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Effect of Temperature On The Properties Of Concrete Containing 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 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. 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. In this paper an attempt is made to find out the effect of temperature on the properties of concrete containing waste glass powder as pozzolana. The cement is replaced by glass powder in different percentages like 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40%. 20% replacement of cement by glass powder is found to be beneficial when concrete is subjected to temperature.

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 SiO_2 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. Pulverised fuel ash (Pfa) and metakaolin (MK) can completely eliminate ASR.[2]

EXPERIMENTAL PROGRAMME

In this paper an attempt is made to find out the effect of temperature on the properties of concrete containing waste glass powder as pozzolana. The cement is replaced by glass powder in different percentages like 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40%. The properties of concrete containing waste glass powder as pozzolana is found when it is subjected to high temperature of 200^0 C and 500^0 C for 12 hours.

In the experimentation 43 grade OPC was used. Locally available sand and coarse aggregate were used in the experimentation. The specific gravity of sand was found to be 2.62 and was zone II sand. The specific gravity of coarse aggregate was found to be 2.93.The coarse aggregate used were of 12mm and down size. To impart workability a superplasticiser Conplast SP 430 was used at the rate of 1% by weight of cementitious materials. The glass powder was obtained by crushing waste window glasses. The waste window glasses were first crushed in Jaw crusher and then they were fed in to ball mill to get more fine powder. The glass powder passing through 600 micron was used for the experimentation. The chemical composition of glass powder is shown in table 1. The different percentage replacement of cement by waste glass powder used in experimentation were 0%,5%,10%,15%,20%,25%,30%,35% and 40%. The mix design was carried out for M20 grade of concrete as per IS 10262:1982[7], which yielded a mix proportion of 1:1.34:3.2 with water cement ratio of 0.45.

The effect of temperature on compressive strength, tensile strength, flexural strength and impact strength were found. For compressive strength, the specimens of dimensions 150 x 150 x 150 were cast. These specimens were tested on compressive testing machine of capacity 2000 KN as per IS 516:1959[8]. For tensile strength, specimens of 150mm diameter and 300mm length were cast. Split tensile strength was obtained by testing the specimens on compressive testing machine of capacity 2000 KN as per IS 5816:1999[9]. For flexural strength, the specimens of dimension 100mm x 100mm x 500mm were cast. Two point loading was adopted on an effective span of 400mm as per IS 516:1959[8]. Impact strength test was conducted on specimens of dimension 150mm diameter and 60mm height. A hammer weighing 4.54 kg (45.4N) was dropped from a height of 0.457m at the centre point of impact specimen, which was kept on the ground. Number of blows required to cause first crack and final failure were noted down from which impact energy was calculated from Eq. 1

$$\text{Impact energy} = WhN \text{ (N-m)} \quad (1)$$

Where W=Weight of ball in N=12.2N

h=Height of fall in metres=1m

N=Average no. of blows required to cause first crack or final failure.

The specimens were cured for 60 days in water. After 60 days of curing, they were weighed and transferred to oven. A constant temperature of 200^0 C and 500^0 C was maintained in the oven for 12 hours. After 24 hours the specimens were removed from the oven and they were accurately weighed. The specimens were observed for change in colour and for hairy cracks. Then they were taken out of oven, cooled for one day and tested for respective strengths.

TEST RESULTS

Table 2,3,4,5, and fig. 1,2,3 and 4 show respectively compressive strength, tensile strength, flexural strength and impact strength test results of concrete when the cement is replaced by waste glass powder in different proportions and when subjected to high temperature of 200^0 C and 500^0 C for 12 hours.

DISCUSSION ON TEST RESULTS

1. It is observed that higher compressive strength for concrete can be obtained when 20% cement is replaced by glass powder without subjecting to high temperature and the percentage increase in the compressive strength is found to be 24%. 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 concrete is not subjected to high temperature. Percentage increase in tensile strength, flexural strength and impact strength (final failure) of concrete for 20% replacement of cement by waste glass powder without subjecting it to high temperature are found to be 30%, 25% and 89% 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 most of the voids.

   Thus it can be concluded that the higher strengths can be achieved when 20% cement is replaced by glass powder in concrete.

2. It is observed that the concrete produced with replacement of cement by 20% of glass powder shows more

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resistance when subjected to a temperature of 200˚C for 12 hours. Compressive strength of SFRC is higher when 20% cement is replaced by glass powder and the percentage increase in the compressive strength is found to be 26% as compared to reference mix. After 20% replacement of cement by glass powder the compressive strength decreases.

Similar trends are observed for tensile strength, flexural strength and impact strength (final failure) of concrete produced with replacement of cement by 20% of glass powder and subjected to a temperature of 200˚C for 12 hours. At 20% replacement concrete shows more resistance when subjected to a temperature and the percentage increase in tensile strength, flexural strength and impact strength (final failure) for 20% replacement of cement by waste glass powder are found to be 44%, 24% and 92% respectively.

This may due to the fact that 20% replacement of cement by glass powder may give rise to maximum pozzolanic reaction which gives the concrete a potential to resist the temperature.

Thus it can be concluded that better resistance to a temperature of 200˚C for 12 hours for concrete can be obtained with 20% replacement of cement by glass powder.

3. It is observed that the concrete produced with replacement of cement by 20% of glass powder shows more resistance when subjected to a temperature of 500˚C for 12 hours. Compressive strength of concrete is higher when 20% cement is replaced by glass powder and the percentage increase in the compressive strength is found to be 27% as compared to reference mix. After 20% replacement of cement by glass powder the compressive strength decreases.

   Similar trends are observed for tensile strength, flexural strength and impact strength (final failure) of concrete produced with replacement of cement by 20% of glass powder and subjected to a temperature of 500˚C for 12 hours. At 20% replacement concrete shows more resistance when subjected to a temperature of 500˚C for 12 hours and the percentage increase in tensile strength, flexural strength and impact strength (final failure) for 20% replacement of cement by waste glass powder are found to be 41%, 22% and 110% respectively. After 20% replacement of cement by glass powder the strength of concrete decreases.

   This may due to the fact that 20% replacement of cement by glass powder may give rise to maximum pozzolanic reaction and effectively resist the expansion caused by the temperature.

   Thus it can be concluded that better resistance to a temperature of 500˚C for 12 hours for concrete can be obtained with 20% replacement of cement by glass powder.

4. It is observed that concrete produced by replacing cement by glass powder and when subjected to 500˚C for 12 hours shows drastic reduction in the strength properties as compared to that of specimens which are not subjected to temperature effect. Also it is observed that there is no much reduction in the strength properties when subjected to 200˚C.

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This may be due to the fact that at 500˚C the concrete may start loosing the water causing dehydration. This results in improper bond or cohesion of different constituent materials.

Thus it can be concluded that the strength properties will be seriously affected when concrete produced by replacing cement by glass powder is subjected to a temperature of 500˚C for 12 hours.

7.6 Conclusions

Following conclusions may be drawn based on experimental observations.

1. Higher strengths can be achieved when 20% cement is replaced by glass powder in concrete.
2. 20% replacement of cement by glass powder in concrete induce better resistance to high temperature of 200˚C for 12 hours
3. 20% replacement of cement by glass powder in concrete induce better resistance to high temperature of 500˚C for 12 hours

4. Strength properties will be seriously affected when concrete produced by replacing cement by glass powder is subjected to high temperature of 500˚C for 12 hours.

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9.IS 5816:1999, "Splitting tensile strength of concrete method of test".

Table 1**:** 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

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Table 2: Compressive strength test results with and without subjecting to high temperature

Percentage replacement of cement by glass powder	Concrete without subjecting to temp		Concrete subjected to 200˚C for 12 hours				Concrete subjected to 500˚C for 12 hours			
	Compressive strength (MPa)	Percentage increase or decrease of comp strength w.r.t. ref.mix	Average percentage weight loss	Comp strength (MPa)	Percentage increase or decrease of comp strength w.r.t.ref.mix	Percentage decrease of comp strength when subjected to temperature	Average percentage weight loss	Comp strength (MPa)	Percentage increase or decrease of comp strength w.r.t.ref.mix	Percentage decrease of comp strength when subjected to temperature
0%(Ref.mix)	26.81	-	1.95	25.20	---	6	4.92	22.68	---	15
5%	28.29	+6	1.44	27.15	+8	4	3.60	24.43	+8	14
10%	29.48	+10	1.14	28.30	+12	4	2.63	25.40	+12	14
15%	31.25	+17	1.06	30.00	+19	4	2.3	26.80	+18	14
20%	33.18	+24	0.56	31.78	+26	4	2.27	28.73	+27	13
25%	30.22	+13	1.00	29.01	+15	4	2.64	26.14	+15	13
30%	23.99	-11	1.27	23.24	-8	3	3.77	20.96	-8	13
35%	22.22	-17	1.40	21.55	-14	3	3.95	19.62	-14	12
40%	18.81	-30	1.71	18.15	-28	4	5.23	16.80	-26	11

Table 3: Tensile strength test results with and without subjecting to high temperature

Percentage replacement of cement by glass powder	Concrete without subjecting to temp		Concrete subjected to 200˚C for 12 hours				Concrete subjected to 500˚C for 12 hours			
	Tensile strength (MPa)	Percentage increase or decrease of tensile strength w.r.t. ref.mix	Average percentage weight loss	Tensile strength (MPa)	Percentage increase or decrease of tensile strength w.r.t.ref.mix	Percentage decrease of tensile strength	Average percentage weight loss	Tensile strength (MPa)	Percentage increase or decrease of tensile strength w.r.t.ref.mix	Percentage decrease of tensile strength
0%(Ref.mix)	3.91	-	2.95	3.34	---	15	3.79	2.87	---	27
5%	4.24	+8	1.74	3.62	+8	15	3.37	3.09	+8	27
10%	4.43	+13	1.40	4.05	+21	9	3.05	3.44	+20	22
15%	4.81	+23	1.08	4.60	+38	4	4.98	3.88	+35	19
20%	5.09	+30	0.80	4.80	+44	6	2.88	4.05	+41	20
25%	4.29	+10	0.59	4.06	+22	5	2.80	3.60	+17	22
30%	3.60	-8	1.18	3.40	+14	6	2.96	3.22	+12	11
35%	3.07	-21	1.56	2.92	-6	5	3.11	2.72	-5	11
40%	2.79	-29	1.90	2.61	-16	6	3.68	2.40	-16	14

Table 4: Flexural strength test results with and without subjecting to high temperature

Percentage replacement of cement by glass powder	Concrete without subjecting to temp		Concrete subjected to 200˚C for 12 hours				Concrete subjected to 500˚C for 12 hours			
	Flexural strength (MPa)	Percentage increase or decrease of flexural strength w.r.t. ref.mix	Average percentage weight loss	Flexural strength (MPa)	Percentage increase or decrease of flexural strength w.r.t.ref.mix	Percentage decrease of flexural strength when subjected to temperature	Average percentage weight loss	Flexural strength (MPa)	Percentage increase or decrease of flexural strength w.r.t.ref.mix	Percentage decrease of flexural strength when subjected to temperature
0%(Ref.mix)	4.78	-	4.65	3.88	---	19	4.38	3.36	----	30
5%	5.13	+7	2.51	4.16	+7	19	3.82	3.60	+7	30
10%	5.56	+16	2.00	4.45	+14	20	2.48	3.89	+16	30
15%	5.75	+20	1.64	4.56	+18	21	2.07	3.97	+18	31
20%	5.92	+25	1.55	4.82	+24	19	1.67	4.11	+22	31
25%	5.28	+9	2.31	4.36	+12	16	2.43	3.72	+11	29
30%	4.68	-2	2.48	3.78	-3	19	3.14	3.28	-2	30
35%	3.77	-21	2.72	3.25	-16	14	3.71	2.90	-14	23
40%	3.18	-33	3.35	2.70	-30	15	3.74	2.45	-27	23

Table5: Impact strength test results strength with and without subjecting to high temperature

Percentage replacement of cement by glass powder	Concrete without subjecting to temp				Concrete subjected to 200˚C for 12 hours					Concrete subjected to 500˚C for 12 hours				
	Impact energy required to cause (N-m)		Percentage increase or decrease of impact energy w.r.t.ref.mix		Impact energy required to cause (N-m)		Percentage increase or decrease of impact energy w.r.t.ref.mix		Percentage decrease of impact energy when subjected to temp	Impact energy required to cause (N-m)		Percentage increase or decrease of impact energy w.r.t.ref.mix		Percentage decrease of impact energy when subjected to temp
	first crack	final failure	first crack	final failure	first crack	final failure	first crack	final failure	final failure	first crack	final failure	first crack	final failure	final failure
0%	165.98	248.97	---	---	110.58	179.67	---	---	28	96.68	138.18	---	---	45
5%	179.67	331.96	+8	+33	138.18	221.17	+25	+23	33	110.58	179.67	+14	+30	46
10%	248.97	373.46	+50	+50	179.67	248.97	+62	+39	33	138.18	207.47	+43	+50	44
15%	318.06	401.05	+92	+61	221.17	276.57	+100	+54	31	193.57	248.97	+100	+80	38
20%	359.55	470.14	+117	89	248.97	345.66	+126	+92	31	207.47	290.46	+115	+110	38
25%	248.97	373.46	+50	+50	138.18	248.97	+25	+39	33	124.48	193.57	+29	+40	48
30%	193.57	235.07	+17	-6	96.68	165.98	-13	-8	29	82.99	138.18	-14	0.00	41
35%	179.67	221.17	+8	-11	82.99	138.18	-25	-23	38	69.09	110.58	-29	-20	50
40%	152.08	207.47	-8	-17	82.99	96.68	-25	-46	53	69.09	82.99	-29	-40	60

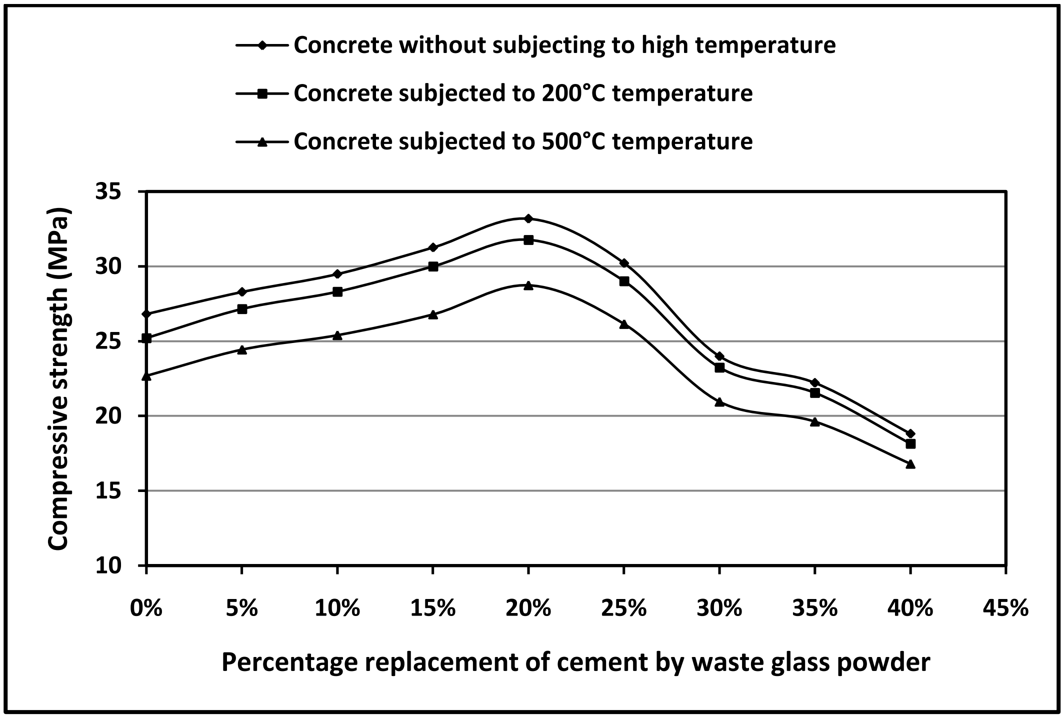

Fig. 1: Variation of compressive strength of concrete when cement is replaced by waste glass powder and when subjected to temperature

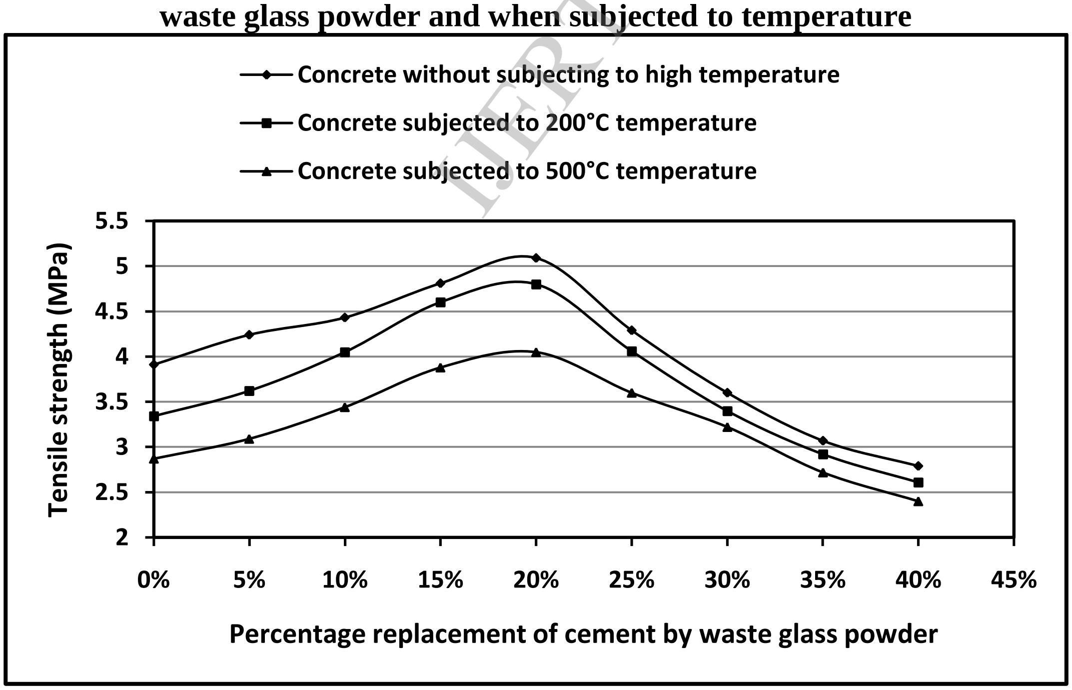

Fig 2: Variation of tensile strength of concrete when cement is replaced by glass powder and when subjected to temperature

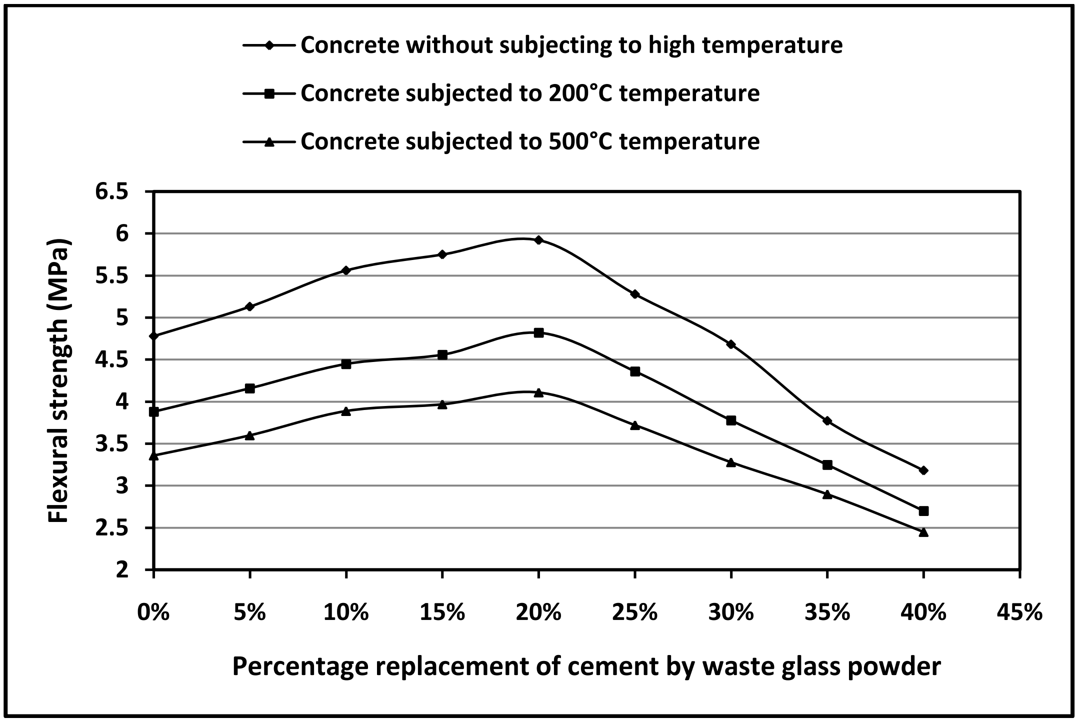

Fig3 Variation of flexural strength of concrete when cement is replaced by glass powder and when subjected to temperature

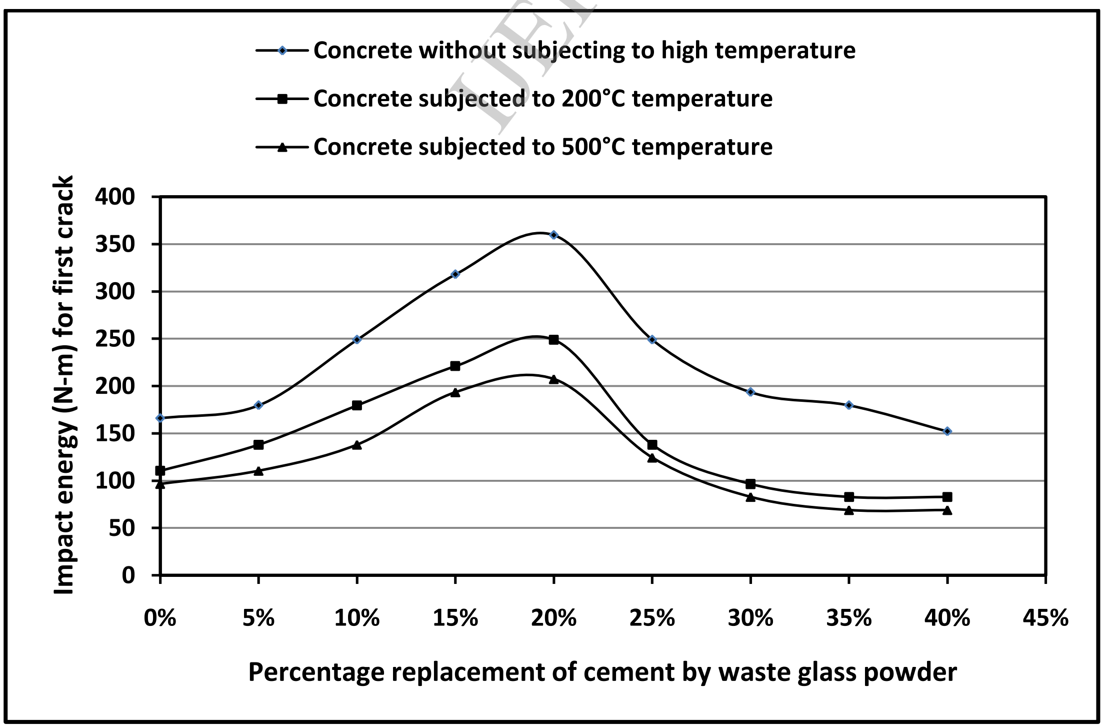

Fig 4: Variation of impact energy of concrete when cement is replaced by glass powder and when subjected to temperature

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