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INVESTIGATION OF MECHANICAL PROPERTIES AND DURABILITY CHARACTERISTICS OF SELF-COMPACTING CONCRETE WITH PARTIAL CEMENT SUBSTITUTION BY GLASS POWDER AND FLY ASH

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Abstract: Self-compacting concrete, sometimes called self-consolidating concrete (SCC), is simple to install in challenging conditions like intricate formwork or strongly reinforced concrete parts because it can flow and consolidate under its own weight. SCC is becoming a common material for building big, intricate structures with a lot of strength and intricate designs. When normal concrete is used in these circumstances, inadequate compaction often results, putting the long-term performance and longevity of the structures at risk. Using a mix of industrial waste materials, including fly ash and glass powder, may save energy and money while also potentially lowering the amount of cement required to produce concrete. Every year, millions of tonnes of glass waste are produced worldwide. Glass does not naturally degrade; therefore, discarding it in landfills when it becomes waste is not sustainable. Silica makes up the majority of glass. Secondary calcium silicate hydrate (C-S-H) is produced when waste glass is ground into microsized particles and reacts with cement hydrates via pozzolanic processes. Utilising waste products on a large scale, including fly ash and glass powder, lowers project costs and prevents natural resources from being wasted in the building sector. The purpose of this study is to examine the potential benefits of using glass powder and fly ash in place of certain cement in construction projects. M30-grade concrete specimens were used in this experiment, with glass powder and fly ash replacing cement inpercentages of 10%, 20%, 30%, and 40%. In order to evaluate the durability requirements, the specimens were tested for split tensile strength, compressive strength, sorptivity, water absorption, and quick chloride penetration. The fifteen 150 x 150 x 150 mm cubes, the forty-five 100 mm diameter x 50 mm height cylinders, and the fifteen 150 mm diameter x 300 mmheight cylinders were all cast and tested. The results of the experiment demonstrated that cement modified with fly ash and glass powder had superior split tensile and compressive strengths than standard SCC. It was shown that resistance to chloride permeability was increased when cement was partly substituted for glass powder.

Keyword: Calcium Silicate Hydrate, SCC, Split tensile strength, Compressive strength, Sorptivity, Water absorption, and Quick chloride penetration

1. INTRODUCTION

For the very first time, concrete has been used as a material for building over the course of more than 150 years. Concrete as a material has been around for a very long period of time. The main material used in the construction industry until that point in time was the natural wood that was used by builders. The one that was built most of the time was constructed from naturally occurring wood. Its popularity and success might be related to the fact that it is inexpensive, easy to obtain and can be shaped into a number of different forms. It's because of the huge appeal and success that it has attained. Perhaps its affordability, ease of acquisition and ability to be made into different forms have something to do with its popularity and success. That can be a possibility. Another benefit that this product has is that it is easy to be made. Besides the reasons given above, the following are some more plausible causes for its enormous popularity. This is a huge advantage, as not only is the material capable of withstanding challenging situations, such as being resistant to water, it is also very easy to create and readily available. That's a big plus. One

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good example of one of those characteristics is the ability to withstand the presence of water. It is well known that concrete is a material widely used in the construction of a wide variety of different types of buildings and structures. The concrete known as "self-compacting concrete" (SCC) is a concrete that can flow under its own weight and fill the formwork without any segregation taking place. It is a concrete that is frequently used for construction projects. However, even when there is a lot of reinforcing, it is still possible to utilise this particular type of concrete. This concrete type has the advantage of not requiring vibration, and the homogeneity of this concrete is maintained along the whole process of application. Vibration is not at all a necessary part. Self-compacting concrete is a type of concrete that can be made to flow and settle without any form of internal or external vibration. This type of concrete is classified as belonging to this group due to its ability to do so.

2. MATERIALS AND METHODS

Cement, glass powder, fly ash, coarse aggregate, fine aggregate, water, and superplasticizer are the different types of aggregate that were used in this experimental investigation.

Cement: The powdered form of cement is one of the most common types of the binding material that is known as cement. On the market, cement may be found in a number of different forms. It is possible to manufacture cement in the form of a paste by adding water, and after it has been formed and moulded into a solid mass, cement takes on the status of being solid. Cement may be produced in this manner. This is one method that may be used to make cement. The kind of cement that is most often used is called 'Portland cement', and its tint may be described as a bluish-grey colour.

Fine Aggregate: The fragments of rock that are broken down into tiny pieces are what make up fine aggregate. This kind of aggregate may be created by crushing rocks. As the fine aggregate in the fabrication of specimens, natural sand that is easily available in the region is used. Both specific gravity and fineness modulus were shown to be real once their existence was investigated.

Table 1 Physical properties of Fine aggregate

Sl.no.	Property	Test method	Results
1.	Specific gravity	Pycnometer confirming toIS2386-Part 2	2.63
2.	Finenessmodulus	Sieve Analysisconfirming toIS2386-Part 2	2.36

Coarse Aggregate: The term "coarse aggregate" refers to the large pieces of stone that have been reduced to a smaller size by being crushed after being extracted from quarries. The IS383:1970 standard stipulated that the maximum size of the coarse aggregate should not exceed 10 millimetresand its specific gravity could not be lower than 2.75. Two of the physical variables that maybe determined for coarse aggregate are its specific gravity and its fineness modulus.

Table 2 Physical properties of Coarse aggregate

Sl.no	Property	Test method	Results
1	Specific gravity	Pycnometer confirming to IS2386-1963 Part 3	2.75
2.	Finenessmodulus	Sieve Analysis confirming to IS2386-1963 Part 2	7.21

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Fly ash: Fly ash is a by-product that is formed as a result of the burning of coal and consists of finely separated ash particles. It contains large amounts of silica and alumina, both of which are abundant in the material. In the course of the experiment, fly ash from Ultratech Cement Ltd. in Miyapur, which is found in the city of Hyderabad, was used. SPECTRO SSA LABS PVT LTD, in the state of Maharashtra, has produced a report detailing the results of tests conductedon both the physical qualities and the chemical attributes.

Glass Powder: After being milled and crushed in the breaker, the powdered glass is granulated by passing it through a series of sieves. Glass powder is considered a waste item. In order to separate the powder from the granules, sieves are put to use. The glass powder that was used in this inquiry was purchased from the business Heera Chemicals, which is located in Mumbai. In this investigation, a powdered form of glass with a specific gravity of 2.62 and consisting of particles with a size of less than 75 microns has been used.

Super Plasticizer: In order to achieve the desired degree of workability, a water reducer that was made up of a superplasticizer that was based on naphthalene was used. Studies that were carried out in thepast have shown that the use of superplasticizers may facilitate an improvement in the workability of self-compacting concrete mixtures. The superplasticizers that were used were manufactured by FORSOC Chemicals (India) Ltd. under the brand name CONPLAST SP 430. These Super Plasticizers were brown in colour and were recognised by their brand name. The properties of CONPLAST SP 430 are outlined for your consideration in the table that can be seen below.

Design Mix:

Table 3: Design mix

Cement	Fly ash	Fine aggregate	Coarse aggregate	water	Super Plast.
0.8	0.2	1.97	1.55	0.4	0.6% by wt of cement

3. RESULTS AND DISCUSSIONS

Through the results of experimental study, the performance of glass powder and fly ashreplacing with cement in SCC was studied.

3.1 Optimization of Glass Powder

3.1.1 Properties of Fresh SCC Mixes: Fresh properties of self-compacting concrete mixes with varying percentages of glass powder (i.e., 10%, 20%, 30%, and 40%) are used to determine the optimum percentage of glass powder and fly ash by conducting a compressive strength test. The fresh properties of self-compacting concrete were studied by testing them for slump flow, T50 cm, V-funnel and L-box. The table shows properties such as slump flow, T50cm, V-funnel and L-box h_2/h_1 ratios.

In terms of slump flow, all SCCs exhibited satisfactory slump flow in the range of 600-850 mm, indicating excellent deformability. The V-funnel flow time is 6 to 12 seconds. The L-box ratio of the mixture is higher than 0.8 for h_2/h_1 and 2–5 seconds for T_{50} cm.

In terms of slump flow, all SCC exhibited satisfactory slump flow in the range of 600-850 mm, which is an indication of excellent deformability. V-funnel flow times ranged from 6 to 12 seconds. The L-box ratio h_2/h_1 for the mixes was between 0.8 and 1.0, and the T_{50} cm time was in the range of 2-5 seconds.

Table 4 Fresh properties of SCC with varying % of glass powder

SNO	Method	Results Obtained	Typical Range of Values asper “IS: 10262-2019”	
			Minimum	Maximum
1	Slump Flow (mm)	650 -700	550	850
2	T50cm Slump Flow (Sec)	3-5	2	5
3	V-Funnel (Sec)	7-10	6	12
4	L-Box	0.84 -1.0	0.8	1.0

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3.1.2 Compressive Strength Test: In order to carry out a compressive test on M30 grade SCC, five cube specimens of 150 millimetres in length, 150 millimetres in width, and 150 millimetres in height were produced. The goal of these specimens was to assess the material's strength. As a result of this, it was feasible to precisely establish the proportion of cement that needed to be used in order to replace the glass powder content. The amounts of glass powder that were used as replacements were as follows: zero per cent, ten per cent, twenty per cent, thirty per cent, and forty per cent, respectively. For the length of the curing process, the specimens were stored in a water tank. After a period of 28 days, the specimens were examined for quality control. The outcomes of the analysis revealed that twenty per cent of the total was the most effective application of glass powder. This was the most efficient use of glass powder. In addition to being shown in Table 5, the results of the tests may also be seen in Picture 1 for your own individual examination.

Table 5 Compressive Strength of Various Percentage of Glass Powder after 28 days

SNO	Glass Powder (%)	Compressive Strength MPa			Average Compressive Strength MPa
1	GP 0%	34.32	32.76	35.23	34.10
2	GP 10%	39.76	41.19	42.03	40.97
3	GP 20%	41.96	43.23	40.84	42.27
4	GP 30%	36.78	34.24	37.13	36.06
5	GP 40%	28.84	26.73	30.07	28.56

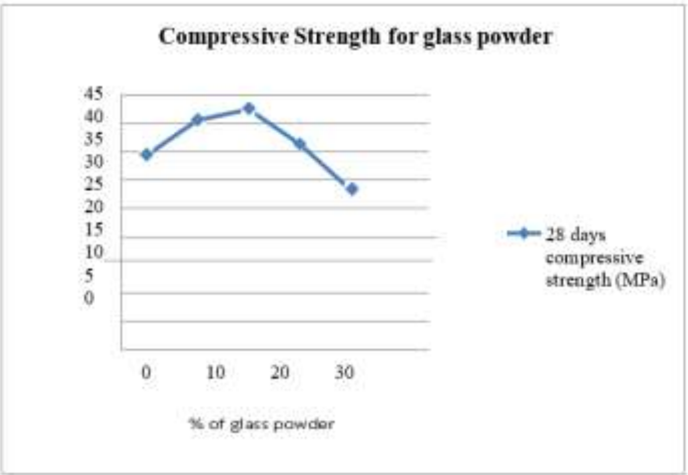

Figure 1 Compressive Strength variations at 28 days

3.2 Optimization of glass powder as partial replacement to cement

3.2.1 Properties of Fresh SCC Mixes: Once it was determined that the glass powder was the appropriate amount of cement, a number of various percentages of glass powder were added to discover the ideal percentage of glass powder content. This procedure was done in order to determine the ideal percentage of glass powder content. The purpose of this experiment was to establish the ideal amount of glass powder to fill the container. The following percentages were included in these totals: 0%, 10%, 20%, 30%, and 40%, respectively. Experiments of several

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kinds were carried out in order to investigate the novel characteristics of the SCC. Slump flow, T50 cm, V-funnel, and L-box were some of the experiments that were performed.

Slump Flow Test

Table 6 slump flow with varying percentage of glass powder

SNO	% of Glass Powder	Slump flow results in (mm)	Typical range values asper " IS: 10262-2019"
1	GP 0%	620	Slump flow class- SF1 (550-650) mm Slump flow class –SF2 (660-750) mm
2	GP 10%	640	
3	GP 20%	650	
4	GP 30%	660	
5	GP 40%	690	

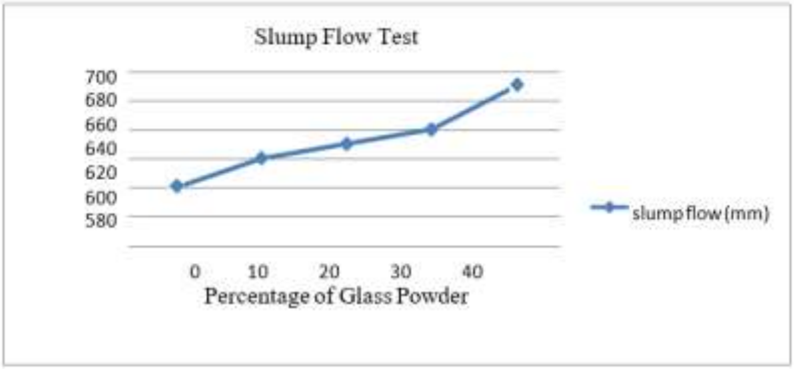

Figure 2 slump flow with varying % of glass powder

V-Funnel test

Table 7 V -Funnel Test with varying % of glass powder

SNO	% of Glass Powder	V-Funnel Time Results In (Seconds)	Typical Range Values (Seconds) as per " IS: 10262-2019"
1	GP 0%	11	6-12
2	GP 10%	10	
3	GP 20%	9	
4	GP 30%	8	
5	GP 40%	8	

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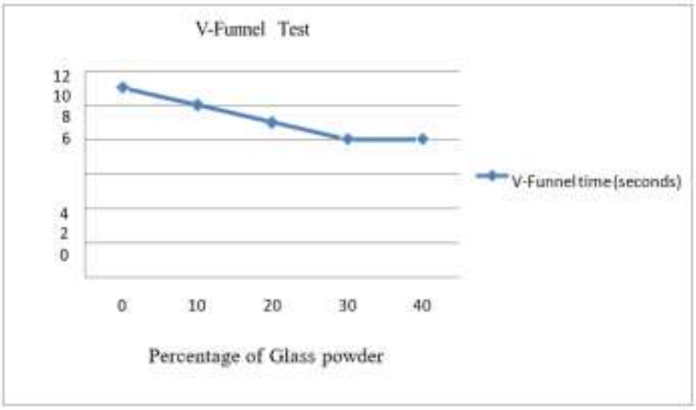

Figure 3 V - Funnel test with varying % of glass powder

L- Box test

Table 8 L-Box Test with varying percentage of glass powder

SNO	% of Glass Powder	L-Box ratio (h2/h1)	Typical Range Values (Seconds) as per " IS: 10262-2019"
1	GP 0%	0.83	0.8-1.0
2	GP 10%	0.87	
3	GP 20%	0.92	
4	GP 30%	0.95	
5	GP 40%	0.98	

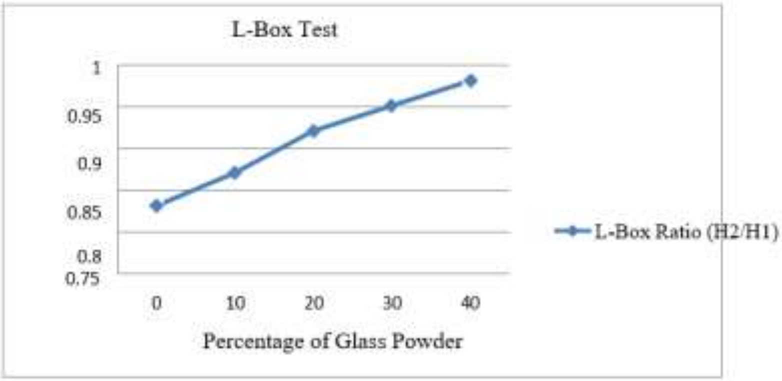

Figure 4 L-Box test for varying percentage of glass powder

3.3 Split Tensile Strength Test: The change trend of split tensile strength is directly related to the change trend of compressive strength. This correlation is directly observed. The proportional relationship between split tensile strength and compressive strength may explain the connection between these two types of strength. This difference is due to the fact that there are two types of strength, compressive strength and split tensile strength. These two types of strengths are very different from each other. The split tensile strength of glass powder as a twenty per cent replacement for cement was increased by up to thirteen and a quarter per cent. Plug it in, and this is what you get. This phenomenon occurs as a result of the replacement. Specifically, this reduction may be due to the alternative

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that was used, i.e., glass powder.

Table 9 Split tensile strength with various percentage of glass powder

SNO	Percentage of Glass Powder	Split tensile strength (MPa)			Average Split tensile strength(MPa) at 28days
1	GP 0 %	3.93	4.18	3.87	3.96
2	GP 10%	4.16	4.52	4.69	4.45
3	GP 20%	4.34	4.49	4.76	4.52
4	GP 30%	4.29	4.12	4.16	4.19
5	GP 40%	3.86	3.71	3.56	3.71

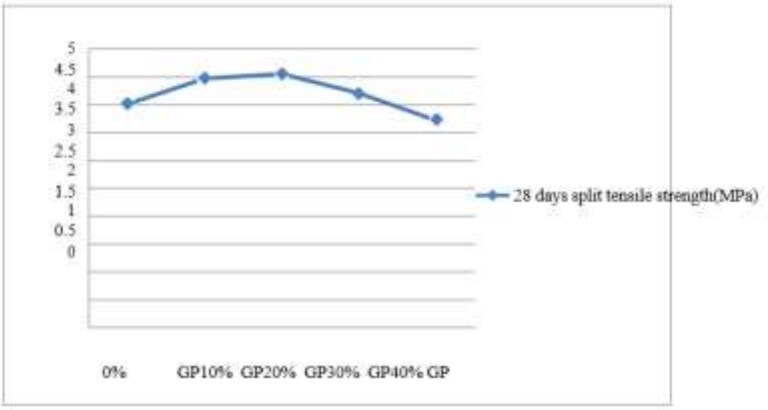

Figure 5 Split tensile strength variations with various Glass powder percentage

3.3 Rapid Chloride Penetration Test

This test was conducted in accordance with the ASTM C1202 standard.

Table 10 Rapid Chloride Penetration Readings

Specimen	Charged Passed (coulombs)	Avg. Charge Passed (coulombs)	Remarks Chloride Permeability
GP 0%	2830	2722	Moderate
	2543		
	2793		
GP 10%	2258	2124	Moderate
	1962		
	2153		
GP 20%	1854	1848	Low
	1628		
	2063		
GP 30%	1954	1764	Low
	1732		
	1606		
	1546		

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GP 40%	1687 1629	1737	Low

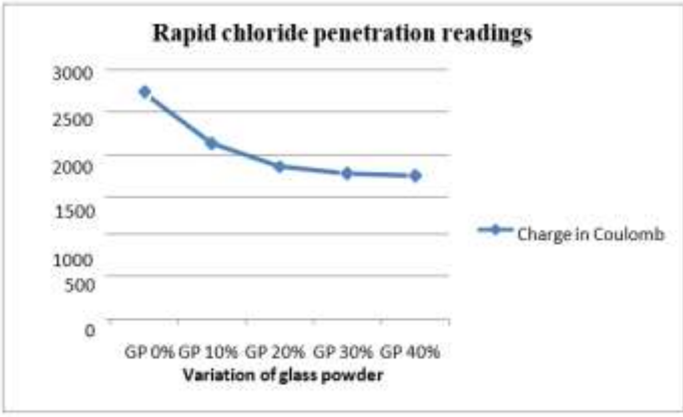

Figure 6 Variation of Rapid Chloride Penetration Readings

4. CONCLUSIONS

- The workability of concrete improved with increase in glass powder contentand the results are within the range specified in IS: 10262-2019.
- Optimum percentage of glass powder replacement with cement found to be 20%.
- The 20% glass powder and 20% fly ash replacement of cement showed 24% increasein compressive strength at 28 days, beyond which the strength decreases.
- Splitting tensile strength increased by 14% at 20% replacement of cement by glass powder and fly ash as compared to conventional SSC and then decreased withincrease in glass powder.
- It is seen that reduction in chloride permeability increased with increasing replacement levels of glass powder and noted that charge passage was reduced to 40.48% at 40% replacement of cement with glass powder.
- With increase in waste glass content, percentage of water absorption decreases, at 20% replacement it is optimum.
- In Sorptivity test, results were found to be lowest for 20% glass powder i.e. 29.13% compared with control mix.

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