Preliminary study of Self Compacting Concrete by adding Silica Fume- A review paper

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Abstract:

Concrete is the construction material widely used throughout the world. Construction materials used in the industry should be friendly with the environment during its usage. Self-compacting concrete (SCC) is an innovative concrete that does not require 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, homogenous and has the same engineering properties and durability as traditional vibrated concrete. In order to obtain the properties of fresh concrete for SCC, proportion of mineral and chemical admixtures to be added. Since its first development in Japan in 1988, SCC has gained wider acceptance in Japan, Europe and USA due to its inherent distinct advantages. The contributingfactors to this reluctance appear to be lack of any supportive evidenceof its suitability with local aggregates and the harsh environmentalconditions. In this study a review is presented based on the development of self-compacting concrete with mineral admixture- Silica Fume. On various percentages of Silica Fume the SCC properties were studied. Silica Fume was added in 10%, 12.5% and 15% by weight of cement.

Keywords: Silica fume, cement, viscosity modifying admixtures, super plasticizers, physical properties, concrete properties, self compacting concrete, workability, fresh concrete, hardened concrete.

Introduction:

Concrete is a highly heterogeneous material produced by mixture of finely powdered cement, aggregates of various sizes and water with inherent physical, chemical and mechanical properties. SCC is made from the same basic constituents as conventional concrete but with the addition of a viscosity modifying admixture and high levels of superplasticising admixtures to impart high workability. The cement (powder) content of SCC is relatively high. The ratio of fine to coarse aggregates is more in self-compacting concrete. Fine fillers such as fly ash, silica fume, slag, metakaoline, marble dust and rice husk ash may be used in addition to cement to increase the paste content[1]. SCC possesses very high workability due to its low yield stress and moderate viscosity, and therefore it canbe placed in every corner of the formwork throughdense reinforcement and well consolidated without anyexternal means of consolidation [2]. Moreover, the highworkability of SCC results in a well compactedmicrostructure with reduced porosity in mortar matrixand interfacial transition zone, and thus improvesthe electrical resistivity and transport properties ofconcrete. This is the key to enhanced durabilityperformance of SCC[3-5]. The low transport propertiesprovide good protection against corrosion, freeze-thawcycles, sulfate attack and alkali-aggregate reactions.High electrical resistivity hinders the electrochemicalreactions and thus impedes the corrosion of steelreinforcement. In addition, adequate air contentensures the freeze-thaw durability of SCC [6].

The mainreasons for the employment of self-compacting concrete canbe summarized as follows:
1. To shorten construction period.
2. To assure compaction in the structure; especially inconfined zones where vibrating compaction is difficult.
3. To eliminate noise due to vibration (effective especially atconcrete product plants) [7].

Silica fume was first discovered in Norway in 1947 when the environmental controls started the filtering of the exhaust gases from furnaces. The main portion of these fumes was a finely composed of a high percentage of silicon dioxide. As the pozzolanic reactivity for silicon dioxide was well known, many studies have been done on it[8].There are over 3000 publications that have been published about silica fume and silica fume concrete. Conforming to AASHTO M 307 or ASTM C 1240, silica fume can be utilised as material for supplementary cementations to increase the strength and durability [9].

Silica fume consists of the fine particles with specific surface about six times of cement because its particles are very finer than cement particles. Hence, it has been found that when silica fume mixes with concrete the minute pore spaces decreases. Silica fume is pozzolanic, because it is reactive, like volcanic ash. Its effects are related to the strength, modulus, ductility, sound absorption, vibration damping capacity, abrasion resistance, air void content, bonding strength with reinforcing steel, shrinkage, permeability, chemical attack resistance, alkali-silica reactivity reduction, creep rate, corrosion resistance of embedded steel reinforcement, freeze-thaw durability, coefficient of thermal expansion (CTE), specific heat, defect dynamics, thermal conductivity, dielectric constant, and degree of fibre dispersion in mixes containing short microfibers[10].Also, addition of silica fume decreases the workability of the mix. Silica fume can solve problems, because of its very loose bulk density and fine particles [11].

Review of Literature:

BertilPersson (2001) carried out an experimental and numerical study on mechanical properties, such as strength, elastic modulus, creep and shrinkage of self-compacting concrete and the corresponding properties of normal compacting concrete. The study included eight mix proportions of sealed or air-cured specimens with water binder ratio (w/b) varying between 0.24 and 0.80. Fifty percent of the mixes were SCC and rests were NCC. The age at loading of the concretes in the creep studies varied between 2 and 90 days. Strength and relative humidity were also found. The results indicated that elastic modulus, creep and shrinkage of SCC did not differ significantly from the corresponding properties of NCC.

Sri Ravindra rajah et al (2003) made an attempt to increase the stability of fresh concrete (cohesiveness) using increased amount of fine materials in the mixes. They reported about the development of self-compacting concrete with reduced segregation potential. The systematic experimental approach showed that partial replacement of coarse and fine aggregate with finer materials could produce self-compacting concrete with low segregation potential as assessed by the V-Funnel test. The results of bleeding test and strength development with age were highlighted by them. The results showed that fly ash could be used successfully in producing self-compacting high-strength concrete with reduced segregation potential. It was also reported that fly ash in self-compacting concrete helps in improving the strength beyond 28 days.

Ahmadi et al (2007) studied the development of Mechanical properties up to 180 days of self-compacting and ordinary concrete mixes with rice-husk ash (RHA), from a rice paddy milling industry. Two different replacement percentages of cement by RHA, 10%, and 20%, and two different water/cementitious material ratios (0.40 and 0.35) were used for both of self-compacting and normal concrete specimens. The results were compared with those of the self-compacting concrete without RHA. SCC mixes show higher compressive and flexural strength and lower modulus of elasticity rather than the normal concrete. Replacement up to 20% of cement with rice husk ash in matrix caused reduction in utilization of cement and expenditures, and also improved the quality of concrete at the age of more than 60 days. It was concluded that RHA provides a positive effect on the Mechanical properties after 60 days.

Shazim Ali Memon et al (2008) studied the use of Rice Husk Ash (RHA) to increase the amount of fines and hence achieving self-compacting concrete in an economical way. They compared the properties of fresh SCC containing varying amounts of RHA with that containing commercially available viscosity modifying admixture. The comparison was done at different dosages of super plasticizer keeping cement, water, coarse aggregate, and fine aggregate contents constant. Test results substantiate the feasibility to develop low cost SCC using RHA. Cost analysis showed that the cost of ingredients of specific SCC mix is 42.47 percent less than that of control concrete

Materials and methods:

Cement:

All types of cement are suitable for SCC. For all mixes in this research, Ordinary Portland Cement Type I meeting(ASTM 150).

Limestone:
SCC has a graded aggregate and a high volume of limestoneas filler (in the range of 0 to 50% of the mass of powder).

Silica-fume:
Silica-fume, also known as condensed silica fume or microsilica(ACI 116R), is very fine, non-crystalline silica producedin electric arc furnaces as a by-product of the production ofelemental silicon or silica-alloys.

Aggregates:
Locally available natural sand with 4.75mm maximum sizewas used as fine aggregate, andcrushed stone with 19mm maximum size was used ascoarse aggregate. Both fine aggregate and coarse aggregateconformed to ASTM Standard Specifications

Mix Design Procedure:
All Concrete batches were prepared in rotating drum mixer.First, the aggregates are introduced and then one-half of themixing water was added and rotated for approximate two minutes. Next, the cement, most manufacturers recommend atleast 5 minutes mixing upon final introduction of admixtures.Once, the mix was determined to have sufficient visualattributes of SCC, the rheological tests were performed inquick succession.

Specimen and Maintanance Procedure:
Specimen for concrete testing has been manufactured without the compacting. Fresh concrete is conducted workability tests such as slump flow, T500 slump flow, V funnel, Visual Stability Index ASTM C 1611 for four times to know trend of workability test. After completing workability test following specimens were cast for three times repetition to make sure results obtained, each time consist of:

- 150 mmx150mmx150mmcubes to measure the compressive strength of hardened concrete at 7 day.

Results and discussion:

The test results for the filling ability (V-funnel flow time , u- box), passing ability (J-ring flow, L- box flow) , Compressive strength using Rebound hammer and Ultra Sonic Pulse Velocity of different SCC mixtures are given in below tables and graphs.

S No	Mix ID	Mix ratio	Replacement of silica fume	Cement Kg/m^3	F.A Kg/m^3	C.A Kg/m^3	Water Kg/m^3	S.P Kg/m^3	VMA Kg/m^3	Silica fume Kg/m^3
1	SCC	20	0	383	546	1187	191.61	0.957	0.383	0
2	SCC1	20	10	344.70	546	1187	191.61	0.957	0.383	38.3
3	SCC2	20	12.5	335.13	546	1187	191.61	0.957	0.383	47.87
4	SCC3	20	15	325.55	546	1187	191.61	0.957	0.383	57.45

Table 1 : Mix proportions self-compacting concrete

S No	Mix ID	Slump dia Mm	V- Funnel Sec	J- Ring Mm	L- Box h_2/h_1	U- Box Mm
1	SCC	650	8	15	0.758	45
2	SCC1	675	6	18	0.764	40
3	SCC2	678	5	17.5	0.780	38
4	SCC3	682	5	19	0.810	30

Table 2 : Fresh concrete properties of self-compacting concrete

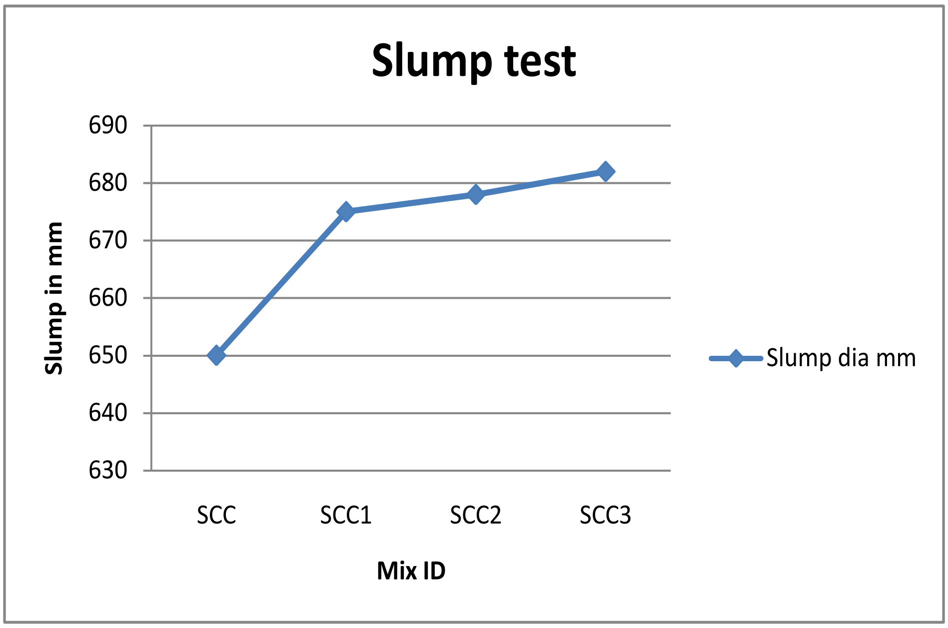

Chart 1 : Graph showing slump test for all mixes

Slump test is done to know how much the concrete is flowing to the surface. The results showed that the slump value is more for SCC of various mixes than conventional SCC. When the Silica Fume is increased the Slump value also increases.

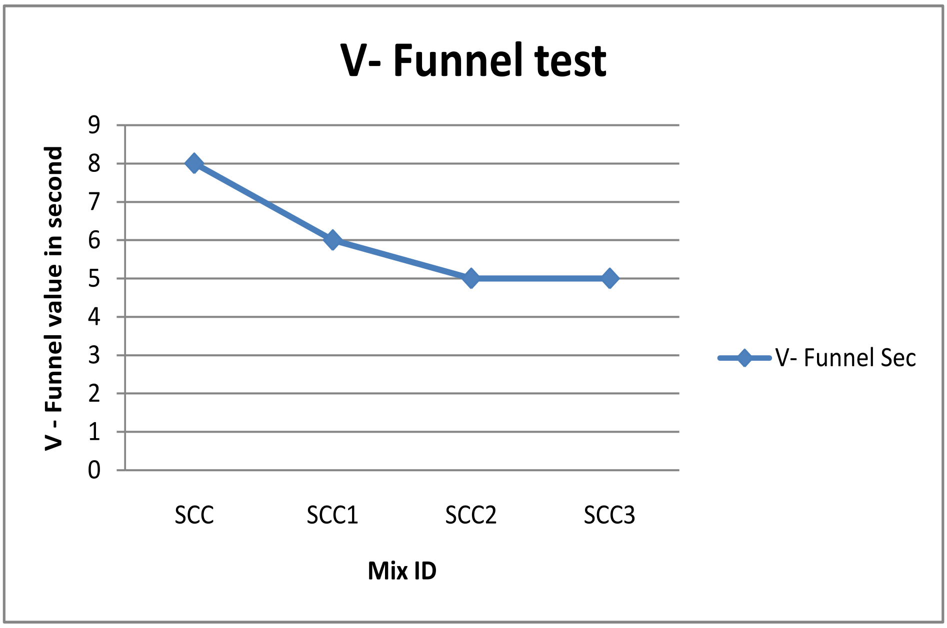

Chart 2: Graph showing V – Funnel test for all mixes

In this test the passing ability of concrete is determined in seconds. From the result it is concluded that for conventional SCC the passing ability is high when compared to SCC added wit Silica Fume.

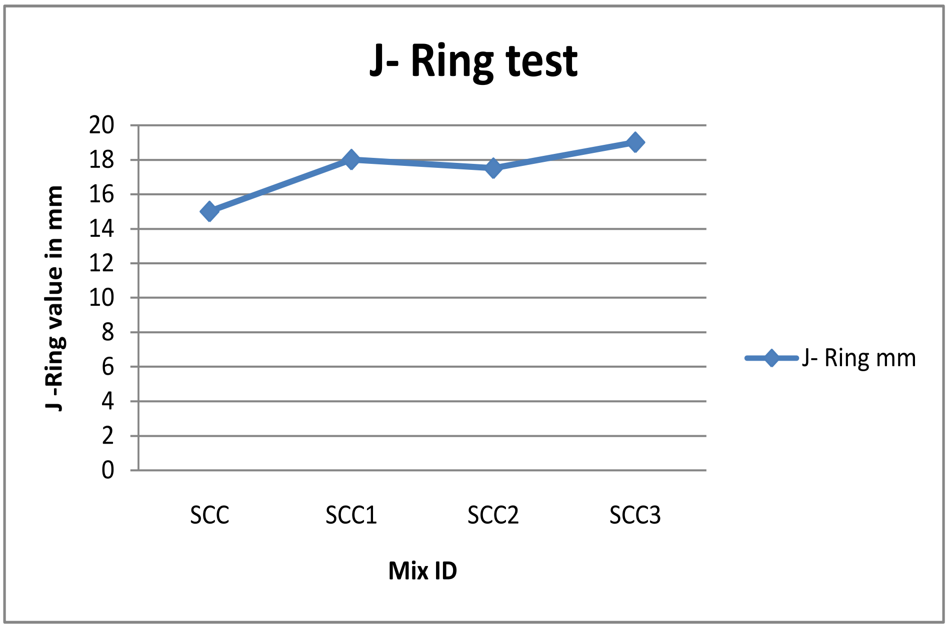

Chart 3: Graph showing J – Funnel test for all mixes

This test is done to determine the flowing capacity of concrete. By the result it is concluded that SCC for various mixes has good flow capacity compared to conventional SCC.

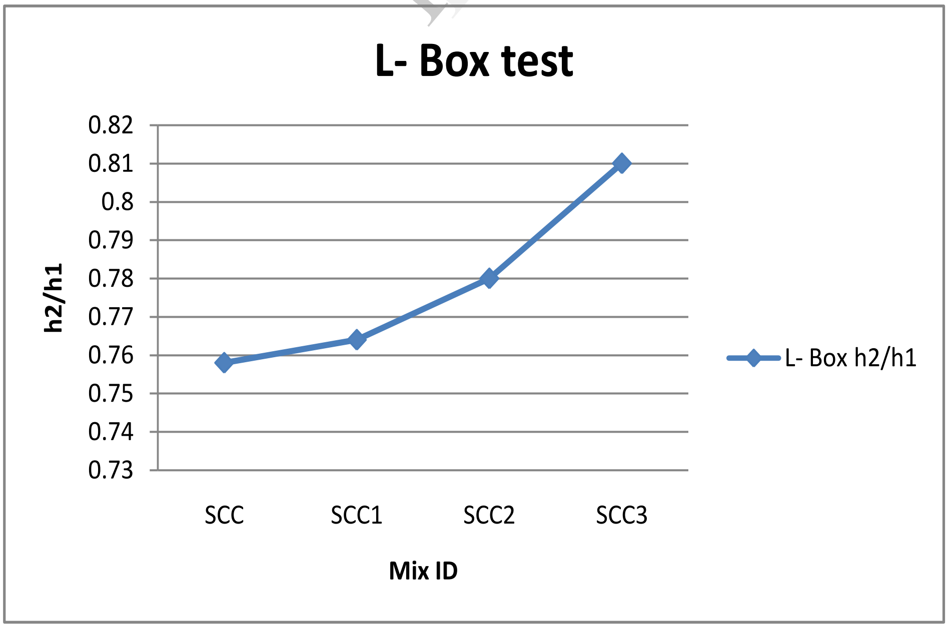

Chart 4: Graph showing L – Box test for all mixes

The compaction ability of concrete is found using L – box test. The results have showed that the compaction ability of SCC for various mixes of Silica Fume is more better than the conventional SCC.

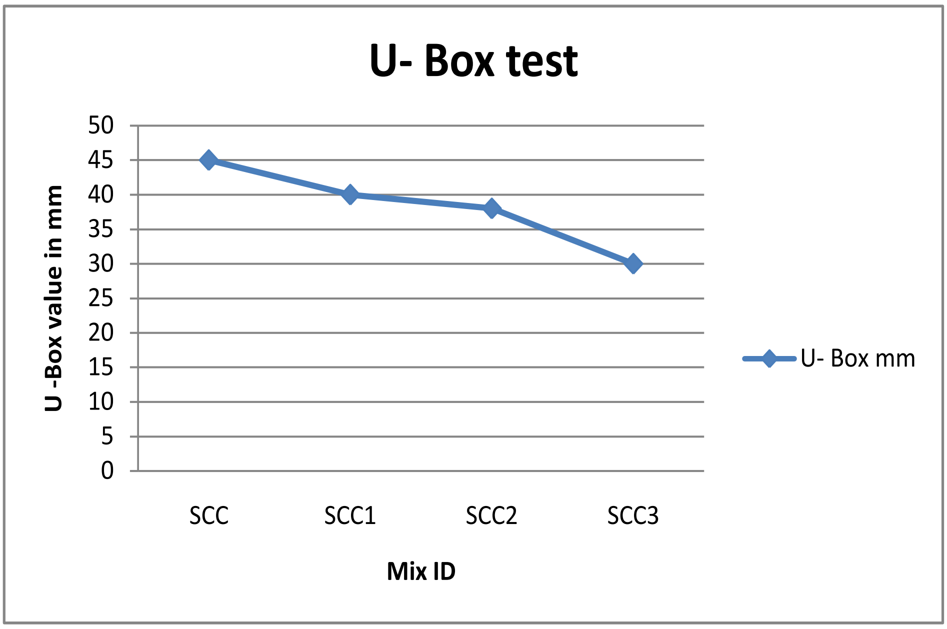

Chart 5: Graph showing U- Box test for all mixes

U – Box test is done to know the filling ability of concrete from one tube to another tube.This test has showed that the filling ability of SCC with various % of Silica Fume is low compared to conventional SCC.

S No	Mix ID	UPV reading µsec	Velocity (L/T) Km/sec	Average Velocity Km/sec
1	SCC	27.1	5.53	
		30	5	
		29	5.17	
		22.5	6.67	
		23	6.52	
		27.2	5.51	
		24	6.25	
		24.5	6.12	
		44	3.41	5.17
2	SCC1	12.7	11.81	
		27	5.56	
		42	3.50	
		34	4.41	
		26	5.76	
		29.3	5.11	
		25.7	5.83	
		28.9	5.19	
		27	5.56	5.85
3	SCC2	14.2	10.56	
		22.3	6.72	
		30.1	4.98	
		29.2	5.13	
		22.8	6.57	

		32.1	4.67	
		30.3	4.95	
		28.2	5.32	
		26.7	5.62	6.05
4	SCC3	29	5.17	
		27	5.5	
		30	5	
		23.5	6.38	
		34.7	4.32	
		27.9	5.37	
		30.2	4.96	
		28.6	5.24	
		20.5	7.31	5.47

Table 3 : Ultra sonic pulse velocity (7days)

Ultra sonic pulse velocity test is done to determine the air voids present in concrete. On addition of Silica Fume to concrete the air voids has been decreased. As the % of Silica Fume increases the air voids gets reduced.

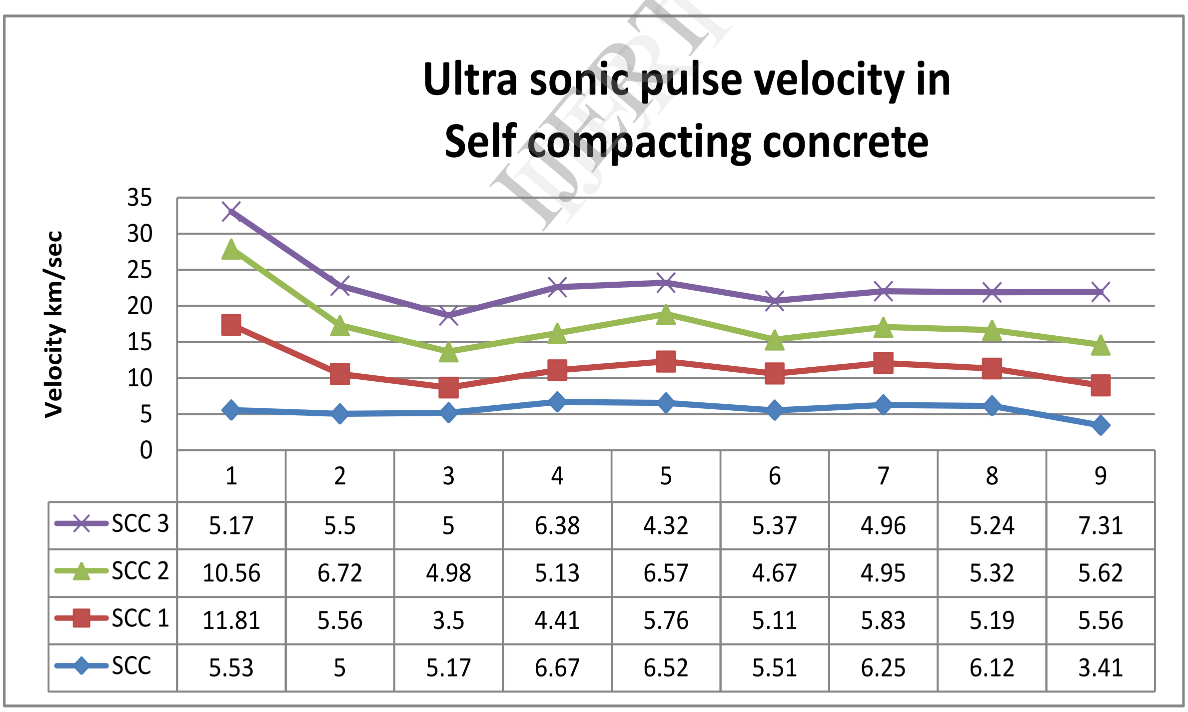

Chart 6: Graph showing Ultra sonic pulse velocity test for all SCC mixes

S NO	Face 1 N/mm^2	Face 2 N/mm^2	Face 3 N/mm^2	Face 4 N/mm^2	SCC N/mm^2
1	12.67	13.32	15.66	13.44	13.77
2	15.23	16.45	12.46	15.38	14.93
3	14.03	14.89	13.85	16.67	14.86
4	15.45	13.04	13.23	16.33	14.51
5	14.39	15.65	16.44	13.67	15.03
6	16.23	13.32	14.12	11.23	13.38
7	14.48	16.09	13.96	14.78	14.82
8	14.57	13.23	15.31	12.34	13.90
9	13.42	12.45	18.01	15.87	14.94
Average	14.49	14.27	14.27	14.41	14.46

Table 4 : Compressive strength test using rebound hammer for Mix ID – SCC (7 days)

S No	SCC N/mm^2	SCC1 N/mm^2	SCC 2 N/mm^2	SCC 3 N/mm^2
1	13.77	16.30	14.56	16.03
2	14.93	15.81	15.47	14.43
3	14.86	15.12	13.98	15.23
4	14.51	14.88	15.02	14.98
5	15.03	16.18	16.44	13.89
6	13.38	15.16	13.76	14.09
7	14.82	14.48	15.24	16.23
8	13.90	15.98	16.12	15.76
9	14.94	14.39	14.76	13.78
10 Average	14.46	15.36	15.04	14.93

Table 5 : Compressive strength test using rebound hammer for various mixes of Silica Fume at 7 days

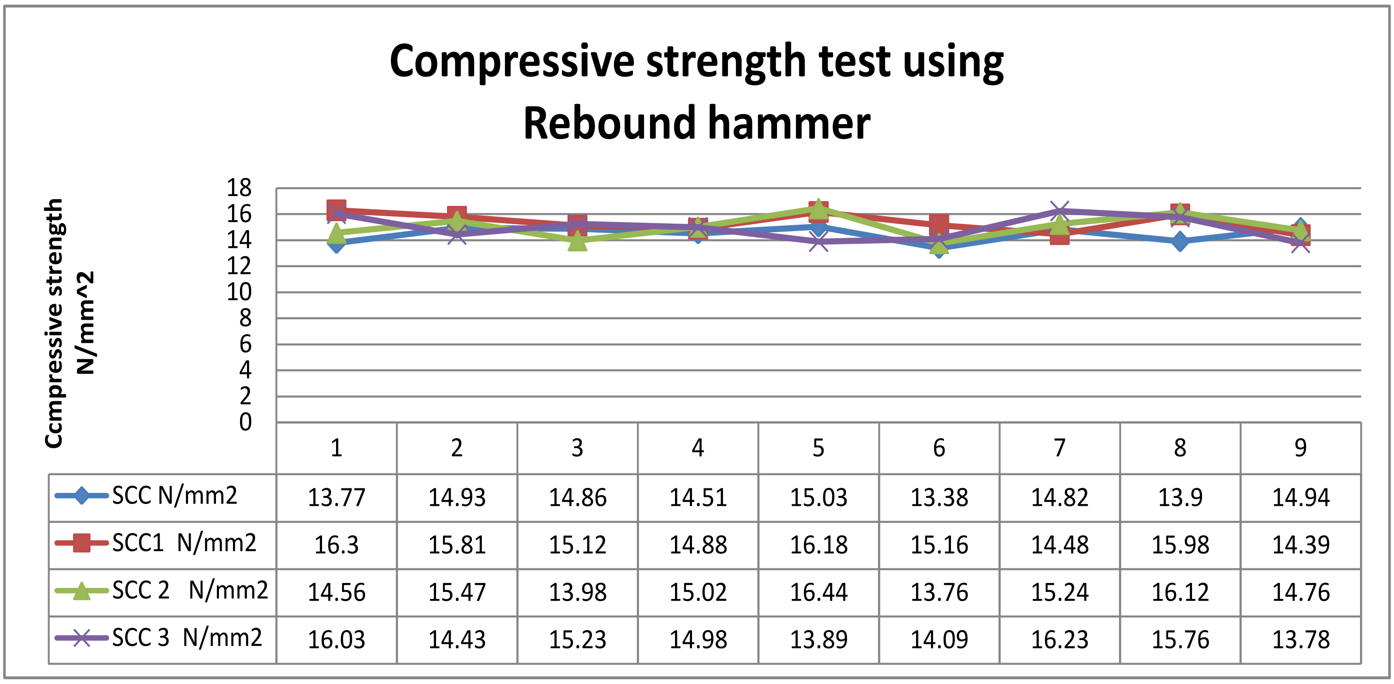

Chart 7: Graph showing Compressive strength test using Rebound hammer for all SCC mixes

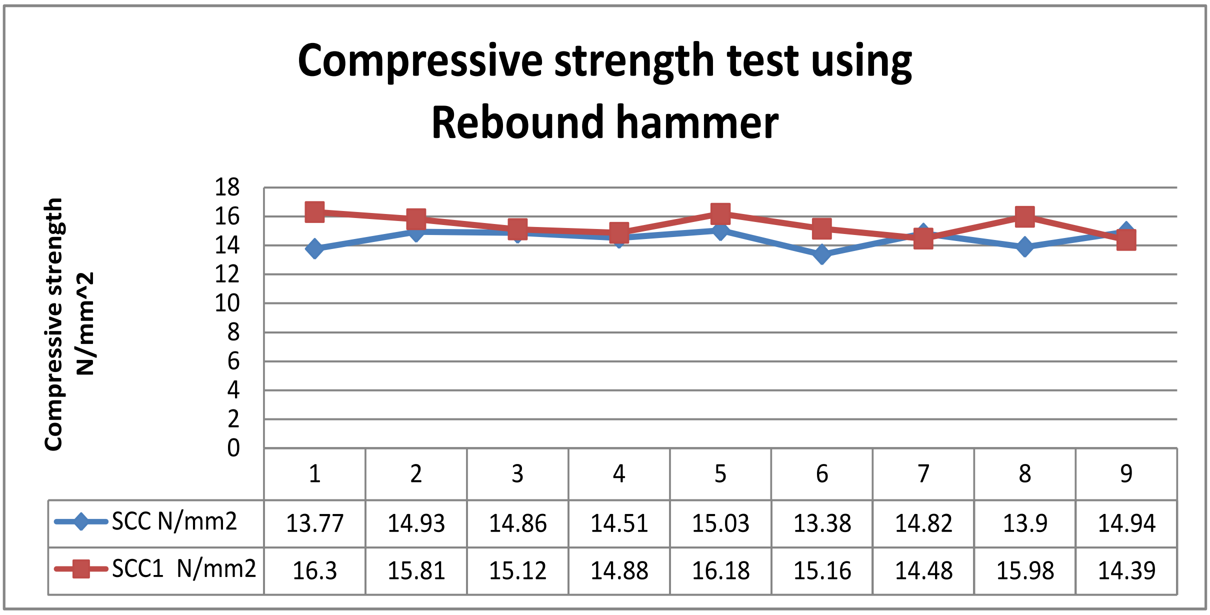

Chart 8: Graph showing Compressive strength test using Rebound hammer for all SCC&SCC1 mixes

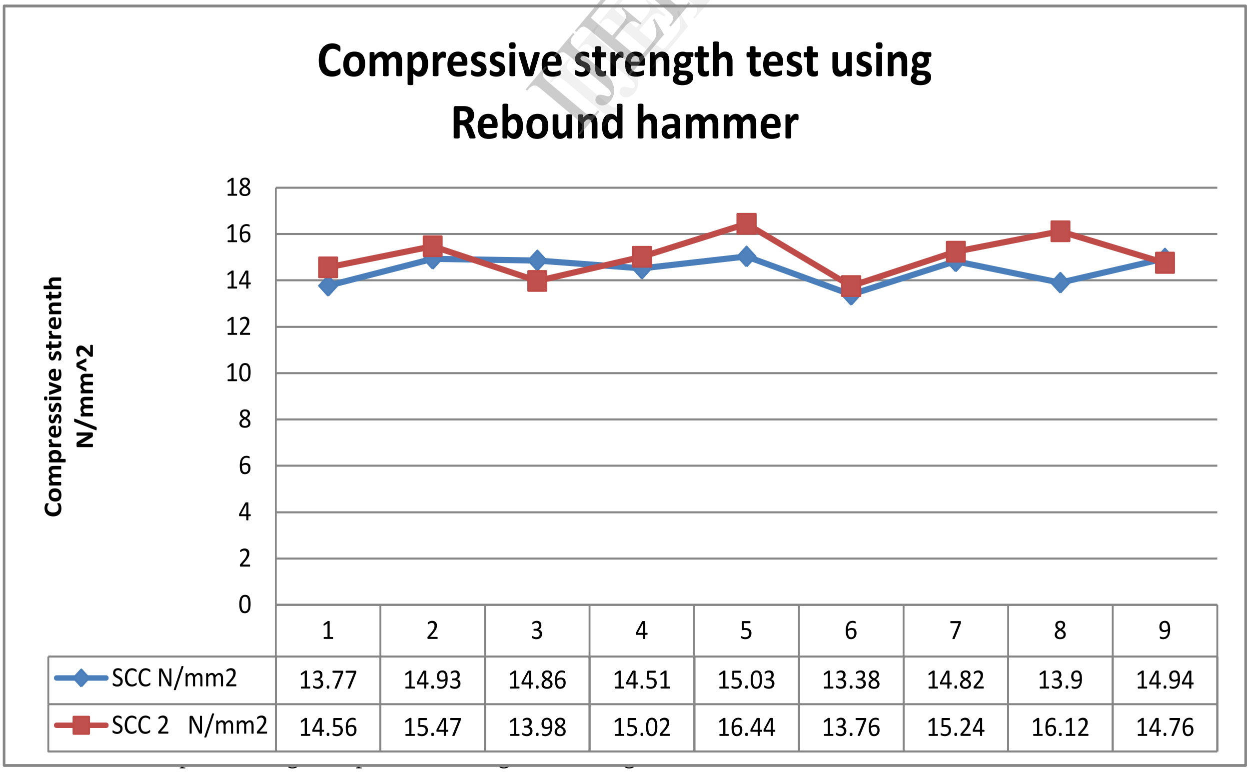

Chart 9: Graph showing Compressive strength test using Rebound hammer for all SCC&SCC2 mixes

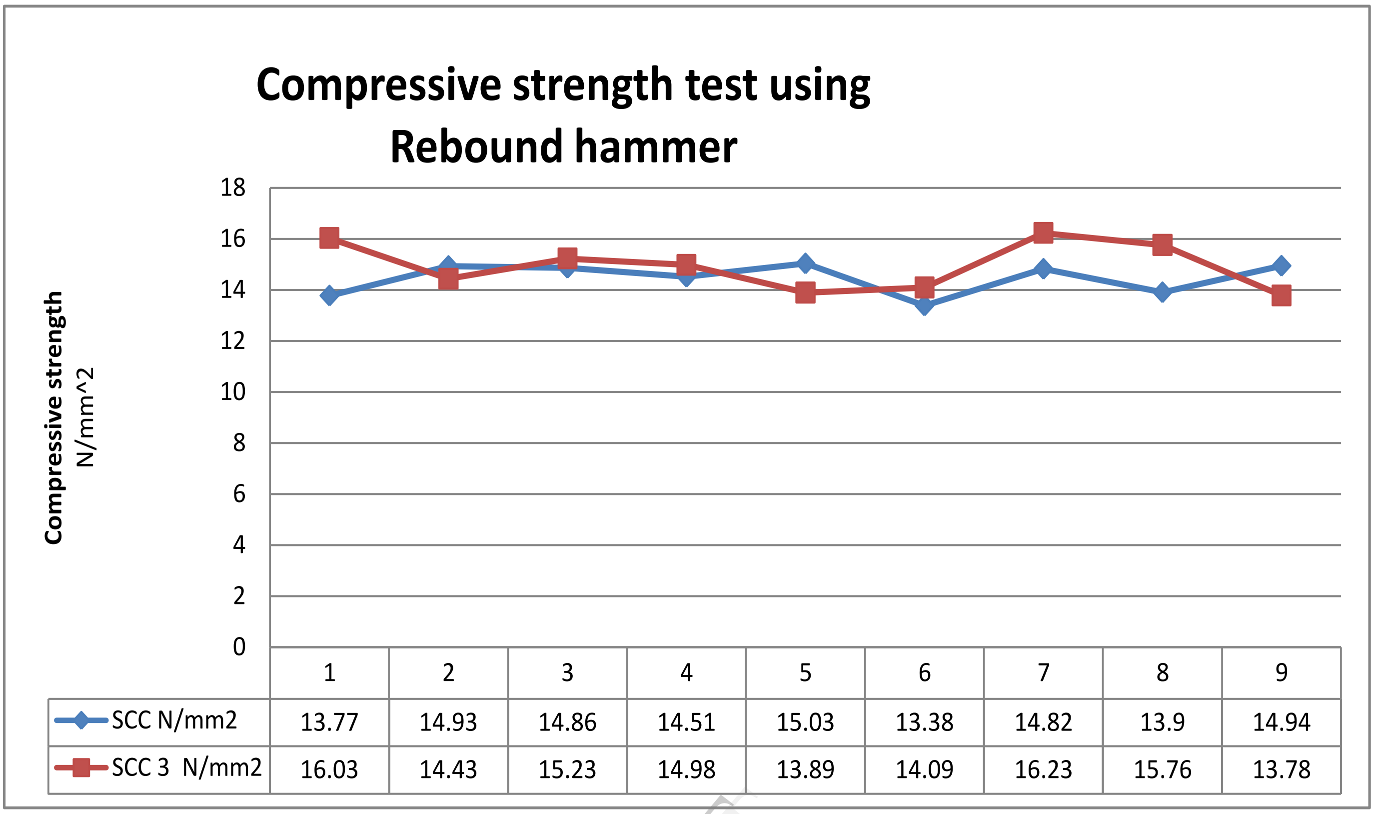

Chart 10: Graph showing Compressive strength test using Rebound hammer for all SCC&SCC3 mixes

High compressive is normally the first property associated with silica fume concrete. Many experiments have shown that the addition of silica fume to concrete mix increases the strength of mix depending on the type of cement, type of mix, use of plasticizers, amount of silica fume, aggregates type, and curing regimes. The tests have revealed that the compressive strength of various mixes of SCC is generally more compared to conventional concrete.

Conclusion:

The application of silica fume in concrete mixture has significantly increased and enhanced the properties of the concrete whether it is in wet stage or in harden condition. Silica fume is a viable secondary mineral material. It leads to higher than usual modulus value and from the mixes studied, it is suggested that no more than 6% silica be replaced by mass. Rheological tests chosen and performed were sufficient to ascertain whether the mix will have all the attributes of SCC or not, i.e., the fresh concrete test used were sufficient to measure the filling ability and passing ability.

SCC provides good resistance to corrosion, freezethawcycles, and sulfate attack due to reducedporosity and decreased transport properties. SCC provides reduced drying shrinkage, lowtransport properties, high electrical resistivity andstable air-voids, which improve concrete durability. Sufficient segregation resistance must be maintained in SCC to decrease the transportproperties, and thus to improve the durability ofconcrete. Comprehensive research is needed to examine theeffect of electrical resistivity and segregation resistance on the durability of SCC.

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