Experimental Investigation on Self Compacting Concrete Using Glass Powder

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ABSTRACT

Self compacting concrete is a type of concrete that get's under its self weight. It is commonly abbreviated as the concrete. Which can placed and compacted in to every corner of a formwork; purely means of its self weight by eliminating the need of either external energy input from vibrators or any type of compacting effort.There is a current trend in all over the world to utilize the treated and untreated industrial by- products, domestic wastes etc. as raw materials in concrete. These not only help in the reuse of the waste materials but also create a cleaner and greener environment. This study aims to focus on the possibility of using waste material in a preparation of innovative concrete. One kind of waste was identified: Glass Powder (GP). The use of this waste (GP) was proposed in different percentage as an instead of cement for production of self compacting concrete. The paper deals with the ingredient of these mixtures (Glass powder, fly ash, super plasticizer, cement) by examining their specific role in self compacting concrete.

Keywords – Glass Powder (GP), Self Compacting Concrete (SCC), Self Compactability, Compressive strength, Flexural strength

1. INTRODUCTION

Worldwide, the use of self-compacting concrete (SCC) has gained wide acceptance in the precast industry, which has many advantages such as: reduces the total time of construction and the costs, improves work conditions by eliminating vibration, makes easier to achieve a better final product (finish and durability), allows the use of complex molds and parts with congested reinforcements [1,2,6].

Nowadays, the ecological trend aims at limiting the use of natural raw materials in the field of building materials and hence there is an increased interest in the use of alternative materials (waste) from industrial activities, which presents significant advantages in economic, energetic and environmental terms. Concrete's performances have continuously rise in order to accomplish the society needs. Many studies have been made concerning the use of additives and super–plasticizers in the concrete for passing the frontier of minimum water content for a good workability of a concrete. As a result of this, high performance concretes developed having a superior durability. Self-compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same mechanical properties and durability as traditional vibrated concrete.

Usually, SCC mixtures have high contents of fines in order to obtain the required rheological properties to achieve self compactability, which usually results in mixtures with high content of Portland cement, and consequently, high values of initial and final strength, much higher than those strictly required by the project. Thus, the costs of the components that constitute a SCC are higher than those of conventional concrete of equal strength.

Other researchers, actuating on the fines content (physical process) obtained medium strength SCC using different types of additions in partial replacement of cement: high percentages of residual quarry limestone powder [4], high percentages of fly ash [2,6], a combination of fly ash and granulated blast furnace slag [7] or fly ash and limestone filler. The aim of this work is to study SCC of medium characteristic strength, in order to encourage its implementation in ''in situ'' construction.

Due to urbanization and industrialization, large amount waste glass is produced every year in the world Due to the high cost of cleaning and colour sorting, only a tiny proportion can be recycled by conventional markets like container manufacture. Most waste glass is sent to landfill as residue. Since glass is not biodegradable, landfills do not provide an environmental friendly solution. The increasing trend has raised social and environmental concerns, resulting in a growing interest in the recycling of waste glass. Crushed or ground glass, ranging from powder to coarse aggregate, has been used in NVC for many years.

The slump of concrete in which cement is replaced by glass powder, decreased with an increase in glass content because of its angular shape. Strength of concrete with glass powder, which depends on the size and content of glass, was comparable to the concrete without glass. The drying shrinkage of concrete with glass powder was higher and decreased with an increase in the fineness of the glass. In addition, the colour of glass does not have remarkable effect on fluidity and strength of the concrete. The composition, colour, contents and particle size of the glass used are also responsible for the ASR of concrete.

Limited work has been carried out on the application of ground glass in SCC. A glass, of which the fineness was not mentioned but which exhibited higher pozzolanic reactivity than Class F fly ash, was successfully applied in a lightweight SCC without segregation and visual bleeding.

Ground glass is an unconventional material for SCC but it is certainly promising considering its recognized feasibility in concrete and potential environmental benefits.

2. EXPERIMENTAL

2.1 Materials

2.1.1 Cement

In this experimental study, Ordinary Portland Cement conforming to IS: 8112-1989 [8] was used. The physical and mechanical properties of the cement used are shown in Table1.

Table. 1: Properties of Cement

Physical property	Results o
Fineness (retained on 90-µm sieve)	8%
Normal Consistency	28%
Vicat initial setting time (minutes)	75
Vicat final setting time (minutes)	215
Specific gravity	3.15
Compressive strength at 7-days	20.6 MPa
Compressive strength at 28-days	51.2 MPa

2.1.2 Fly ash

The flow ability of self compacting concrete depends on the powder and paste content. Hence, in order to increase the flow ability, mineral admixtures such as fly ash has been used. The fly ash used was obtained from Thermal Power Station, PARAS, Akola (M.S) India. The normal consistency of the fly ash was found to be 43%.
Table 2 gives the physical properties of the fly ash.

Table. 2: Properties of Fly Ash

Physical Properties	Test Results
Colour	Grey (Blackish)
Specific Gravity	2.13

2.1.3 Aggregates

Locally available natural sand with 4.75 mm maximum size was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table 3 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in Table 3 was used as coarse aggregate. Table 3 gives the physical properties of the coarse and fine aggregates.

Table 3. Physical Properties of Coarse and Fine Aggregates

Property	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.66	2.95
Fineness Modulus	3.1	7.69
Surface Texture	Smooth	--
Particle Shape	Rounded	Angular
Crushing Value	---	17.40
Impact Value	---	12.50

2.1.4 Glass powder (GP)

The chemical compositions of soda-lime glass which is the most commonly used in containers are compared with fly ash and cement in Table 4. As shown, the chemical compositions of glass do not vary significantly irrespective of different origins. The SiO2 and (Na2O + K2O) of glass are much higher than those of fly ash and cement. The total reactive component (SiO2 + Al2O3 + Fe2O3) contents of glass and fly ash are about the same. Other main constituent contents are in the similar range to those of fly ash and cement.

Table 4: The comparisons between soda-lime glass, fly ash and cement.

Products	Soda-lime glass						Fly ash	Cement
References	[3]	[9]	[10]	[11]	[12]	[5]	UKQAA[a]	[13]
SiO_2	73	72.5	72.8	72.61	72.5	72.3	38–52	17–25
Al_2O_3	1	0.4	1.4	1.38	0.16	1.04	20–40	3–8
Fe_2O_3	0	0.2	0	0.48	0.2	0.17	6–16	0.5–6.0
CaO	12	9.7	4.9	11.70	9.18	8.61	1.8–10	60–67
MgO	0.6	3.3	3.4	0.56	3.65	3.89	1.0–3.5	0.5–4.0
SO_3	–	–	–	0.09	0.39	–	0.35–2.5	2–3.5
Na_2O	13.5	13.7	16.3	13.12	13.2	13.31	0.8–1.8	0.3–1.2
K_2O		0.1	0.3	0.38	0.12	0.52	2.3–4.5	
LOI	–	–	–	0.22	–	–	3–20	–
Density	–	2490	–	–	2470	2510	2300	3150

Glass powder was obtained from glass factory at Nagpur. The powder product consisted of angular and flaky particle shapes. Table 5 gives the physical properties of the glass powder.

Table 5: Physical properties of the glass powder.

Physical Properties	Test Results
Colour	white
Specific Gravity	2.11

2.1.5 Super plasticizer (SP)

The admixture used was a superplasticizer based on modified polycarboxylates, with a density of 1.08 kg/l and a solids content of 32.5%. It was used to provide necessary workability.

2.2 Mix Proportioning

The mix proportion was done based on the method proposed by Nan. et.al.[14]. The mix designs were carried out for concrete grades 20, 25, and 30. This method was preferred as it has the advantage of considering the strength of the SCC mix. Unlike other proportioning methods like the Okamura [15] and EFNARC [16] methods, it gives an indication of the target strength that will be obtained after 28days of curing. The water to powder ratio was varied so as to obtain SCC mixes of various strengths. A total of 12 trial mixes were done by varying the proportions of water and powder within the calculated ranges. The details of the mixes are as in Table 6. All the ingredients were first mixed in dry condition. Then 70% of the calculated amount of water was to be added to the dry mix and mixed thoroughly. Then, 30% of water was mixed with the super-plasticizer and included in the mix. Then, the mix was checked for self compact ability by flow test, Vfunnel test and L-Box test.

Table. 6: Mixture Proportion for 1 m^3 of SCC.

Mix	W/P	Water (kg/m³)	Cement (kg/m³)	GP (kg/m³)	GP (%)	Fly ash (kg/m³)	FA (kg/m³)	CA (kg/m³)	SP (%)
G1	0.48	237	410	0.00	0	82	892	715	0.90
G2			389.5	20.50	5	82	892	715	0.88
G3			369	41.00	10	82	892	715	0.86
G4			348.5	61.50	15	82	892	715	0.84
G5	0.46	237	430.2	0.00	0	86	892	715	0.90
G6			408.69	21.51	5	86	892	715	0.88
G7			387.18	43.02	10	86	892	715	0.86
G8			365.67	64.53	15	86	892	715	0.84
G9	0.42	227	452	0.00	0	90.4	892	715	0.90
G10			429.40	22.60	5	90.4	892	715	0.88
G11			406.80	45.20	10	90.4	892	715	0.88
G12			384.20	67.80	15	90.4	892	715	0.84

2.2.1Self Compactability Tests on SCC mixes

Various tests were conducted on the trial mixes to check for their acceptance and self compactability properties. The tests included Flow test and V-funnel tests for checking the filling ability and L-box test for the passing ability. The mixes were checked for the SCC acceptance criteria given in Table 7.

Table 7: SCC - Acceptance Criteria

Method	Properties	Range of values
Flow value	Filling ability	650-800mm
V-funnel	Viscosity	6-12 sec
L-box	Passing ability	0.8-1.0

Table 8: SCC - Test Results of SCC Mixes

Mix code	Flow (mm)	V-funnel time (s)	L-box h_2/h_1	Segregation	Remark
G1	720	8.6	0.90	NO	SCC
G2	710	8.9	0.88	NO	SCC
G3	705	9.7	0.87	NO	SCC
G4	685	10.8	0.85	NO	SCC
G5	715	8.8	0.94	NO	SCC
G6	707	9.5	0.93	NO	SCC
G7	697	10.6	0.91	NO	SCC
G8	675	11.8	0.90	NO	SCC
G9	710	9.3	0.95	NO	SCC
G10	700	10.1	0.94	NO	SCC
G11	688	11.2	0.92	NO	SCC
G12	670	11.9	0.91	NO	SCC

The results of the self compactability tests are tabulated in Table 8. The all mixes satisfied the acceptance criteria for self compacting concrete. Hence, these mixes were chosen as the successful mixes. The cube specimens of size 150 x 150 x 150mm were cast for the successful mixes and were tested for the 7-day and 28-day compressive strengths.

3. RESULT AND DISCUSSION

3.1 Fresh properties SCC with Glass powder

Glass powder was used to replace the cement content by three various percentages (5, 10 and 15%). The partial replacement with glass powder was carried out for three grades of concrete. Due to the angular and flaky glass particle shape, the concrete mixes required a relatively small increase in water/powder ratio and decrease in superplasticizer dosage with an increase in glass content. The mixing sequence was modified as follows. All the ingredients were first mixed in dry condition. Then, 70% of the calculated amount of water was added to the dry mix and mixed thoroughly. Then, 30% of water was mixed with the super plasticizer.

Then the mix was checked for selfcompactability by Flow test, V-funnel test, L-Box test etc. The test results are presented in Fig 1 through Fig 3.

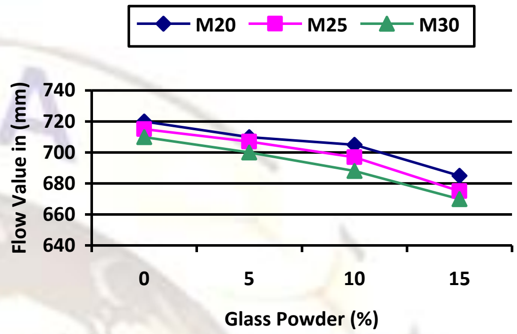

Fig. 1: Flow Value with varying glass powder content

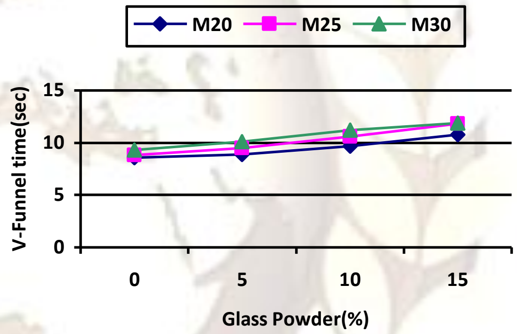

Fig. 2: V-Funnel Time with varying glass powder content

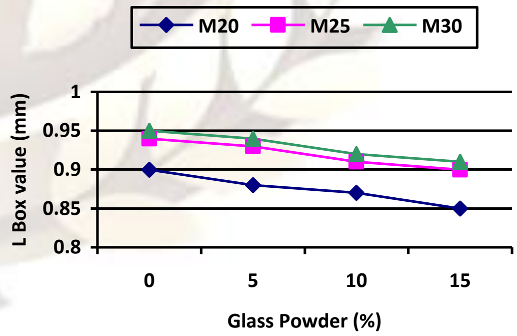

Fig. 3: L-Box Value with varying glass powder content

It can be inferred from the results that the addition of glass powder in SCC mixes reduces the filling ability, passing ability and segregation resistance. The flow value is seen to decrease by an average of 1.30%, 2.5% and 5.36% for glass powder replacements of 5%, 10% and 15% respectively. Hence, the relative flow area reduced with increase in glass powder content, which is an indicator of a decrease in deformability of the mix. The V-funnel time, which is a representative of the filling ability of the mix, was observed to increase by an average of 6.21%, 15% and 22.54% for glass powder contents of 5%, 10% and 15% respectively. This increase in the V-funnel time indicates decreased values of relative flow time and thereby the higher viscosity (resistance to flow) for the mixes. The L-box value was also observed to follow a decreasing trend with an average variation of 1.5%, 3.20% and 5% for glass powder contents of 5%, 10% and 15% respectively.

3.2 Hardened properties of SCC with Glass Powder

All the mixes were tested for various hardened properties like compressive strength, and flexural strength. Fig 4 through Fig 5 shows the variation in compressive strength and flexural strength values obtained for SCC & SCC made by partially replacing cement with varying percentages of glass powder.

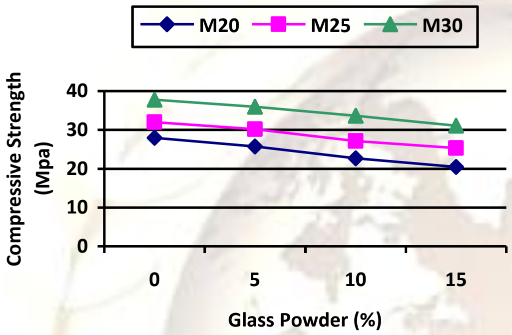

Fig. 4: Compressive Strength with varying glass powder content

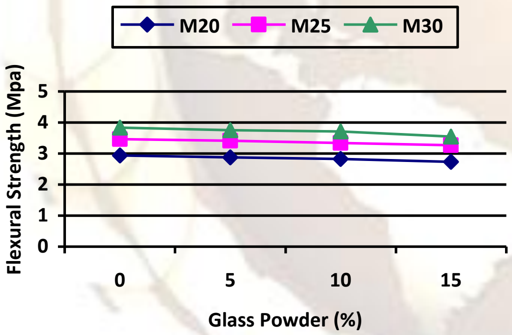

Fig. 5: Flexural Strength with varying glass powder content

According to the results, a decrease on compressive strength had been observed for glass powder added SCC composite compared to conventional SCC. It was observed that the glass powder distribution within the composite was uniform, but the compressive strength varied inversely with the percentage of glass powder content. The average reduction in compressive strength for all grades was around 6%, 15% and 20% for glass powder contents of 5%, 10% and 15% respectively. The flexural strength of the mixes was also observed to decrease with increase in glass powder content. But, the rate of decrease was found to be much smaller than that of the compressive strength. The average reduction in flexural strength were observed to be 2%, 3.7% and 6.75% for glass powder content of 5%, 10% and 15% respectively.

4. CONCLUSIONS

The latest researches are concentrating on ways to create new concrete by using various industrial wastes. The addition of glass powder into concrete was a step that was taken to utilise glass powder obtained from the waste glass factory in an effective manner. Various properties of the glass powder integrated SCC mixes such as self compactability, compressive strength, and flexural strength were evaluated and compared with those of conventional SCC. From the experimental investigations, the following conclusions were arrived at:

i. The addition of glass powder in SCC mixes reduces the self compactability characteristics like filling ability, passing ability and segregation resistance.
ii. The flow value decreases by an average of 1.3%, 2.5% and 5.36% for glass powder replacements of 5%, 10% and 15% respectively.
iii. The V-funnel time was observed to increase by an average of 6.21%, 15% and 22.54% for glass powder contents of 5%, 10% and 15% respectively. This increase in the V-funnel time indicates decreased values of relative flow time and thereby the higher viscosity (resistance to flow) for the mixes.
iv. The L-box value was also observed to follow a decreasing trend with an average variation of 1.5%, 3.2% and 5% for glass powder contents of 5%, 10% and 15% respectively.
v. The mechanical properties of SCC follow inverse relations with the glass powder contents for all grades of concrete. The compressive strength decreases with even increase in glass powder contents. The average reduction in compressive strength for all grades was around 6%, 15% and 20% for glass powder contents of 5%, 10% and 15% respectively.
vi. The flexural strengths of the mixes were observed to decrease with increase in glass powder contents. The average reduction in flexural strengths for all grades was around 2%, 3.7% and 6.75% for glass powder contents of 5%, 10% and 15% respectively.

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