powder can be done without sacrificing the compressive strength.

Keywords: Concrete, Glass powder, Compressive strength, Split tensile strength, Workability

INTRODUCTION

Glass is a substance that defies easy scientific categorization. It is not a solid, not a gas, and not quite a liquid either. The term glass contains several chemical diversities including soda-lime silicate glass, alkali-silicate glass and boron-silicate glass. It has been estimated that several million tons of waste glasses are generated annually worldwide. The key sources of waste glasses are waste containers, window glasses, windscreen, medicinal and liquor bottles, tube lights, bulbs, electronic equipments, etc. Storage and safe disposal of waste glass is a major problem for municipalities everywhere, and this problem can be reduced or eliminated by reusing the waste glass. Several investigators in India and abroad have researched on the partial replacement of cement with waste glass powder. A few recent studies are mentioned here. Vijayakumar *et al.* (2013) have examined the possibility of using glass powder as a partial replacement of cement for

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concrete. 10%, 20%, 30% and 40% of cement was replaced with glass powder and the concrete was tested for its compressive, tensile and flexural strength up to 60 days of age. They concluded that glass powder can be used as cement replacement material up to particle size less than 75 µm. Patil and Sangle (2013) and Gunalaan Vasudevan and Pillay (2013) have also studied the effect of using waste glass powder in concrete as partial replacement of cement.

EXPERIMENTAL WORK

Waste glass when ground to a very fine powder (Figure 1) shows pozzolanic properties. Finely ground glass has the appropriate chemical composition including SiO_2 to react with alkalis in cement and form cementitious product that helps in strength development. Table 1 gives the composition of waste glass powder and cement. In the present study, the effect of partially replacing cement in M20 concrete (characteristic strength = 20 MPa) with waste glass powder is experimentally investigated. The materials used for production of glass powder concrete are cement, fine aggregate, coarse aggregate, mineral admixture (glass powder), chemical admixture (super-plasticizer) and water. The mix proportion for M20 grade (characteristic strength = 20 MPa) concrete was obtained by Bureau of Indian Standards Method (Krishna Raju, 2012). The mix proportion used for glass powder concrete is 1.00: 2.34: 4.27 with w/c ratio of 0.45, superplasticizer (normal) 2% by the weight of cement. Nine different mixes were made using cement partially replaced with waste glass powder at varying percentages of 0, 5, 10, 15, 20, 25, 30, 35 and 40 by volume. To impart workability to the mix, normal superplasticizer from a reputed company was used with a dosage of 2% by weight of cement. The glass powder was obtained by crushing waste glass pieces in a cone crusher mill. The compressive and split tensile tests were conducted on the concrete specimens in a compression testing machine for 7 days, 28 days and 60 days in accordance with the Bureau of Indian Standards specifications. The compressive

Figure 1: Waste Glass Crushed into Fine Powder

Table 1: Chemical Composition of Glass Powder and Cement

Item	% by mass in	
	Glass Powder	Cement
SiO_2	72.5	20.2
Na_2O	13.7	0.19
CaO	9.7	61.9
Al_2O_3	0.4	4.7
MgO	3.3	2.6
K_2O	0.1	0.82
SO_3	-	3.0
Fe_2O_3	0.2	3.9

strength test was conducted on cube specimens of 150 mm size. The split tensile strength test was conducted on cylindrical specimens of 150 mm diameter and 300 mm height cast and cured in the same manner as the cubes in the compressive test. Two wooden strips were placed, one at the top and the other at the bottom of the specimen as shown in Figure 2 and the cylindrical specimen was loaded. To determine the workability of concrete, slump test was conducted (Figure 3).

Figure 2: Split tensile strength test for concrete cylinder

Figure 3: Slump Test on Concrete

TEST RESULTS

The results of the compressive strength test conducted on concrete cubes are presented in Table 2 and plotted in Figure 4. The results of the split tensile strength test conducted on concrete cylinders are presented in Table 3 and plotted in Figure 5.

Figure 4: Compressive Strength of Concrete Versus Percentage Of Replacement of Cement By Glass Powder

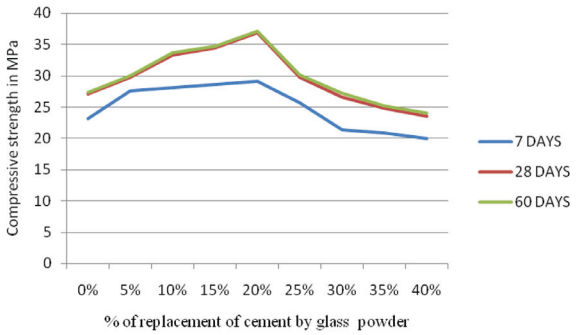
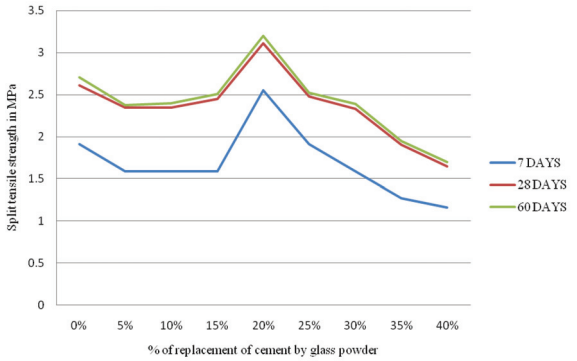


Figure 5: Split Tensile Strength of Concrete Versus Percentage of Replacement Of Cement By Glass Powder



The results of the slump test conducted on concrete are presented in Table 4 and plotted in Figure 6. The results of the density test conducted on concrete are presented in Table 5 and plotted in Figure 7.

DISCUSSION OF TEST RESULTS

From Table 2 and Figure 4, it is observed that

Figure 6: Slump of Concrete Versus Percentage Of Cement Replaced By Glass Powder

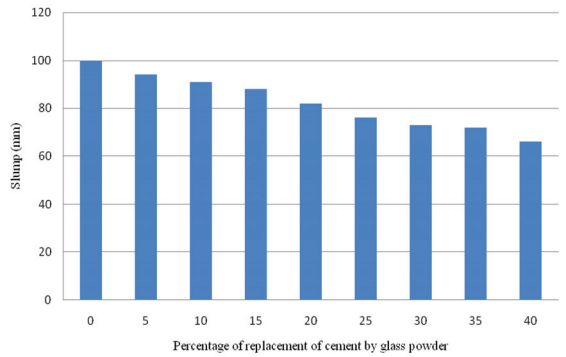
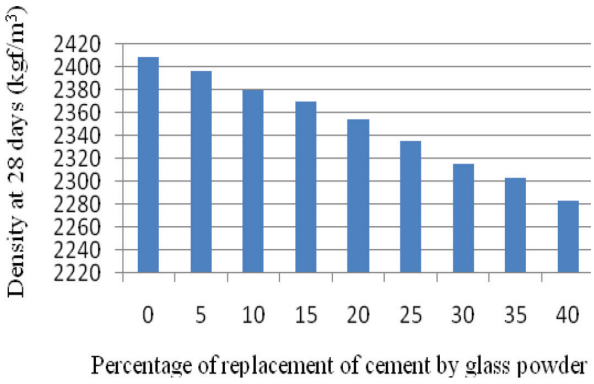


Figure 7: Density of Concrete Versus % of Cement Replaced by Glass Powder



the 7 days, 28 days and 60 days compressive strengths of concrete initially increase as the replacement percentage of cement with glass powder increases, become maximum at about 20% and later decreases. From Table 3 and Figure 5, it is observed that the split tensile strength of concrete initially increases as the replacement percentage of cement with glass powder increases, becomes maximum at about 20% and later decrease. From Table 4 and Figure 6, it is observed that the workability of concrete reduces as the replacement percentage of cement with glass powder increases. From Table 5 and Figure 7, it is observed that the unit weight of concrete decreases monotonically as the replacement percentage of cement with glass powder increases. It is due to the lower value of specific gravity of waste glass (=2.58) when compared with that of cement (=3.15).

Table 2: Compressive Strength of Concrete With Cement Partially Replaced By Glass Powder

Mix Designation	% of Replacement of Cement By Glass powder	7 days	28 days	60 days
Mix-1	0	23.11	27.11	27.33
Mix-2	5	27.55	29.77	30.00
Mix-3	10	28.05	33.33	33.69
Mix-4	15	28.55	34.44	34.70
Mix-5	20	29.10	36.88	37.10
Mix-6	25	25.71	29.77	30.10
Mix-7	30	21.33	26.66	27.20
Mix-8	35	20.88	24.88	25.20
Mix-9	40	20.00	23.55	24.10

Table 3: Split Tensile Strength of Concrete With Cement Replaced Partially By Glass Powder

Mix Designation	% of Replacement of Glass Powder by Cement	7 days	28 days	60 days
Mix-1	0	1.91	2.61	2.71
Mix-2	5	1.59	2.35	2.38
Mix-3	10	1.59	2.35	2.40
Mix-4	15	1.59	2.45	2.51
Mix-5	20	2.55	3.11	3.20
Mix-6	25	1.91	2.48	2.52
Mix-7	30	1.59	2.33	2.39
Mix-8	35	1.27	1.91	1.95
Mix-9	40	1.16	1.65	1.70

Table 4: Slump of Concrete With Cement Replaced Partially By Glass Powder

Mix designation	% of cement Replaced by glass powder	Slump (mm)
Mix-1	0	100
Mix-2	5	94
Mix-3	10	91
Mix-4	15	88
Mix-5	20	82
Mix-6	25	76
Mix-7	30	73
Mix-8	35	72

Table 5: Density of Concrete With Cement Replaced Partially By Glass Powder

Mix designation	% of cement Replaced by glass powder	Weight Density (kgf/m^3)
Mix-1	0	2408
Mix-2	5	2396
Mix-3	10	2379
Mix-4	15	2369
Mix-5	20	2354
Mix-6	25	2335
Mix-7	30	2315
Mix-8	35	2303
Mix-9	40	2283

CONCLUSION

The following conclusions are made based on the above study:

- The 7 days, 28 days and 60 days compressive strengths of concrete increase initially as the replacement percentage of cement with glass powder increases, and become maximum at about 20% and later decreases.
- The split tensile strength of concrete increases initially as the replacement

percentage of cement with glass powder increases, and becomes maximum at about 20% and later decrease.

- The slump and weight density of concrete decrease monotonically as the replacement percentage of cement with glass powder increases. The workability decreases when cement is replaced partially with glass powder.
- The present study shows that there is a great potential for the utilization of glass powder in concrete as partial replacement of cement. About 30% of cement may be replaced with glass powder of size less than 100 µm without any sacrifice on the compressive strength.

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