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ORIGINAL ARTICLE

Effect of Freezing and Thawing on the Properties of SFRC Containing Waste Glass Powder as Pozzolana

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ABSTRACT

It has been estimated that several million tones of waste glasses are generated annually worldwide. The key sources of waste glasses are waste containers, window glasses, window screen, medicinal bottles, liquor bottles, tube lights, bulbs, electronic equipments etc. Only a part of this waste glass can be used in recycling. The remaining waste glass cannot be used for any purposes. But recently research has shown that the waste glass can be effectively used in concrete either as glass aggregate (as fine aggregate or as coarse aggregate) or as a glass pozzolana. The waste glass when grounded to a very fine powder shows some pozzolanic properties. Therefore the glass powder to some extent replaces the cement and contributes for the strength development. In this experimentation an attempt is made to study the characteristic strength properties of steel fibre reinforced concrete produced by replacing the cement by waste glass powder in various percentages like 0%, 10%, 20%, 30%, and 40% and subjecting it to freezing and thawing cycles. Replacement of 20% cement by glass powder is found to be beneficial when concrete is subjected to freezing and thawing cycles.

KEYWORDS: *Freezing and thawing, steel fibre reinforced concrete, waste glass powder*

INTRODUCTION

Almost every industry produces waste irrespective of the nature of their products. The effective disposal of these wastes is a challenging task ahead. In olden days such wastes were used as land fill materials for the low-lying areas. Waste generation and its disposal in landfill sites are unsustainable. The industrial wastes like fly ash, silica fume, blast furnace slag etc. and other wastes like solid waste, waste plastics, waste glass, waste tiles and other agricultural wastes are causing the environmental pollution in one or the other way. The efficient safe disposal or efficient recycling is one of the challenging tasks ahead of engineers.

The concrete industry, to some extent is making use of these industrial wastes effectively in the production of concrete. For example the use of industrial wastes like flyash, silica fume and blast furnace slag in concrete can act as pozzolana and replace a part of cement. The pozzolanic reaction adds to the strength of concrete and also results in savings of cement. Thus nowadays the cement industries are making use of flyash, silica fume, and blast furnace slag as pozzolanas to replace a part of cement [1].

It has been estimated that several million tones of waste glasses are generated annually worldwide [2]. The key sources of waste glasses are waste containers, window glasses, window screen, medicinal bottles, liquor bottles, tube lights, bulbs, electronic equipments etc. Only a part of this waste glass can be used in recycling. The remaining waste glass cannot be used for any purposes. But recently the research has shown that the waste glass can be effectively used in concrete either as glass aggregate (as fine aggregate or as coarse aggregate) or as a glass pozzolana [3]. The waste glass when grounded to a very fine powder shows some pozzolanic properties. Therefore the glass powder to some extent can replace the cement and contribute for the strength development.

Post consumer and other waste glass types are a major component of the solid waste stream in many countries and most is currently landfilled [3]. Alternatively, waste glass could be used as a concrete aggregate, either as a direct replacement for normal concrete aggregates (low value) or as an exposed, decorative aggregate in architectural concrete products (high value). Expansive alkali silica reactions (ASR) can occur between glass particles and cement paste, particularly in moist conditions and with high alkali cements. This reaction is not confined to glass aggregates but can occur whenever aggregates contain reactive silica. However it is now fairly well accepted that by controlling the reactive silica, cement alkali level and moisture, the reaction can be reduced or totally mitigated [4, 6].

Finley ground glass has the appropriate chemical composition to react with alkalis in cement (pozzolanic reaction) and form cementitious products. The pozzolanic properties are likely to be derived from the high SiO2 content of glass. Powdered glass used in combination with Portland cement contributes to strength development.5 Various suppressants can minimize ASR of glass aggregate concrete. Pulverized fuel ash (Pfa) and metakaolin (MK) can completely eliminate ASR [2]

EXPERIMENTAL PROGRAMME

In this experimentation an attempt is made to study the characteristic strength properties of steel fibre reinforced concrete produced by replacing the cement by waste glass powder in various percentages like 0%, 10%, 20%, 30% and 40% and subjecting it to freezing and thawing cycles.

The properties of cement, fine aggregate and coarse aggregate were shown in table 1. Corrugated steel fibres (length = 40mm, width = 2.2mm, thickness = 0.50mm and aspect ratio = 80) were used at the rate of 1% (by volume fraction). To impart workability a superplasticiser was used at the rate of 1% by weight of cement which is based on sulphonated naphthalene polymers. Glass powder was obtained by crushing the waste glass in a cone crusher mill. Glass powder passing through 600 micron was used for the experimentation. Chemical composition of glass powder is shown in table 2. Different percentage replacement of cement by waste glass powder used in experimentation were 0%, 10%, 20%, 30%, and 40%.

Mix design was carried out for M20 grade of concrete by IS 10262:1982[7], which yielded a mix proportion of 1:1.34:3.2 with a water cement ratio of 0.45.Specimens were prepared according to the mix proportion and by replacing cement by glass powder in different proportions. Entire mix was dry mixed by adding 1% steel fibres (by volume fraction) and then water was added (w/c=0.45) along with superplasticizer at a dosage of 1% (by weight of cement).The entire mix was homogeneously mixed and specimens were cast.

For the resistance to freezing and thawing, specimens after their 60 days of curing were transferred to a cold storage unit where in a temperature of -18°C was maintained. Before transferring them in to the cold storage they were weighed accurately. Test specimens were kept for freezing for 5 days and kept in water for 1 day for thawing. After finishing of 15 cycles they were again weighed accurately and then transferred to a curing tank for one day. Percentage weight loss was calculated and the specimens were tested for their respective strengths like compressive, tension, flexural and impact strength.

To find out the compressive strength, specimens of dimensions 150mmX150mmX150mm were cast and tested under compressive testing machine of capacity 2000 KN as per IS 516:1959 [8]. To find out tensile strength, cylindrical specimens of dimensions 150mm diameter and 300mm length were cast. Split tensile strength was obtained by testing the specimens on CTM of capacity 2000 KN as per IS 5816:1999 [9]. To find out the flexural strength, specimens of dimensions 100mmX100mmX500mm were cast. Two point loading was adopted on an effective span of 400mm and tested as per IS 516:1959 [8].For impact strength test, specimens were of dimension 150 mm diameter and 60 mm height. Drop weight test was adopted for testing impact specimen using Shrudders impact testing machine. They were kept in Shrudder's impact testing machine and the hammer weighing 4.54 kg was dropped from a height of 457 mm. Number of blows required to cause first crack and final failure were noted down. Impact energy is calculated by the following formula.

Impact energy = WhN (N-m)

Where W = Weight of ball in N= 45.4 N

h = Height of fall in metres = 0.457 m

N = Number of blows required to cause first crack or final failure

TEST RESULTS

Table 3, 4, 5 and 6 and Fig 1, 2, 3 and 4 show respectively the compressive strength, tensile strength, flexural strength and impact strength test results of steel fibre reinforced concrete when the cement is replaced by waste glass powder in different proportions and with and without subjecting to freezing and thawing cycles.

DISCUSSIONS ON TEST RESULTS

1. It is observed that higher compressive strength for SFRC can be obtained when 20% cement is replaced by glass powder without subjecting the SFRC to any freezing and thawing cycles and the approximate percentage increase in the compressive strength is found to be 16%. After 20% replacement of cement by glass powder the compressive strength decreases.
   Similar trends are observed for tensile strength, flexural strength and impact strength when SFRC is not subjected to freezing and thawing cycles. Approximate percentage increase in tensile strength, flexural strength and impact strength of SFRC for 20% replacement of cement by waste glass powder without subjecting it to freezing and thawing cycles are found to be 12 %, 12% and 25% respectively.
   This may be due to the fact that 20% replacement of cement by glass powder may give rise to maximum pozzolanic reaction and hence contributes towards more strength. Also it may be due to the fact that 20% replacement of cement by glass powder may fill all the voids.
   Thus, it can be concluded that 20% replacement of cement by glass powder will result in higher strengths for SFRC.
2. It is observed that higher compressive strength for SFRC can be obtained when 20% cement is replaced by glass powder and when it is subjected to 15 cycles of freezing and thawing for 90 days and the approximate percentage increase in the compressive strength is found to be 16%. After 20% replacement of cement by glass powder the compressive strength decreases.
   Similar trends are observed for tensile strength, flexural strength and impact strength when SFRC is subjected to freezing and thawing cycles. Approximate percentage increase in tensile strength, flexural strength and impact strength of SFRC for 20% replacement of cement by waste glass powder when subjected to freezing and thawing cycles are found to be 26%, 5 % and 25% respectively.
   This may be due to the fact that 20% replacement of cement by glass powder may give rise to maximum pozzolanic reaction and hence contribute towards more resistance to freezing and thawing. Also it may be due to the fact that 20% replacement of cement by glass powder may fill all the voids.
   Thus, it can be concluded that 20% replacement of cement by glass powder will result in SFRC which can resist the freezing and thawing pressures in a better way.
3. It is observed that there is a decrease in the strength properties (compression, tension, flexure and impact) of SFRC when subjected to 15 cycles of freezing and thawing as compared to SFRC without subjecting to freezing and thawing cycles.
   This may be due to the fact of conversion of droplets of water into icelets which cause pressure in the concrete and result in minute cracks. These minute cracks affect the strength characteristics of SFRC subjected to freezing and thawing cycles.
   Thus, it can be concluded that the freezing and thawing cycles will affect the strength properties of SFRC containing glass powder.

Table 1: Properties of materials

Properties of cement	Properties of sand	Properties of coarse aggregate
Type = 43 grade OPC Specific gravity = 3.15 Initial setting time=100 minutes Final setting time = 300 minutes Compressive strength of mortar cubes a. 7days = 35 00 MPa b. 28 days = 48.00 MPa	Specific gravity = 2.62 Class = zone II	Specific gravity =2.93 Size = 12 mm and down size

Table 2: Oxide content for waste glass

Oxide	Content (%)
SiO_2	72
Na_2O	14
CaO	9
Al_2O_3	2
MgO	2.2
K_2O	0.5
Fe_2O_3	0.2
Cr, S, and Co	0.1

Table 3: Compressive strength test results

Percentage replacement of cement by glass powder	SFRC without subjecting to freezing and thawing		SFRC subjected to freezing and thawing		Percentage decrease of compressive strength when subjected to freezing and thawing	Percentage weight loss when subjected to freezing and thawing
	Compressive strength (MPa)	Percentage increase or decrease in compressive strength w.r.t. ref.mix	Compressive strength (MPa)	Percentage increase or decrease in compressive strength w.r.t. ref.mix		
0%(Ref. mix)	37.18	-	34.22	-	8	4
10%	38.81	+4	36.10	+11	7	3
20%	43.25	+16	39.85	+16	8	2
30%	40.59	+9	36.00	+5	11	3
40%	35.55	-4	33.19	-3	7	4

Table 4: Tensile strength test results

Percentage replacement of cement by glass powder	SFRC without subjecting to freezing and thawing		SFRC subjected to freezing and thawing		Percentage decrease of tensile strength when subjected to freezing and thawing
	Tensile strength (MPa)	Percentage increase or decrease in tensile strength	Tensile strength (MPa)	Percentage increase or decrease in tensile strength	
0%(Ref. mix)	6.18	-	4.34	-	30
10%	6.33	+2	4.89	+13	23
20%	6.92	+12	5.45	+26	21
30%	6.68	+8	4.44	+2	34
40%	6.00	-3	4.14	-5	31

Table 5: Flexural strength test results

Percentage replacement of cement by glass powder	SFRC without subjecting to freezing and thawing		SFRC subjected to freezing and thawing		Percentage decrease of flexural strength when subjected to freezing and thawing
	Flexural strength (MPa)	Percentage increase or decrease in flexural strength	Flexural strength (MPa)	Percentage increase or decrease in flexural strength	
0%(Ref. mix)	6.84	-	6.00	-	12
10%	7.07	+3	6.16	+3	13
20%	7.64	+12	6.28	+5	18
30%	6.27	-8	5.32	-11	15
40%	5.73	-16	5.20	-13	9

Table 6: Impact strength test results

Percentage replacement of cement by glass powder	SFRC without subjecting to freezing and thawing				SFRC subjected to freezing and thawing				Percentage decrease of impact energy when subjected to freezing and thawing	
	Average impact energy required to cause (N-m)		Percentage increase or decrease in impact energy with respect to reference mix		Average impact energy required to cause (N-m)		Percentage increase or decrease in impact energy with respect to reference mix			
	first crack	final failure	first crack	final failure	first crack	final failure	first crack	final failure	first crack	final failure
0% (Ref. mix)	4730.49	5269.94	-	-	4253.86	4744.32	-	-	10	10
10%	5394.42	5767.88	+14	+9	4647.00	5263.00	+9	+11	14	9
20%	6348,82	6570.13	+35	+25	5740.20	5927.00	+35	+25	10	10
30%	6023.77	6113.68	+27	+16	5525.85	5588.13	+30	+18	8	9
40%	5726.39	6009.94	+21	+14	5166.2	5491.35	+21	+16	10	9

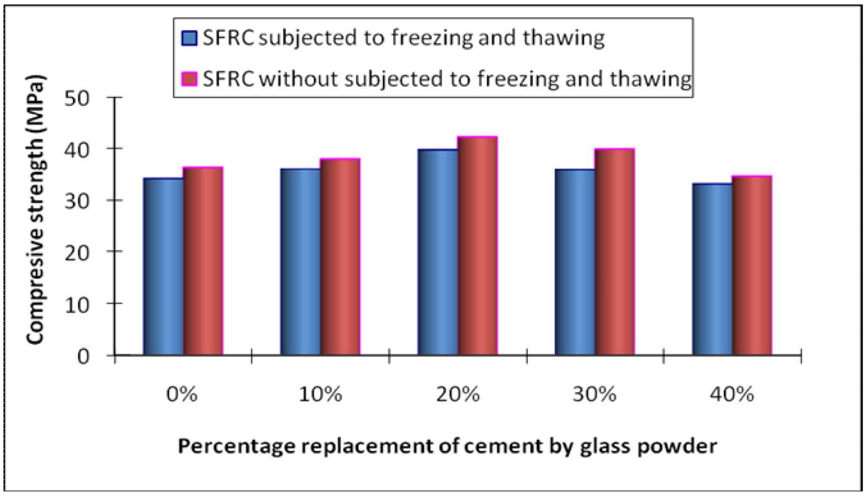

Fig.1: Variation of compressive strength of SFRC with and without subjecting to freezing and thawing

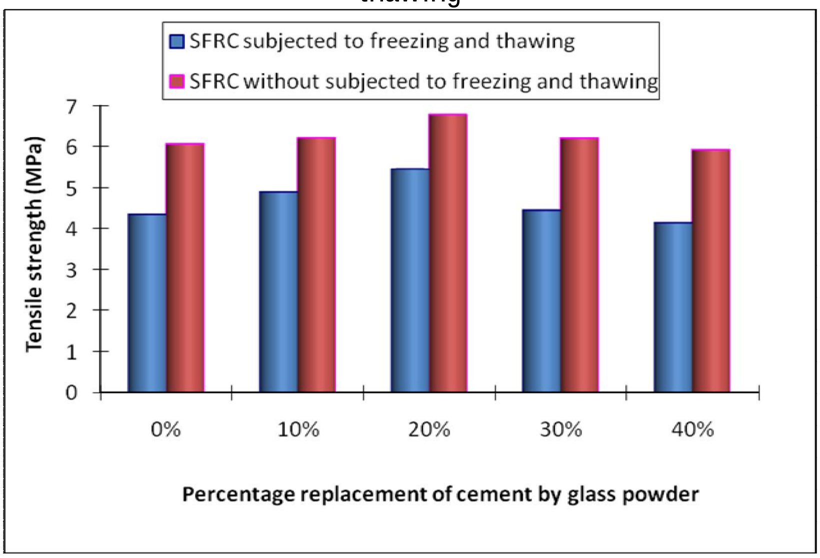

Fig.2: Variation of tensile strength of SFRC with and without subjecting to freezing and thawing

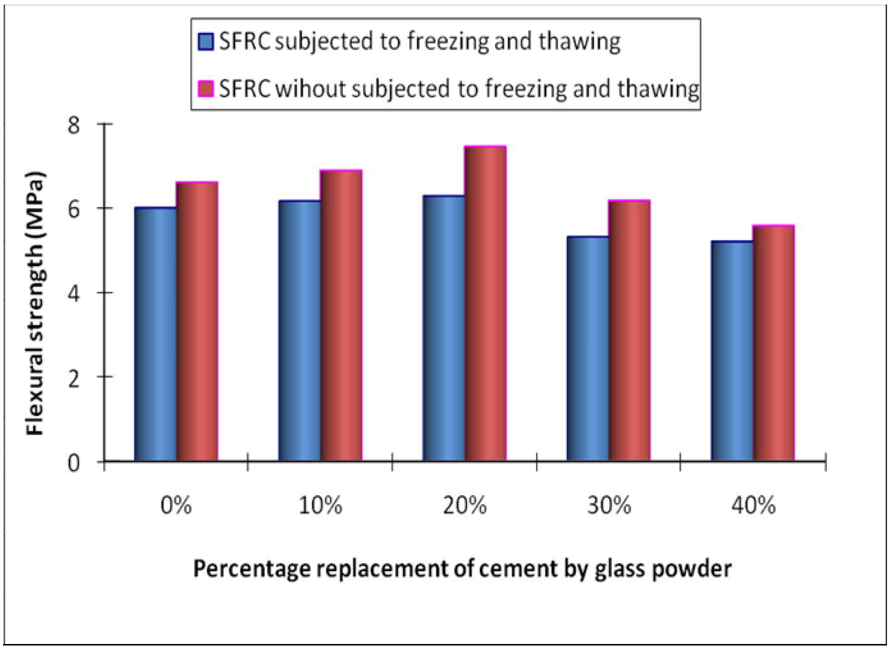

Fig.3: Variation of flexural strength of SFRC with and without subjecting to freezing and thawing

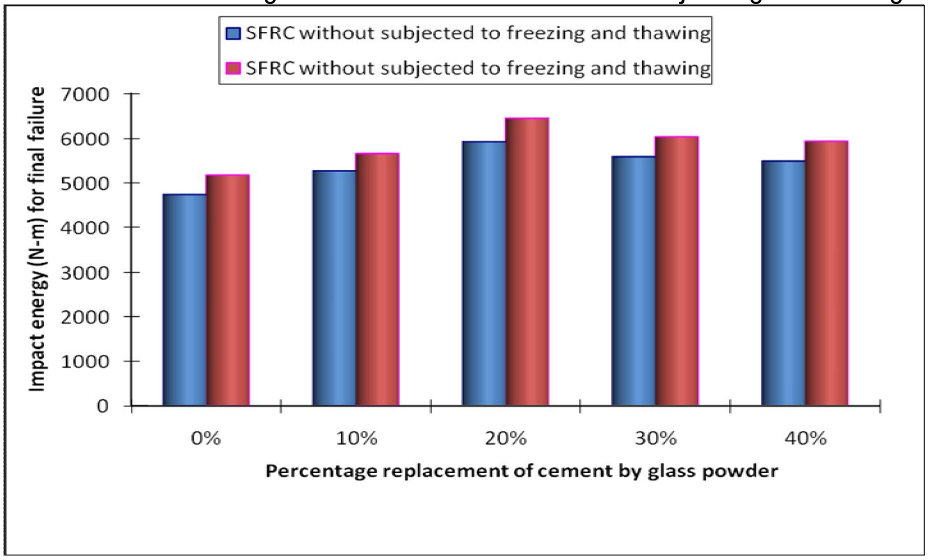

Fig.4: Variation of impact energy (for final failure) of SFRC with and without subjecting to freezing and thawing

CONCLUSIONS

Following conclusions may be drawn based on experimental observations.

1. 20% replacement of cement by glass powder will result in higher strengths for SFRC.
2. 20% replacement of cement by glass powder will result in SFRC which can resist the freezing and thawing pressures in a better way.
3. Freezing and thawing cycles will affect the strength properties of SFRC containing glass powder.
4. SFRC containing glass powder can be recommended for the construction of pavements in cold countries where freeze –thaw action is predominant.

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