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An Experimental Investigation on High Strength Self Compacting Concrete by using Fly Ash and Class C Calcareous Material

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ABSTRACT: The different properties of self-compacting concrete of high workability without loss of strength were considered in this experimental study. This study presented the results of quest on engineering properties of self-compacting concrete (SCC) consists of lime powder (calcareous material) and fly ash. Both fly ash and lime will be employed as a cementitious material with various percentages of lime (5%, 7.5%, and 10%) and fly ash of binder or powder content. The SCC will be developed in laboratory and the properties of fresh concrete and hardened concrete will be examined using appropriate tests. Fresh concrete tests such as J-ring, V-funnel, slump flow and L-box were done for the various percentages of lime. Hardened concrete was experimentally examined. It satisfies the both workability and strength behaviour.

KEYWORDS: Self-compacting concrete, workability, fly ash, lime powder, Calcareous material.

I. INTRODUCTION

Self-compacting concrete (SCC) is considered as a concrete which can be placed and compacted under without or little vibration effort or its self-weight, and which is at the same time cohesive more than enough to be handled without bleeding or segregation of fresh concrete. SCC mixes usually consists of superplasticizer, high content of fines. The use of super plasticizer maintains the fluidity; the fine content provides stability of the mix gives the resistance against segregation and bleeding. It is an innovative concrete that does not needs vibration for compaction and placing. It is able to flow under its self-weight, achieving full compaction, completely filling formwork, even in the presence of congested reinforcement. The hardened concrete is homogeneous, which has the same engineering properties and durability as traditional vibrated concrete and dense [1].

It is appraised that SCC may give the result in upto 40% faster construction than using normal concrete [2, 3]. The use of SCC can enhance the productivity in structural applications such as facilitates the filling of restricted sections and repair. Such concrete has been used widely to make the construction operations easier, especially in sections possessing special difficulties to casting and vibration such as sides of beams, bottom, slabs, and girders [4]. SCC consists of same components as conventionally vibrated concrete, which are cement, aggregates and water, with the addition of mineral admixtures and chemical admixtures in various proportions. The predominant point to be considered when designing SCC is to restrict the volume of the coarse aggregate. This reduction necessitates the use of a higher volume of cement which increases the cost besides resulting in a greater temperature rise. So cement should be replaced by high volume of fly ash or lime powder [5, 6].

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Generally, the chemical admixtures are used high-range water reducers and viscosity-modifying agents (VMA), which change the rheological properties of concrete. Mineral admixtures are used as additional fine material, partially instead of cement. Saving in labour cost might offset the increased cost, but the use of mineral admixture such as fly ash, lime filler could increase the slump of the concrete mixture without increasing its cost [7, 8, 9].

II. RELATED WORKS

1. **Te-Ho Sun et al., 2016**, presented the results of an investigation on engineering properties of self-compacting concrete (SCC) containing oxidizing and reducing slag generated from stainless steel making. The oxidizing slag was employed as fine and coarse aggregates substituting to natural materials with various percentages (0%, 50%, and 100%). Meanwhile, the reducing slag partially replaces for Portland cement (0%, 10%, 20%, and 30%). As a result, a total of 12 mixes with a fixed water-binder ratio ($w/b = 0.4$) were developed in laboratory and its properties in hardened properties such as compressive strength, ultrasonic pulse velocity and surface resistivity were experimentally examined.
2. **Behnam Vakhshouri et al., 2016**, evaluated the utilization of mineral and chemical admixtures in concrete technology has led to changes in the formulation and mix design which has, in turn, made the concrete stronger and more durable. Light Weight Concrete (LWC) is an excellent solution in terms of decreasing the dead load of the structure, while self-compacting concrete (SCC) eases the pouring and removes construction problems. Combining the advantages of LWC and SCC is a new field of research. Considering its light weight of structure and ease of placement, Light-weight self-compacting concrete may be the answer to the increasing construction requirements of slender and more heavily reinforced structural elements.
3. **Stanislav Seitl et al., 2016**, tested the unique properties of self-compacting concrete of high workability without loss of stability and improved durability allow better protection of steel reinforcement in concrete structures. Recently, fatigue behaviour has become more important for the design of constructions due to slimmer structures, which are more sensitive to fatigue loading. This article aims to evaluate the fatigue crack propagation rate in vibrated concrete and self-compacting concrete under different stress ratios using the Paris-Erdogan law, based on crack mouth opening displacement measurement from cyclic three-point bend tests on single edge notched beams.
4. **Malgorzata Pajak et al., 2016**, considered compressive and flexural parameters of self-compacting concrete reinforced with combination of steel and polypropylene fibers. Three volume ratios of steel fibers (0.5%, 1.0%, 1.5%) were mixed with two amounts (0.3%, 0.9%) of two types of polypropylene fibers. The influence of hybrid fibers on the compressive strength of SCC was negligible and comprised in the range of 5 to 11% of the strength of the matrix. Based on the flexural tensile tests on hybrid fibre-reinforced mixes it was noticed that steel fibers play the most important role in enhancement of the mechanical parameters. Meanwhile, in the hybrid mix of polypropylene fibers only slightly improve the toughness, irrespectively of the length of the PP fibers. The highest applied amount of the longest polypropylene fibers indeed improved the flexural parameters of the SCC matrix reinforced with steel fibers but on the other hand such concrete did not satisfy the requirements for SCC in the fresh state.

III. MATERIALS AND METHODS

3.1 Cement

Cement is a substance and a binder, which is used in construction that sets and can bind other materials together and hardens. Portland pozzolanic cement was used for this study. The specific gravity of the cement was experimented as 3 which conforms EN 197-1: 2000.

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3.2 Aggregate

20 mm nominal maximum size of aggregate was used as coarse aggregate and the fine aggregate was the natural sand which is free from impurities.

3.3 Lime powder

A high quality lime stone powder usually permits a reduction in water content of a concrete mixture, without loss of workability. The test result of specific gravity for lime powder given as 2.2. It categorized as Class C Calcareous material based on IS 712:1984. Lime powder in SCC which conforms EN 197-1:2000 and act as medium for the following,

1. Creates a mechanical bond: The fine particle size of lime allows the mortar to penetrate deep into the concrete. More intimate contact with the unit enhances bond strength.
2. Self-healing: Hairline cracks can be filled by the reaction of carbon dioxide and hydrated lime in exposed areas of the crack.
3. Cementitious: Hydrated lime enhances strength in concrete and mortars.
4. Pozzolanic reaction: Unreacted pozzolans in the cement can chemically combine with the lime to form a cementitious compound.

3.4 Superplasticizer

Conplast X42II chemical admixture was added to the SCC as superplasticizer. It was added 1.5 % of cementitious material based on trial and error method.

3.5 Mix proportion

The mentioned volume batching in Table 1 has been followed in the experimental part and the powder content added in SCC 1, SCC 2 and SCC 3 were 32%, 28%, and 24% respectively. Powder content includes cement, fly ash and lime powder (Calcareous material). In 32% of powder content (SCC 1) contains 75% of cement, 20 % of fly ash and 5% of lime. In 28% of powder content (SCC 2) contains 72.5% of cement, 20 % of fly ash and 7.5% of lime. In 24% of powder content (SCC 3) contains 70% of cement, 20 % of fly ash and 10% of lime. The coarse and fine aggregates were added in the remaining percentages appropriately with fixed water powder ratio of 0.5.

Table 1. Mix combinations (Volume Batching)

Material		SCC-1		SCC-2		SCC-3	
Powder Content	Cement	32%	75%	28%	72.5%	24%	70%
	Fly Ash		20 %		20%		20%
	Lime		5%		7.5%		10%
Fine Aggregate		40%		41%		42%	
Coarse Aggregate		28%		31%		34%	
Water /Powder Ratio		0.5		0.5		0.5	

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IV. RESULTS AND DISCUSSION

4.1 Properties of concrete in fresh state

In general, a workability change depends upon binder to aggregate ratio which conform EFNARC standards; by this the workability tests for filling and passing ability were conducted. SCC should satisfy both workability and strength criteria. Slump flow test, V-funnel test are responsible for filling ability of SCC. J-ring test and L-box test are responsible for passing ability of SCC. V-funnel at 5 minutes is responsible for segregation resistance of SCC. From the experimental results, workability decreases when lime content increases. According to the theory, lime should enhance the workability but here workability decreases when percentage of lime increases. This is mainly due to insufficiency of cement paste in SCC 2 and SCC 3. If SCC 1 has 10% of lime and 28 % of coarse aggregate it may give better strength and workability. But now SCC 1 has 5 % lime, then gives higher strength than other two mixes. The investigation results of workability are presented in Table 2.

Table 2. Workability Investigation Results

Property to be checked	Test	Unit	SCC1	SCC2	SCC3	EFNARC recommendation
Filling ability	Slump flow test	mm	697	682	668	650 - 800
	V-funnel test	S	7	9	12	6 - 12
Passing ability	J-ring test	mm	4.3	6.5	8.2	0 - 10
	L-box test	h2/h1	0.9	0.85	0.8	0.8 – 1.0
Segregation resistance	V-funnel @ 5 min.	S	0	1.19	2	0 - 3

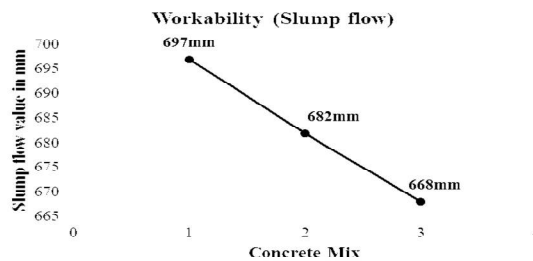


Fig. 1. Workability of concrete (slump flow)

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4.2 Compressive Strength

Compressive strength was tested for the SCC mixes in the specimen size of 150 ×150 ×150 mm. From the results (Table 3), it is clearly observed that, compressive strength decreased when the volume of coarse aggregate and lime powder percentages increased from the SCC mixes 1 to 3. Compressive strength is high even the volume of coarse aggregate is less, due to more cement paste present in mix 1. The results presented in shown Fig. 2.

Table 3. Compressive Strength test results

SCC Mix	7 days strength N/mm ²	28 days strength N/mm ²
1	27.35	38
2	22.36	35.24
3	16.94	33.7

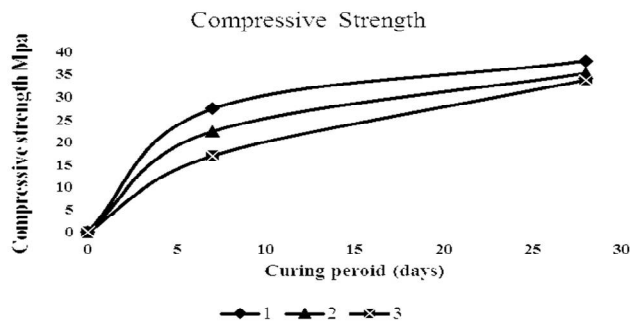


Figure 2. Compressive strength for various SCC

4.3 Split tensile strength

The tensile strength of concrete is one of the predominant properties for the hardened concrete which determined by the split tensile strength test with a cylinder specimen. The concrete is weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Fig. 3 illustrates the split tensile strength of three SCC mixes. It showed that, when the percentage of lime and volume of coarse aggregate was increased then the split tensile strength was decreased which shows that split tensile strength of the concrete does not depends on coarse aggregates present in the mix. The higher splitting tension was obtained when the lime and volume of coarse aggregate as 5% and 28% respectively.

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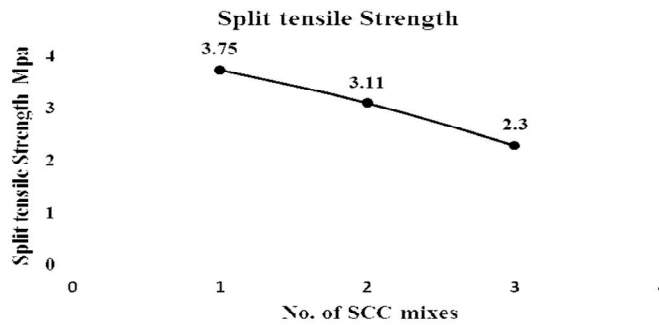


Fig. 3. Split tensile Strength for three SCC

4.4 Flexural Strength

Flexural strength is also important engineering property of hardened concrete. Fig. 4 shows the flexural strength of three SCC under two point loads. In three SCC mixes, SCC 1 gave higher flexural value which was 19% of compressive strength but in general when the compressive strength of the cube is greater than 25 MPa. The flexural strength would be 8 to 11 % of compressive strength, but while using lime and fly ash resulted more flexural strength.

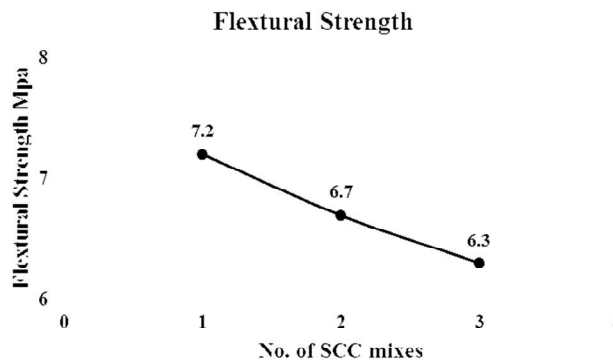


Fig. 4. Flextural strength of SCC mixes

4.5 Density study

Density is the major factor of hardened concrete in case of SCC, density and strength depends on the volume of cement paste and volume of coarse aggregate. The relation of density to strength of three SCC mixes is presented in Fig. 5.

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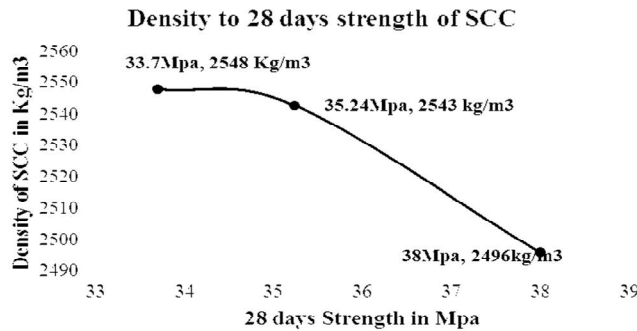


Fig. 5. Density to Strength plot

4.6 Effect of cement paste on strength of SCC

In general cement paste influences in strength behaviour of concrete. When the water added into cement the heat of hydration process (exothermic) starts then the C-S-H gel forms, which is responsible for most engineering properties of concrete. When the volume of cement paste was increased, then the bonding also increased and also shrinkage cracks were increased. When the calcareous material of lime used in concrete, the hairline cracks can be arrested. The effect of cement paste volume in compressive strength as shown in Fig. 6.

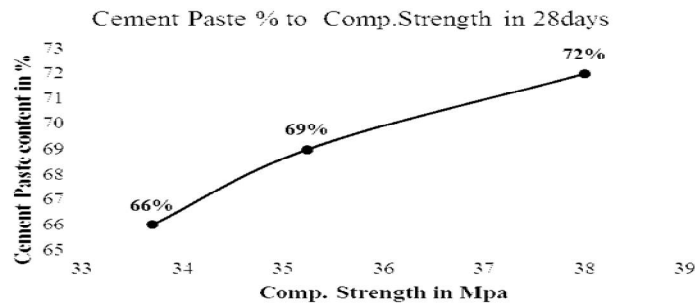


Fig. 6. Effect of Cement paste to Strength plot

V. CONCLUSION

From the experimental results obtained, the following conclusions were made from workability, compressive strength, split tensile strength and flexural strength.

1. From the workability study, SCC 1 had the better workability from the tests such as V-funnel, J-ring, L-box, and slump flow conducted as per EFNARC standard.
2. Compressive strength, split tensile strength and flexural strength were decreased when the lime percentage was increased, it also depends on volume of coarse aggregate present in each mix.
3. In case of flexural strength, SCC 1's flexural strength was 7.2 Mpa which was 19% of Compressive strength obtained. In general when the compressive strength is above 25 Mpa then the flexural would be 8 – 11% of compressive strength. But in this case 19% was obtained, so SCC1 results more flexural strength.
4. SCC1 has less density due to less coarse aggregate and more cement paste content present in the mix which has 5 % lime.

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5. From this experimental study, it was evident that, the fly ash and lime combination was well fitted to SCC and it reduces the hairline cracks. Further, the engineering properties might increase, when the volume of lime 10%, 7.5%, 5 (reverse order of above mix combination, Table 1) in SCC 1, SCC 2 and SCC 3 respectively.

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BIOGRAPHY



Dr. T. Bhagavathi Pushpa obtained her Bachelor's degree in Civil Engineering from Madras University, her Master's degree in Environmental Engineering and received Ph.D. degree from Anna University Chennai. Her teaching experience spans over 12 years. She has published 25 international journals and 20 national and international conferences in her professional career. She is the reviewer in the various International Journals. She is an editorial board member for the journal of Environmental Biotechnology & Research. She is member of various professional bodies like Indian Society for Technical Education, International Association of Civil Engineers, International Association for Hydro-Environment Engineering and Research, Asia-Pacific Chemical, Biological & Environmental Engineering Society, Institute of Public Health Engineers, Indian Water Works Association and The Institute of Engineers.



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