Improving Workability and Compressive Strength of Self-Compacting Concrete Using Different Admixtures

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ABSTRACT

Self-compacting concrete (SCC) is a high-performance concrete and it has very unique property to flow under its own weight and do not require vibrators. The use of admixtures can further improve the properties of SCC. The study aims to improve workability and compressive strength of SCC. Four types of admixtures were used in this study: fly ash, silica fume, red brick powder and rice ash husk. Fresh properties or workability of self-compacting concrete was tested using the Slump flow, U-box test, L-box test and V-funnel test. Compressive strength was estimated at ages 7 and 28 days of casted cube by compression test machine.

Keywords Self-compacting concrete, workability, Rice husk ash, Brick masonry

1.INTRODUCTION

Self-compacting concrete (SCC) is a type of concrete which have high compressive strength, it flows easily and do not need vibration for compaction. It was developed in Japan around 1980s. Self-compacting concrete is defined as a concrete that do not require vibration and assistance of workers for its hardening and solidification. When SCC is hardened it possess a great compressive strength. Adding to its advantage it has high level of workability. It can easily pass through difficult area and even able to pass through obstacles and complicate reinforcements. When we add admixture it makes concrete to behave like liquid and obtain plastic like properties which cause concrete to flow easily and causes no segregation in it. For testing workability in SCC we use methods such as slump flow, v-funnel, l-box, u-box, j-ring unlike the tests we use in normal concrete.

In this study, we investigated the effects of using various admixtures on the workability and properties of SCC. Fly ash, silica fume, red brick powder, and rice husk ash were used as mineral admixtures in different proportions. Fly ash is a by-product of coal combustion and is widely used as a pozzolanic material in concrete. Silica fume is a by-product of silicon and ferrosilicon metal production and is known for its high pozzolanic activity. Red brick powder is a waste material from the construction industry and has been found to improve the workability of concrete. Rice husk ash is an agricultural waste material and has been found to improve the compressive strength of concrete.

We investigated the effects of using these admixtures on the workability and properties of SCC. The aim of this study was to determine which type of admixtures that can enhance the performance of SCC while reducing its environmental impact. The results that obtained in this study have much important implications for the construction industry as it helps to improve the quality and sustainability of SCC.

2.LITERATURE REVIEW

The project focus is on improving the workability of SCC by using various mineral admixtures as well as suitable compressive strength in that concrete. Various research has been done to improve SCC by a number of scientists.

A similar project, titled "Fresh Properties and Compressive Strength of Self-Compacting Concrete with Fine Aggregate Replacement using Red Brick Powder and Rice Husk Ash" was carried out by Hakas Prayuda, Martyana Dwi Cahyati and Fanny Monica. In their work they replaced fine aggregates rice husk ash red brick powder and determined its workability and compressive strength on 3, 7, 15 and 28 days of casting of SCC.

"Performance of Self-Compacting Concrete Containing Different Minerals" was the title of a separate piece of research that was carried out by P.Ramanathan, I.Baskar, P.Muthupriya and R.Venkatasubramani . In their work they used GGBS, fly ash and silica fume as admixtures and concluded GGBS have better workability properties.

"Sustainable High Performance, Self-Compacting Concrete using Ladle Slag" was the title of similar study that was carried out by G.M. Sadiqul Islam, Suraiya Akter, Tabassum Binte Reza of Department of Civil Engineering at Chittagong University of Engineering and Technology, Bangladesh. In this project they used steel industry waste instead of tradition cement. They replaced cement with ladle slag up to 15% and increased compressive and tensile strength and 70MPa strength was achieved.

Such similar studies were also done with steel fibre, GGBS and other mineral admixtures. The aim of these projects was to either increase workability or increase compressive strength of SCC by replacing minerals or using waste materials.

3.METHODOLOGY

In this study, we used a laboratory-based experimental approach to test and determine the effects of using various mineral admixtures on the workability and compressive strength of SCC. The specific steps followed are described below.

3.1 MIX DESIGN AND MATERIALS

Materials that were used in this project, were Ordinary Portland cement 43, coarse aggregate having size less than 19mm, fine aggregate i.e. sand having size less than 4.5mm. It also included fly ash, silica fume, red brick powder and rice husk ash according to IS code mix proportions. Chemical water reducer and water is also used as materials. Then we used a mix design according to guidelines given by IS 456:2000 and IS 10262:2019 and modified it by adding different proportions of mineral admixtures. The mix design consisted of cement to total aggregate ratio, both coarse and fine of 0.31, sand to total aggregate at ratio of 0.34 and have water cement ratio of 0.37. The proportions of the mineral admixtures were varied in different combinations. The mixed design was prepared for M20 and M40 strength. The results are then checked after 7 and 28 days to determine its strength. The obtained concrete then tested through various instruments such as V-funnel, L-box, U-funnel and Slump test. The obtained values for these tests are shown in figure 2 and 3. It can clearly be seen that by using of rice ash husk and silica have greater workability than other admixtures.

The test is performed on 4 samples where a pair of admixtures are used having appropriate mix design is determined and workability tests are performed and then cubes were casted for compressive strength analysis.

The samples are described as S1, S2, S3 and S4. In S1 fly ash and silica fume are used as admixtures and mix proportion was done for M20 strength. Similarly, in S2 fly ash and red brick powder, in S3 fly ash and rice husk ash, in S4 rice husk ash and silica fume are used as admixtures. In samples S2, S3 and S4 mix proportion was done for M40 strength.

The mix design for each of the sample is illustrated in table 1. It can easily be seen the amount of fine and coarse aggregate, cement, water and mineral admixtures which are used in the project. Mix design of SCC is done through the recommendations given in IS 456:2000 and IS 10262:2019. It should also be noted that requirement for water and chemical admixture may vary due to external conditions so it is mixed according to the requirement. The size of coarse and fine aggregate is also taken through IS code recommendations but may vary according to availability and need. In this mix design coarse aggregate of 19mm and fine aggregate of 4.5mm is used.

Table 1 Mix design of self-compacting concrete for 1gm/cm3

Sample	Cement	Fine Aggregate	Coarse Aggregate	Water	VMA	Fly Ash	Silica Fume	RBP	RHA
1.	0.22	0.97	0.70	0.17	0.001	0.22	0.018	-	-
2.	0.33	0.36	0.70	0.16	0.002	0.099	-	0.033	-
3.	0.32	0.27	0.53	0.11	0.002	0.096	-	-	0.032
4.	0.35	0.74	1.12	0.18	0.005	-	0.035	-	0.02

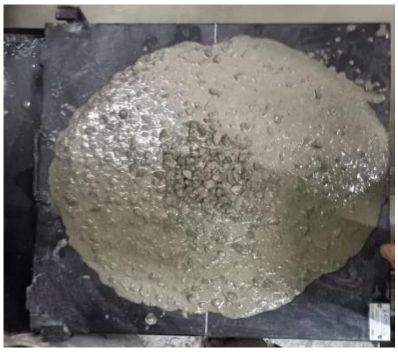
3.2 TESTS ON SCC

Tests performed in this project is categorised into two parts, they are, fresh SCC properties which exhibit the workability of SCC and compressive strength which exhibit the load it can bear. Upon testing workability of SCC first slump flow test is done. The acceptable value of slump flow ranges from 650-800mm. Also T500 slump flow value must me within 2-5 seconds. L-box test is used to check the passing ability of concrete through various obstacle and reinforcements so that it does not segregate at one place. To determine workability in SCC, U-funnel and V-funnel test is also used. Some of the equipment can also be seen in figure 1. L-box and U-box are used to determine the passing ability of SCC. The range of ratio for L-box is 0.8-1 and for U-box the difference should be less than 30 mm. V-funnel is used to test flowability of SCC and have recommended range of 8-12 seconds. All these values determine the workability of concrete. Compressive strength of SCC can be determined at 3, 7, 15 and 28 days of curing. In this project it is determined on 7th and 28th day.

Figure 1 (a) L-box; (b) Slump flow; (c) V-funnel; (d) U-funnel

(b)

(a)



(c)

(d)

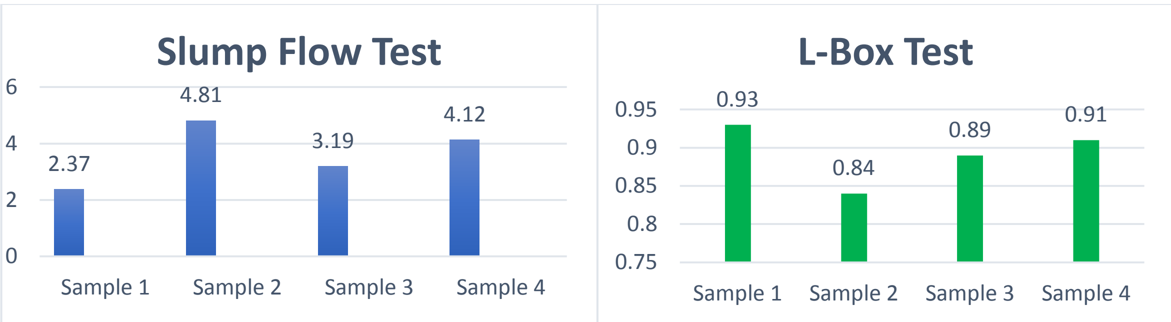
4.RESULTS

4.1 WORKABILITY

All the tests related to workability is done when concrete is fresh. Slump flow test is done earliest. The acceptable limit for slump flow test is 650-800mm and for t500 acceptable range is 2-5 seconds. In this study we found out that using fly ash and silica fume as admixtures gave best value for slump test. As for other admixtures through S2 to S4 its value is higher than S1. S1 gave value of 2.37 seconds, S2 gave 4.81, S3 through 3.19 and S4 gave 4.12 seconds. It can also be seen in figure 2(a). As it indicates S2, fly ash and red brick powder have lowest value for slump flow test.

After slump test there comes L-box test. In L-box the value is determined in ratio of h1 and h2. The acceptable ratio ranges from 0.8 to 1. As in given test S1 performed best as it has much closer value to 1 and in succession it comes S4 as its shown in figure 2(b). Rice husk ash and silica fume also have great segregation resistance and passing ability. All the admixtures used gave satisfactory value towards workability.

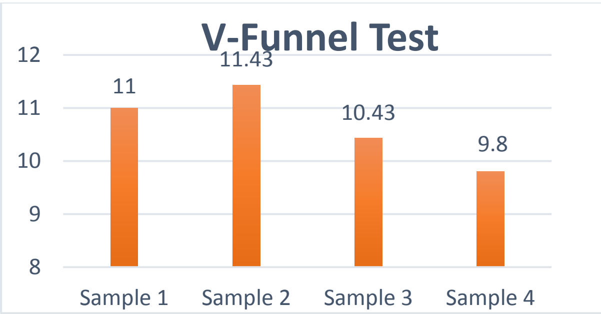
Figure 2 (a) Slump flow test (value in sec); (b) L-box test (value in h2/h1)



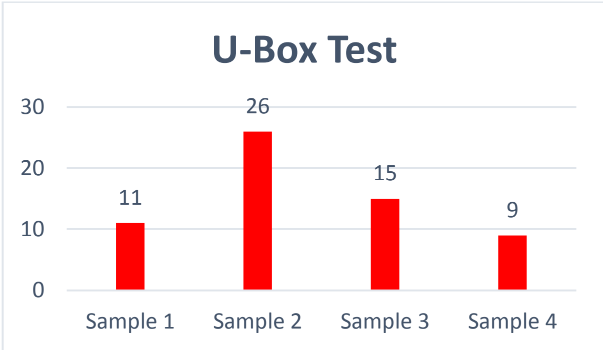
(a) (b)

Now for V-funnel test the recommended value is 8-12 seconds. Through v-funnel it determines the flowability of SCC. It is clearly seen in figure 3(a), SCC having rice husk ash and silica fume have given best value for v-funnel test. It can flow easily and take the shape of the surface. S2, admixture having fly ash and red brick powder have the highest value it means it have lowest ability to flow through all the samples. These are the fresh properties so these tests must be done while concrete is fresh. Through all the tests admixtures silica fume and rice husk ash gave constant results.

For last test, we determined U-box test. The recommended condition for u-box is in form of h1-h2 is less than 30mm. U-box result is shown in figure 3(b) where again admixture rice husk ash and silica fume gave 9mm difference. Similar value is also given by silica fume and fly ash. Except for admixture of fly ash and red brick powder which gave 26mm difference.



(a)



(b)

Figure 3 (a) V-funnel test (value in sec); (b) U-box test (value in mm)

4.2 COMPRESSIVE STRENGTH

The result of compressive strength is shown in figure 4. The value is determined after testing it under the load of compressive machine. After casting, concrete is moulded into cube having dimensions 15cmx15cmx15cm. On average 8 cubes are casted for one sample. The obtained cube is then cured for 28 days and its strength on various days are calculated. After 7 days SCC almost gain 70% of its original strength. After 15 days it can almost gain 90% of its absolute strength. In this study compressive strength on 7^{th} and 28^{th} day of curing. Curing is done in clean drinkable water. As for S1, its mix design is done for M20 strength. As we can see in figure 4 it gained 17.26MPa in 7 days and 24.67 as overall strength. It achieved its target strength hence mix is acceptable.

As we go from sample 2 to 4, all the design mix is done for M40 strength. Now as we can see in figure 4, S3 having admixture rice husk ash and silica fume achieved strength of 46.68MPa in 7 days and 66.75MPa in 28 days. It achieved highest compressive strength in all three samples. Similar strength is also achieved by S2 having admixtures fly ash and red brick powder. It achieved strength of 45.88MPa in 7 days and 65.55 in 28 days. Through all the samples S4 having admixtures silica fume and rice husk ash gave best workability but in terms of compressive strength it's at last place in all three samples. It gave 36.23MPa strength in 7 days and 51.81MPa strength in 28 days.

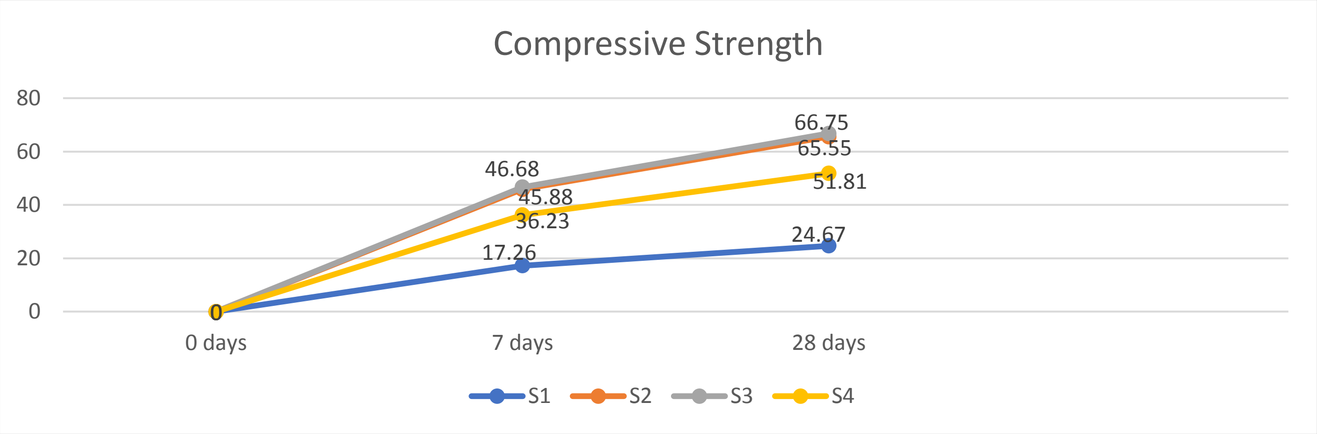


Figure 4 Compressive strength of SCC (strength in MPa)

5.CONCLUSION

Through result and discussion it can be concluded that rice husk ash and silica fume as admixtures provide best workability but do not provide exceptional strength. Same goes for fly ash and red brick powder admixture gave one of the best compressive strength but was not on par in terms of workability. As we see S3, admixtures as rice husk ash and fly ash provided best strength and were on equal footing in terms of workability. It is clearly the best choice for SCC of greater strength. In M20 strength fly ash and silica fume gave better workability and required strength.

It also seemed that out of four, fly ash is used to determine property in three SCC mix design and to gain desired results. It also boosts paste quality of SCC. In the given four samples fly ash is used in three of them. By use of different admixture as combinations it is showed that by use of different admixtures workability and compressive strength of SCC can be enhanced and it provides great impact on SCC. By using various admixture that are present in our surroundings we can enhance strength of SCC along with reducing its cost of preparation. It also reduces the waste which are thrown in environment.

In all the mix design, similar type of water reducer is used and it affected with each admixture in different ways. Such water should be chosen which affect the admixture in positive way and enhance its property. Use of chemical admixture is done when water is poured in mix design for about 65-70%. Upon further examining the results it is seen that upon increasing water cement ratio, it increases workability but decreases compressive strength of SCC. It is seen in S3 as it may have great workability but gave much less compressive strength.

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