Study on Self Compacting Concrete Using Glass Powder as Partial Replacement for Cement with Addition of Steel Fibres

Sheikh Adil Hussain

M.Tech Scholar
Department of Civil Engineering
Swami Devi Dyal Institute of Engineering and Technology, Panchkula, India

***Abstract*: Self Compacting Concrete is the concrete that gets compacted without vibration. It is a flowing concrete mixture that consolidates under its own weight. The advantages of self compacting concrete as compared to normally vibrated concrete is faster construction, better surface finish, improved durability, easier placing, safer working environment etc. In recent times more emphasis has been laid on the use of waste materials in concrete. Waste glass comprises a major portion of solid waste in India. Waste glass is one of the materials that has found its application in concrete. The use of glass in concrete aims at reducing the landfill required for dumping the waste glass and also to reduce the environmental pollution caused due to the manufacture of cement.**

In this study glass powder has been used as partial replacement for cement in self compacting concrete of grade M 35. Cement has been replaced by glass powder in percentages of 20%, 25%, 30% and 35% with addition of steel fibres. The percentage of steel fibre used is 0.75% by weight of cementitious material. The flow properties of fresh self compacting concrete have been determined by using slump flow test, V-funnel test and L-box test. The hardened properties were determined by compressive strength test, split tensile strength test and flexural strength test at the end of 7 days and 28 days. From this study, it can be concluded that the optimum replacement of cement by glass powder with addition of steel fibres is 25% for self compacting concrete.

***Keywords*: Self Compacting Concrete, Glass Powder, Steel Fibres, Compressive Strength, Split Tensile Strength, Flexural Strength.**

1. INTRODUCTION

Self Compacting Concrete is the concrete that gets compacted without vibration. It is a flowing concrete mixture that consolidates under its own weight. The fluid nature of SCC makes it suitable for placing in sections having congested reinforcement. SCC gains its fluid properties by the usage of high proportion of fine aggregate combined with superplasticizers and viscosity modifying agents. When compared to normally vibrated concrete, the self compacting concrete possesses enhanced qualities. Self compacting concrete with a similar water cement ratio will usually have slightly higher strength compared to normally vibrated concrete. The lack of vibration results in improved interface between the aggregate and hardened paste. Due to the absence of compaction the segregation of the solid particles and the adjacent liquid is avoided which results in less porous transition zones between paste and aggregate. It also imparts a more even colour to the concrete. SCC also makes possible the casting of concrete in congested structures. It reduces the construction time as well as labour cost.

Glass is a non-crystalline amorphous solid having widespread practical and technological usage. Glass is an important component of the Indian economy as it generates more than 21 million metric tons of consumer products each year. The glass segment accounts for 10% of the total packaging industry. Glass is a completely inert material that can be recycled. Waste glass can be combined with other raw materials to produce glass containers without changing the chemical properties of glass. However, since glass is usually found in a combination of different colours, its reproduction is very challenging. Sorting and cleaning of glass is extremely expensive and results in glass recycling of only small quantities. Therefore, most of the waste glass is discarded to landfills. This creates various environmental hazards as glass is a non-biodegradable substance. Glass has a good history as replacement for concrete constituents. Glass is known for its aesthetic appearance, durability and for improving the mechanical properties of concrete. Several studies have mentioned that glass powder having particle size smaller than 75µm, acts as a pozzolanic material and hence can be used as partial replacement for cement. In India about 280 million tonnes of cement is produced every year. The utilisation of waste glass as partial replacement of cement can give huge economical advantage and also reduces the amount of glass that is discarded to landfills, thereby helping in protecting the environment.

Fibre is a small piece of reinforcing material. They can be circular or flat. The fibre is described by a parameter known as the 'aspect ratio'. The aspect ratio of the fibre is the ratio of its length to its diameter. The typical values of aspect ratio ranges from 30 to 150. Steel fibre is the most commonly used fibre. The diameter varies from 0.25 mm to 0.75 mm. The use of steel fibre makes significant improvements in the strength of the concrete. When steel fibre is added to concrete it transforms a brittle material into a more ductile one. Catastrophic failure of concrete is virtually eliminated because the fibres continue supporting the load after cracking occurs. It has been reported that upto aspect ratio of 75, increase in the aspect ratio increases the ultimate strength of the concrete linearly. Beyond 75, relative strength and toughness is reduced. The use of steel fibre in self compacting concrete has been depicted in a number of studies. The optimum content for steel fibre in self compacting concrete has been found out to be 0.75% by weight of cementitious material.

2. MIX PROPORTIONING

The mix proportioning was done as per EFNARC guidelines for self compacting concrete mix design. The grade of self compacting concrete mix was M 35. The first mix was the control mix prepared in accordance to the mix design and in other four mixes partial replacement of cement by glass powder was carried out in percentages of 20%, 25%, 30% and 35% respectively. The ingredients were first mixed in dry condition. Then, 70% of the total water was added to the dry mix and mixed thoroughly. Then, 20% of water was mixed with super plasticizer and 10% with viscosity modifying agent and added to the mix. The mix was checked for flow properties by slump flow test, V-funnel test and L-box test. The concrete was tested for hardened properties at 7 days and 28 days by compressive strength test, split tensile strength test and flexural strength test.

Table 2.1 Concrete mix proportioning for M35 design mix per m^3

Mix	Cement (kg)	Glass Powder (%)	Glass Powder (kg)	Fly Ash (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (litre)	Super Plasticizer (litre)	Viscosity Modifying Agent (litre)	Steel Fibre (kg)
M1	408	0	0	72	921.33	828.45	162	4.8	1.92	0
M2	326.4	20	81.6	72	921.33	828.45	162	4.8	1.92	3.6
M3	306	25	102	72	921.33	828.45	162	4.8	1.92	3.6
M4	285.6	30	122.4	72	921.33	828.45	162	4.8	1.92	3.6
M5	265.2	35	142.8	72	921.33	828.45	162	4.8	1.92	3.6

3. EXPERIMENTAL PROGRAMME AND RESULTS

3.1 TESTS ON FRESH CONCRETE

Various tests were conducted on the different mixes to determine the self compacting properties of the fresh concrete. The tests included slump flow test, V-funnel test and L-box test.

Table 3.1 Tests on Fresh Concrete

Mix	Slump flow (mm)	V-funnel time (sec)	L-Box (H_2/H_1)
M1	718	8.6	0.95
M2	694	9.8	0.91
M3	689	10.1	0.90
M4	683	10.6	0.88
M5	674	11.8	0.86

3.2 TESTS ON HARDENED CONCRETE

Various tests were conducted on the hardened concrete to determine the strength of various mixes of self compacting concrete. The compressive strength test, split tensile strength and flexural strength were conducted at 7 days and 28 days.

Table 3.2 Compressive Strength

Mix	7 Day Compressive	28 Day Compressive
M1	29.93	46.33
M2	30.78	47.82
M3	28.33	44.96
M4	24.85	41.00
M5	21.33	35.45

Table 3.3 Split Tensile Strength

Mix	7 Day Split Tensile Strength (N/mm^2)	28 Day Split Tensile Strength (N/mm^2)
M1	3.73	5.85
M2	4.05	6.15
M3	3.68	5.71
M4	3.25	5.09
M5	2.64	4.15

Table 3.4 Flexural Strength

Mix	7 Day Flexural Strength (N/mm^2)	28 Day Flexural Strength (N/mm^2)
M1	4.56	7.16
M2	4.90	7.50
M3	4.38	6.91
M4	3.97	6.22
M5	3.21	5.01

4. DISCUSSION

4.1 SLUMP FLOW TEST: - The slump flow value was observed to decrease by 3.34 %, 4.04 %, 5.12 % and 6.13 % for partial replacement of cement by 20 %, 25 %, 30% and 35% glass powder respectively.

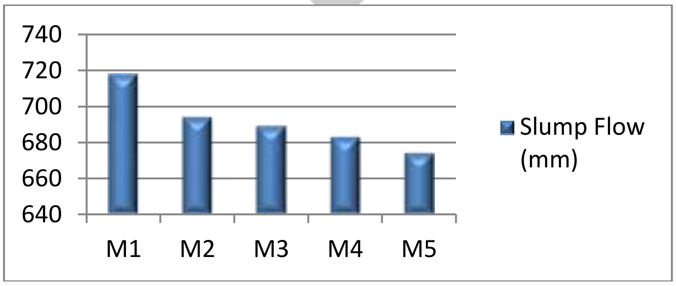

Figure 4.1 Slump Flow Test

4.2 V-FUNNEL TEST: - The V-funnel time which is a representative of the filling ability of the mix, was observed to increase by 13.95 %, 17.44 %, 23.26 % and 37.21 % for partial replacement of cement by 20 %, 25 %, 30% and 35% glass powder respectively.

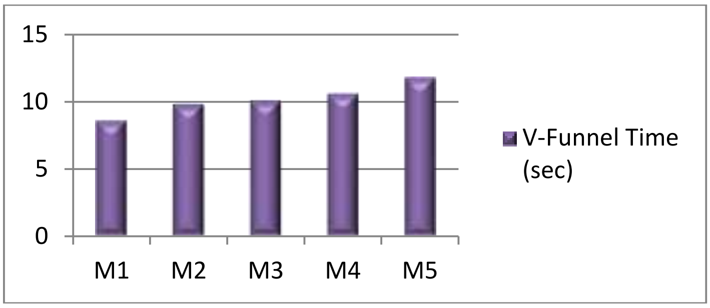

Figure 4.2 V-Funnel Test

4.3 L-BOX TEST: - The L-Box value was also observed to follow a decreasing trend by 4.21 %, 5.26 %, 7.37 % and 9.47 % for partial replacement of cement by 20 %, 25 %, 30% and 35% glass powder respectively.

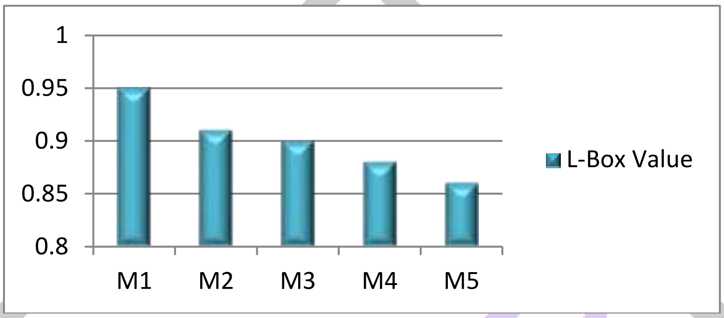

Figure 4.3 L-Box Test

4.4 COMPRESSIVE STRENGTH TEST: - The experimental investigations show that for 7 day compressive strength, the partial replacement of cement by 20% of glass powder increases the compressive strength by 2.84%, the partial replacement of cement by 25% of glass powder decreases the compressive strength by 5.35%, the partial replacement of cement by 30% of glass powder decreases the compressive strength by 16.97% and the partial replacement of cement by 35% of glass powder decreases the compressive strength by 28.37%. For 28 day compressive strength, the partial replacement of cement by 20% of glass powder increases the compressive strength by 3.22%, the partial replacement of cement by 25% of glass powder decreases the compressive strength by 2.96%, the partial replacement of cement by 30% of glass powder decreases the compressive strength by 11.50% and the partial replacement of cement by 35% of glass powder decreases the compressive strength by 23.48%.

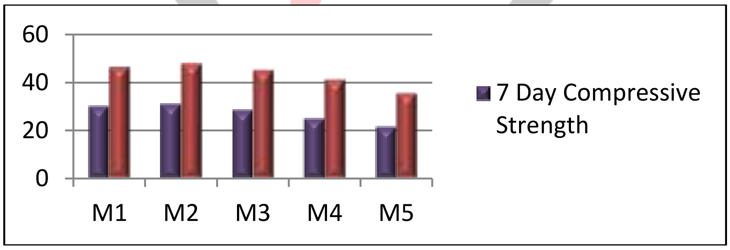

Figure 4.4 Compressive Strength

4.5 SPLIT TENSILE STRENGTH TEST: - The experimental investigations show that for 7 day split tensile strength, the partial replacement of cement by 20% of glass powder increases the split tensile strength by 8.58%, the partial replacement of cement by 25% of glass powder decreases the split tensile strength by 1.34%, the partial replacement of cement by 30% of glass powder decreases the split tensile strength by 12.87% and the partial replacement of cement by 35% of glass powder decreases the split tensile strength by 41.29%. For 28 day split tensile strength, the partial replacement of cement by 20% of glass powder increases the split tensile strength by 5.13%, the partial replacement of cement by 25% of glass powder decreases the split tensile strength by 2.39%, the partial replacement of cement by 30% of glass powder decreases the split tensile strength by 12.99% and the partial replacement of cement by 35% of glass powder decreases the split tensile strength by 29.06%.

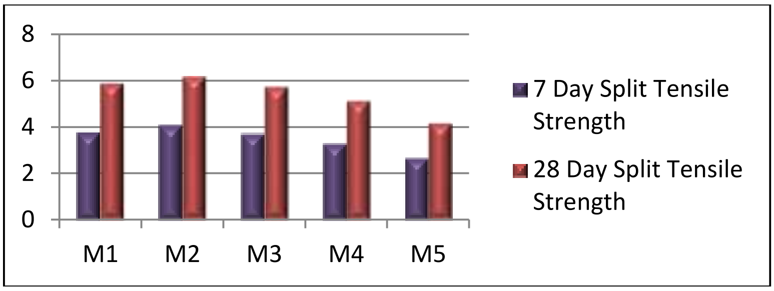

Figure 4.5 Split Tensile Strength

4.6 FLEXURAL STRENGTH TEST: - The experimental investigations show that for 7 day flexural strength, the partial replacement of cement by 20% of glass powder increases the flexural strength by 7.46%, the partial replacement of cement by 25% of glass powder decreases the flexural strength by 3.95%, the partial replacement of cement by 30% of glass powder decreases the flexural strength by 12.94% and the partial replacement of cement by 35% of glass powder decreases the flexural strength by 29.61%. For 28 day flexural strength, the partial replacement of cement by 20% of glass powder increases the flexural strength by 4.75%, the partial replacement of cement by 25% of glass powder decreases the flexural strength by 3.49%, the partial replacement of cement by 30% of glass powder decreases the flexural strength by 13.13% and the partial replacement of cement by 35% of glass powder decreases the flexural strength by 30.03%.

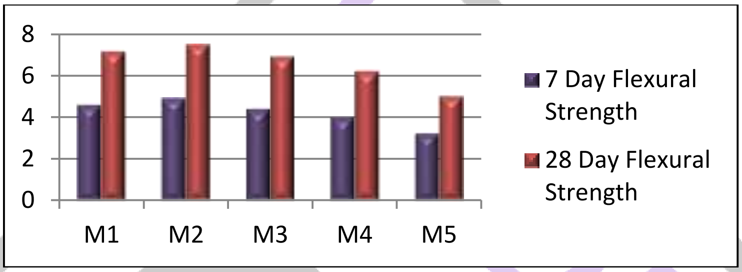

Figure 4.6 Flexural Strength

5. CONCLUSIONS

- The decrease in flow area of slump flow test is an indicator of a decrease in the deformability of the mix.
- The increase in the V-funnel time indicates a decrease in the relative flow time and thereby higher resistance to flow.
- The decrease in the L-box value indicates a decrease in the relative flow of the mix.
- The research has shown that partial replacement of cement by glass powder in self compacting concrete by 20% with addition of steel fibres increases the 7 day and 28 day compressive strength, split tensile strength and flexural strength of the concrete.
- Further increase in glass powder content reduces the 7 day and 28 day compressive strength, split tensile strength and flexural strength. However, for 25% replacement of cement by glass powder the compressive strength is above the target mean strength for M 35 concrete.
- For 30% replacement of cement by glass powder the compressive strength drops below the target mean strength.
- For 35% replacement of cement by glass powder the compressive strength is almost equal to characteristic strength.
- Hence, it can be recommended that the optimum replacement of cement by glass powder with addition of steel fibres is 25% for self compacting concrete.

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