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Performance evaluation of concrete incorporating glass powder and fly ash as supplementary cementing material

T.R. Danya, J. Sushma
Department of civil engineering, Karpagam college of Engineering , Coimbatore

ABSTRACT- This study shows the property of concrete containing waste glass powder and fly ash as a cement replacement material. The use of wastes or by-product in concrete production has advantages for improving some or all of the concrete properties and utilization of waste products. Waste glass contains about 75.31%, SiO_2.When it was grounded to the fineness of around 90 µm, SiO_2 in it reacts with alkalis in cement (pozzolanic reaction) to form supplementary cementitious products. This work examines the possibility of using Glass powder as a partial replacement of cement for M25 concrete. Glass powder was partially replaced as 10%, 15% and 20% and fly ash content kept constant at 15% and tested for its mechanical properties at 7 and 28 days of age and was compared with those of nominal concrete.

Key words - Fly Ash, glass powder, mechanical properties, supplementary cementitious materials.

1. Introduction

Concrete is the second most consumed materials after water and it shapes our built environment. Popularity of concrete as construction material is on the three counts 1) excellent mouldability 2) adequate strength and 3) amenable to the utilization of local materials as ingredients. Cement industry accounts considerable share for CO_2 emission due to high environmental carbon footprint of cement. The carbon footprint is a measure of the amount of CO_2 released through combustion and expressed as tons of carbon emitted per annum. In order to reduce carbon footprints of cement applications, manufacturers have started looking towards low carbon cements around the world. These cements will use available natural pozzolana, industrial products, inert fillers, reactive powders etc. to replace clinker and improve the quality of constructions. Waste glass and fly ash finds a numerous applications in concrete in a variety of paths and Waste glass can be used as inert filler aggregate with larger sized particles or supplementary cementing material (SCM) with finer particle gradation size less than 90µm [2]. A major concern regarding the use of amorphous glass in concrete is the chemical reaction that takes place between the silica- rich glass particle and the alkali in pore solution of concrete, which is called Alkali-silicate reaction (ASR) that can be very detrimental effects on concrete, unless appropriate precautions are taken to minimize its effects. ASR can be reduced by adding mineral admixtures in the concrete, common mineral admixtures used to minimize ASR are fly ash, silica fume and metakaolin. The scope of work will include studying the performance of waste glass and flyash as partial replacement of Ordinary Portland cement (OPC) in concrete. The results of the investigation will give the mechanical properties of concrete made using waste glass powder and flyash as partial replacement of OPC.

2. Significance

The main importance of the investigation is to use finely ground glass as an excellent filler and pozzolonic behaviour to serve as partial cement replacement. Thus it contributes to higher compressive, tensile and flexural strength compared to conventional concrete. A better understanding of the performance of a cement replacement material such as glass powder and flyash could lead to increased usage of this material, consequently contributing to sustainability.

3. Experimental approach

Experiments were conducted on concrete prepared by partial replacement of cement by waste glass powder of particle size 90µm and flyash. Cement is replaced by 10%, 15% and 20% of waste glass powder and 15% of flyash content was kept constant and the mix design was prepared. The physical and chemical characteristic of the cementitious materials are determined and the workability of concrete and mechanical properties has been computed.

Materials for geopolymer concrete mixture

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Cement

In this investigation, cement which is of the Ordinary Portland cement of 43 grade confirming to IS 8112 was used throughout the work. Physical properties of cement are shown in Table 1.

Table 1 Physical properties of cement

Properties	Results
Specific Gravity	3.14
Normal Consistency	30%
Final Testing Time	260 min
Initial Testing Time	40 min
Fineness	98 %

Fly ash

In this study, local available low calcium class-F fly ash with specific gravity 2.84 is procured from Tuticorin thermal power plant in Tamilnadu. The chemical composition of fly ash as determined by X-ray Fluorescence (XRF) analysis with minimum requirements as per IS 3812: 2003 [17] is given in Table 2. Physical properties are shown in Table 3.

Table 2 Chemical compositions

Chemical compositions	Cement %	Glass powder %	Fly ash %
CaO	63.0	8.83	1.1
SiO_2	22.8	75.31	99.2
$77Al_2O_3$	5.9	1.11	23.33
Fe_2O_3	3.5	-	2.9
MgO	1.5	2.80	0.3
SO_3	2	-	0.3
Alkalies (K_2O,Na_2O)	1	11.18	0.2
LOI	1.5	0.32	1.4

Table 3 Physical properties of class F fly ash and glass powder

Physical properties	Glass powder	Fly ash
Color	white	Grey
Specific gravity	2	2.84
fineness	96%	92%

Glass powder

Glass powder was obtained by crushing available waste glass pieces using a crusher of size 90μm. Chemical composition of glass powder is shown in Table 2.

Aggregate

The fine aggregate used in this investigation was clean river sand, whose max size is 4.75mm the sand was first air-dried in order to reduce its moisture content. Coarse aggregate collected from nearby quarry. Coarse aggregate having size 20mm – 4.75mm was used. Physical properties of aggregate are shown in Table 4.

Table 4 Properties of aggregate

Property	Fine aggregate	Coarse aggregate
Specific gravity	2.6	2.71
Fineness modulus	3.68	4.08
Water absorption	2.24%	0.38%

4. Casting of specimens

For this investigation concrete of grade M25 is taken. The water binder ratio adopted was 0.4 and the mix proportion is found to be 1:1.4:2.4 (cement:FA:CA). The mix design was done in accordance with 10262-2009. The amount of cement replaced by glass powder was 10%, 15% and 20% and the amount of fly ash was maintained constant as 15%. Table 5 shows the mix percentages of the materials.

Table 5 Percentage mix for cementitious materials

Mix	Cement %	Glass powder %	Fly ash %
M1	100	0	0
M2	75	10	15
M3	70	15	15
M4	65	20	15

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5. Results and discussion

Workability

The workability of fresh GPC was determined immediately after mixing of concrete using the slump cone test. It was confirmed that the slump values of concrete at different glass replacement level remained within the target slump range of 80-100 mm without changing the water content. The slump and air content shows a decreasing trend with waste glass addition due to the higher specific surface area and particle shape [3]. Greater the volume of glass powder content less will be the slump value this is due to the fact that glass powder absorbs more water. To overcome these superplasticizers may be used.

Compressive strength

The cube samples of size 150X150X150 mm are tested for compressive strength. The testing is done on a set of three identical samples for each case at the age of 7 and 28 days. The mean values obtained for the compressive strength at different percentage of cementitious materials are represented in Fig. 1. The higher strength achieved for glass powder indicates the enhanced pozzolanic reactivity and pore filler properties leading to higher C-S-H formation[3].

Table 8 Compressive strength results

MIX	Compressive strength (N/mm^2)	
	7 days	28 days
M1	21.11	30
M2	22.67	34
M3	16.44	30.44
M4	15.56	28

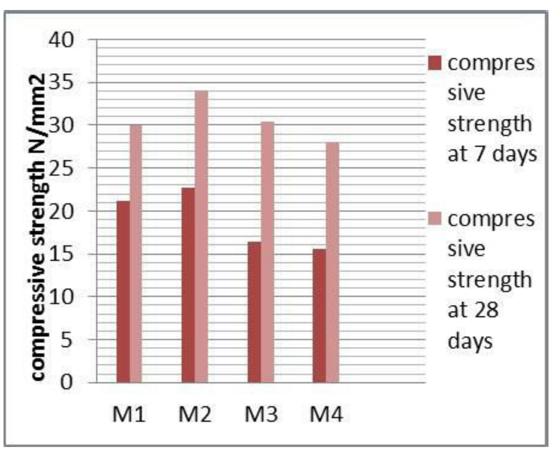

Fig.1. Chart for compressive strength

Fig.2 Testing of cube specimen

Split tensile strength

Cylindrical specimens of diameter 150 mm and length 300 mm were prepared. Tension test was carried out on 1000 KN capacity compression testing machine as per IS 5816-1999. The 28-days split tensile strength of modified concrete is increased by 5.49% at 10% replacement and decreased by 2.75%, 8.24% at 15% and 20% replacement of cement by glass powder compared to conventional concrete.

Table 9 Split tensile strength results

MIX	Split tensile strength (N/mm^2)	
	7 days	28 days
M1	1.56	2.55
M2	1.49	2.69
M3	1.42	2.48
M4	1.27	2.34

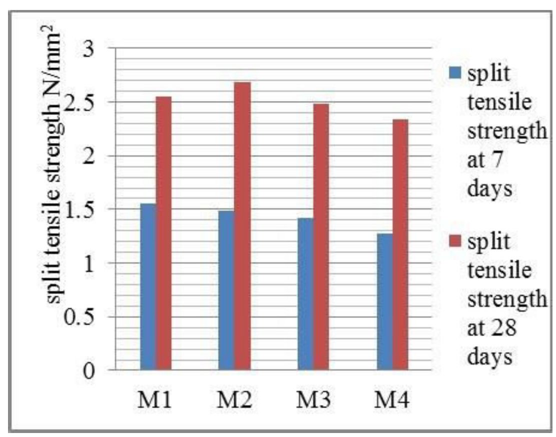

Fig.3 Chart for split tensile strength

Fig.4 Testing of cylinder

Flexural strength

The flexural strength was carried out at 7 and 28 days at beams of size 500 x 100 X 100 mm. At 28 days, the flexural strength of mix M3 with 15% glass powder and 15% fly ash gained better results compared to conventional concrete. This may be due to the pore filler properties and the reaction of fly ash with $Ca(OH)_2$ decomposed at elevated temperatures [13]. The mean values obtained for the flexural strength at different percentage of cementitious materials are represented in Fig. 5.

Table 10 Flexural strength results

MIX	Flexural strength (N/mm^2)	
	7 days	28 days
M1	2.2	3.4
M2	2.4	3.2
M3	2.9	3.6
M4	2.6	3.2

6.

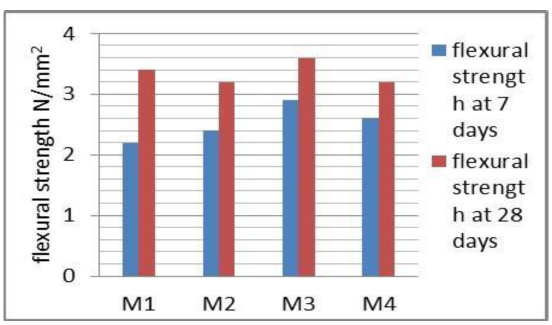

Fig.5 Chart for flexural strength

Fig.6 Testing of beam

Conclusion

In this project mechanical properties of geopolymer concrete and conventional concrete is compared. From the observations of test results following conclusions are made:

1) The 28-days compressive strength of modified concrete is increased by 13.33%, 1.47% at 10% and 15% replacement and decreased by 6.67% at 20% replacement of cement by glass powder compared to conventional concrete.
2) The 28-days split tensile strength of modified concrete is increased by 5.49% at 10% replacement and decreased by 2.75%, 8.24% at 15% and 20% replacement of cement by glass powder compared to conventional concrete.
3) The 28-days flexural strength of modified concrete is increased by 5.88% at 15% replacement and decreased by 5.88% for both 10% and 20% replacement of cement by glass powder compared to conventional concrete.
4) The 28-days compressive strength and split tensile strength of modified concrete reaches the optimum value at 10% replacement of cement by glass powder compared to conventional concrete.
5) The 28-days flexural strength of modified concrete reaches the optimum value at 15% replacement of cement by glass powder compared to conventional concrete.
6) Workability of concrete decreases with the increase in percentage of glass powder because glass powder absorbs more quantity of water.
7) Using Glass powder can reduce the use of cement in concrete and the associated energy demand and impact on air pollution and CO_2 emission.
8) Hence glass powder and fly ash can be used as the replacement materials for cement.

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