International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 06, June-2015

Experimental Investigation on Properties of Self-Compacting and Self-Curing Concrete with Silica Fume and Light Weight Aggregates

Mr.Vivek,
M.Tech. Student
Mrs. Bhavana B.,
Assistant Professor
Dr. Prema Kumar W.P.,
Senior Professor and P.G.Coordinator
Dr.Prathap Kumar M.T.,
Senior Professor and Research Coordinator
Department of Civil Engineering,
Reva Institute of Technology and Management,
Bengaluru 560 064

Abstract*— Concrete is the second most consumed material in the world after water and it is used most widely in the construction industry due to its high compressive strength and other properties. This paper deals with an experimental investigation on the characteristics of self-compacting concrete (SCC) and self-compacting and self-curing concrete (SCSCC) prepared by (i) partially replacing coarse aggregate with light weight aggregate (LWA) and (ii) adding super absorbent polymer (SAP) in the form of sodium polyacrylate as a self-curing admixture to cure the concrete internally at ambient temperature. 60 concrete cube specimens (SCC and SCSCC) and 60 concrete beam specimens (SCC and SCSCC) were cast for determining the compressive strength and flexural strength. Silica fume (SF) (11% of weight of cement) and superplasticizer (SP) (1% of weight of cement+silica fume) were used in all the test specimens. The self-compacting concrete (SCC) specimens were cured in water at ambient temperature for 7, 14, 21 and 28 days in the conventional manner. The SCSCC specimens were self-cured. The conventional Slump, T_{50cm} slump, J-ring, V-funnel, U-box and L-box tests were carried out on fresh SCC and fresh SCSCC having different proportions. The compressive and flexural strengths of SCC as well as SCSCC in the hardened state were also determined. All the concrete types viz., SCC, SCSCC-1 (0.15% SAP), SCSCC-2 (0.3% SAP), SCSCC-3 (10% LWA) and SCSCC-4 (15% LWA) considered in the present work satisfy the flow criteria. For all the concrete types, both the compressive strength and flexural strength increase with age. SCSCC-2 gives the highest value for compressive strength as well as flexural strength at any age compared to others. SCSCC-4 gives lowest value for compressive strength as well as flexural strength at any age compared to others. SCSCC-1 and SCSCC-2 have better flexural strengths compared to SCC and SCSCC-3 and SCSCC-4.

Keywords—Self-compacting concrete; self-curing concrete; silica fume; light weight aggregate; super absorbent polymer

1. INTRODUCTION

The concept of self-compacting concrete was proposed in 1986 by Professor Hajime Okamura, but it was first developed in 1988 in Japan by Professor Ozawa (1989) at the University of Tokyo. Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under self-weight filling formwork and achieving full compaction even in the areas of congested steel reinforcement. In the hardened state, SCC has strength and durability that are comparable to that of conventional concrete. Worldwide, the use of self-compacting concrete (SCC) has gained wide acceptance in the precast industry as well as in-situ constructions on account of reduction in the time of construction, reduction in the noise of construction by eliminating vibration, possibility of usage of complex formworks and members with highly congested reinforcement etc leading to achievement of a better final product in terms of finish and durability. SCC consists of the same ingredients as the conventionally vibrated concrete viz., cement, aggregates and water along with chemical and mineral admixtures in varied proportions.

Self-curing concrete is a special concrete that overcomes difficulties such as insufficient curing due to human negligence, scarcity of water in arid areas, inaccessibility of structure in difficult terrains and in areas where the presence of fluorides in water may adversely affect the characteristics of concrete. Self-curing in concrete occurs due to internal curing which is a process by which the hydration of cement occurs because of the availability of additional internal water that is not a part of the mixing water (ACI:308 Code).

Light weight aggregate such as the one shown in Fig.1 is highly porous and has a density of about $0.25 g/cm^3$. Lightweight aggregate concrete (LWAC) has been used successfully for structural purposes since the late nineteenth century. Lightweight aggregate concrete has advantages of a higher strength/weight ratio, better strain capacity, lower coefficient of thermal expansion and superior heat and sound insulation characteristics due to air voids existing in lightweight aggregate (LWA).

Fig.1. Light weight aggregate

Super absorbent polymers (SAPs) are a group of polymeric materials that have the ability to absorb a significant amount of liquid from the surroundings through hydrogen bonding with the water molecule and to retain the liquid within their structure without dissolving. The commercially important SAPs are covalently cross-linked polyacrylate and copolymerized polyacrylamide/ polyacrylate.

Silica fume is ultrafine non-crystalline silica produced in electric arc furnace as a by-product during the production of elemental silicon or alloys containing silicon and consists of spherical particles with an average particle diameter of 150 nm (vide Fig.2). It has excellent pozzolanic properties. By using silica fume along with super plasticizers it is relatively easier to obtain compressive strengths of the order of 100 MPa – 150 MPa in laboratory. Addition of silica fume also reduces the permeability of concrete due to chloride ions which protect the reinforcing steel from corrosion especially in chloride rich environments such as coastal regions and those of humid continental roadways and runways and bridges across salt water flow.

Fig.2. Silica fume

A good amount of literature exists on self-compacting concrete, self-curing concrete and self-compacting and self-curing concrete. A few important ones are mentioned here. Reference [1] deals with research carried out on self-compacting concrete independently in the summer of 1988, after Okamura began his research in 1986 and succeeded in developing self-compacting concrete for the first time. A prototype of SCC was developed by using available materials and different types of superplasticizer. It was observed that the flowing ability of concrete is drastically improved by partial replacement of Portland cement with fly ash and blast furnace slag. After trying different proportions of admixture, he found that addition of 10 – 20 % of fly ash and 25 – 45 % of slag cement by mass shows better flowing ability and strength characteristics. Reference [2] has compared the splitting tensile strength and compressive strength values of self-compacting and normal concrete specimens. The SCC mixtures exhibited higher values of splitting tensile and compressive strengths compared to those of normal concrete. The bonding between the coarse aggregate and the cement paste were examined using the scanning electron microscope. It was noticed from the images taken on concrete samples having water-cement ratios of 0.3, 0.4, and 0.6 using the scanning electron microscope that inter transition zone is weaker for normal concrete when compared to SCC. Thus the aggregate-cement bonds were noticed to be better for SCC than for normal concrete. Reference [3] deals with the development of self-compacting light weight concrete (SCLWC) using light expand clay aggregates (Leca). Different mix proportions were selected on trial and error basis and specimens cast. Tests such as slump, L-box, V-funnel, J-ring were conducted on fresh concrete. The 28 days compressive strength was also determined. The experimental results revealed that, by using Leca as lightweight aggregate, self-compacting lightweight concrete having compressive strength of 20.8 MPa and 28.5 MPa at 28 days could be developed. Reference [4] deals with the development of self-compacted concrete by using Portland Pozzolana cement, hydrated lime and silica fume. Lime was used as a filler material. Silica fume improved the aggregate-matrix bond resulting from the formation of a less porous transition zone in concrete. It was concluded that Portland Pozzolana cement can be used for the development of self-compacting concrete. Silica fume provides mechanical strength to SCC; 8% replacement of cement by silica fume has best effect on compressive strength of concrete. Addition of silica fume and lime enables the concrete to develop filling and passing ability. Reference [5] is a comparative study on the use of different materials as binder content in SCC and their effects on the workability properties. Reference [6] deals with the production and evaluation of SCC made using high volumes of fly ash. It was observed that the compressive strength ranging from 15 to 31 MPa (7 days) and from 26 to 38 MPa (28 days) were developable with no extra cost. This investigation has shown that it is possible to design a self-compacting concrete incorporating high-volume of Class F fly ash. The utilization of fly ash in SCC solves the problem of its disposal thus keeping the environment free from pollution. Reference [7] deals with the use of a mix of Portland cement and ground rice husk-bark ash (GRHBA) in producing self-compacting concrete (SCC). This work suggested that the GHRBA is effective in producing SCC at 30% of GHRBA replacement level. Reference [8] deals with the development of high strength self-compacting concrete of M70 grade. Reference [9] deals with self-curing concrete of grade M40. The self curing material used was Super Absorbent Polymer (SAP) which is a wax based membrane curing compound applied on the demoulded concrete specimens to arrest the water evaporation. It was found that the optimum dosage of SAP was 0.3%. Addition of SAP leads to a significant increase of mechanical strengths (compressive and splitting tensile strengths). Compressive strength of self-cured concrete for dosage of 0.3% was higher than water cured concrete. Flexural strength of self-cured concrete for dosage of 0.3% was lower than water cured concrete. The self-cured concrete using SAP was more economical than the conventionally cured concrete. Reference [10] deals with internal curing of high performance concrete using Super Absorbent Polymer and Light Weight Aggregate. The SAP specimens exhibited a significant improvement of about 6.88 % increase in compressive strength. The LWA specimens were found to have 28days compressive strength 12.35% greater than that of the control concrete mix. The durability studies showed that internal curing by means of SAP has less chloride penetration than internally cured specimens using LWA. Internally cured specimens proved to be better than conventionally cured specimens. Reference [11] *d*eals with the use of water-soluble polyvinyl alcohol as self-curing agent. The test results indicated that the use of polyvinyl alcohol (0.48% by the weight of cement) as self curing agent provides higher compressive, split tensile as well as flexural strengths than those of the conventional mix. Water retention for the concrete mixes incorporating self-curing agent is higher compared to conventional concrete mixes as found by the weight loss with time. Reference [12] deals with the strength behavior of Self-Curing Fly Ash Concrete of grade M30 with steel fibers. Self-curing was done by Super Absorbent Polymer (SAP). Addition of 1.5% steel fiber in self-curing fly ash concrete gave higher strength than that of conventional concrete. Self-curing fly ash concrete gave higher compressive strength, tensile strength and flexural strength when compared to externally cured fly ash concrete. Reference [13] examines the effects of two different curing agents in order to compare them for optimizing the performance of concrete. The first used type is the pre-soaked lightweight aggregate (leca) with different percentages of 0, 10, 15 and 20 by volume of sand; and the second type is a chemical agent of **polyethylene**-glycol (PEG) with different percentages of 1, 2 and 3 by weight of cement. Reference [14] deals with the production and evaluation of SCC made with limestone powder (LP) with silica fume, quarry dust and clinkers. The results of this study suggested that certain combinations of quarry dust (QD), SF and LP can improve the workability of SCCs more than each of QD, SF and LP alone. From the experimental investigation, it was observed that a maximum of 8% of lime stone powder with silica fume, 30% of quarry dust and 14 % of clinkers could be used without affecting the self-compaction. Reference [15] explores the relationship between permeability and compressive strength of AR Glass fiber-reinforced concrete. In addition, it determined the influence of AR Glass fiber reinforcement on concrete permeability. The AR Glass fibers decreased the permeability of specimens with increased volume of fibers. Reference [16] deals with self-compacted concrete of medium strength. The concrete specimens were divided into 3 groups/batches. Three different curing methods were employed. First batch was cured in a temperature controlled curing tank in the laboratory. The second batch was cured by the application of an external curing compound under prevailing site conditions. The third batch was cured with internal curing agent. It was observed that the immersion method was the best method for curing giving maximum strength. External curing with curing compound method gave about 9% less compressive strength at 28 days than immersion curing. Internal curing with Polyethylene Glycol gave 5% less compressive strength than immersion curing. Reference [17] deals with the use of an optimum amount of Sodium Polyacrylate, SP, to be mixed in ordinary plain concrete. Several batches were prepared to determine the most effective amount of SP to be used in the concrete mix. From the results obtained it was concluded that the use of sodium polyacrylate in concrete increases the concrete strength due to internal curing process. This increase is relatively small even at the optimum amount of sodium polyacrylate used in the concrete. This may become advantageous in the absence of concrete curing. Excessive amount of sodium polyacrylate used in concrete has a substantial negative effect on the concrete strength. Reference [18] deals with the experimental evaluation of the effects of replacing the cement by silica fume, fine aggregate by Manufactured sand (JSW) and coarse aggregate by light weight aggregate on fresh and hardened state properties of M40 grade concrete. The silica fume percentage was kept constant at 10. The replacement percentages of fine aggregate were 0, 10, 20, 30 and 40. The replacement percentages of coarse aggregate for the purpose of internal curing were 10 and 15. The compressive strength and split tensile strength of specimens with 30% replacement of FA and 15% of LWA (internally cured concrete at ambient room temperature), specimens with 30% replacement FA and 10% LWA (internally cured concrete at ambient room temperature) gave higher values than those of normal concrete with conventional curing. The flowability and passability measurements indicated that SCC mixes with partial replacement materials of M-sand and LWA were better when compared to that of control mix.

2. PRESENT EXPERIMENTAL INVESTIGATION

2.1 General

In the present work, the fresh and hardened state properties of M70 grade of self-compacting concrete with silica fume (designated as SCC), M70 grade self-compacting and self-curing concrete with silica fume and SAP (0.15% and 0.30% of weight of cement) (designated as SCSCC-1 and SCSCC-2), M70 grade self-compacting and self-curing concrete with silica fume and LWA (replacing 10% and 15% of coarse aggregate by weight) (designated as SCSCC-3 and SCSCC-4) are determined. The fresh and hardened state properties of each of SCSCC-1, SCSCC-2, SCSCC-3 and SCSCC-4 are compared with those of SCC. Slump flow, T_{50cm} slump flow, V-funnel, U-Box, L-box and J-ring tests are conducted to determine the fresh state properties. The hardened state properties are here limited to compressive strength and flexural strength tests. Cube specimens of size 150 mm × 150 mm × 150 mm are used for determining the compressive strength in accordance with IS:516-1959. Standard specimens of size 500 mm × 100 mm × 100 mm are used for determining the flexural strength in accordance with IS:516-1959. The compressive and flexural strengths are determined at 7, 14, 21 and 28 days of age.

2.2 Materials used

In the present work, ordinary Portland cement of 43 grade conforming to IS 12269:1987 was used. The physical properties of cement obtained by conducting tests in accordance with BIS specifications and procedures are given in Table I.

TABLE I. PHYSICAL PROPERTIES OF CEMENT

Sl.No.	Property	Experimental Value
1	Fineness	2.5%
2	Soundness	1 mm
3	Initial Setting Time	60 min
4	Standard consistency	30%
5	Specific gravity	3.1

The silica fume used in this work was of 920D grade. Three tests were conducted to determine the specific gravity of silica fume and the average value of specific gravity obtained was 2.2. River sand was used as fine aggregate and sieve analysis was performed. The fineness modulus computed was 3.37. The sand conformed to zone II. The average value of specific gravity obtained from the 3 tests is 2.7. The average value of bulk density obtained from the 3 tests is 1450 kg/m^3. The locally available crushed stones of 12.5 mm down size were used as coarse aggregates. The average bulk density was experimentally found to be 1337 kg/m^3. The average specific gravity of the coarse aggregate was experimentally found to be 2.87. Sieve analysis was performed on the coarse aggregates and the fineness modulus was obtained as 7. Artificial light weight aggregate of 12.5 mm down size procured from M/S ARAVIND LTD., Kengeri, Bengaluru was used. The specific gravity of LWA is 1.06 and the bulk density is 574.60 kg/m^3 as per supplier. Potable water was used for mixing and curing of concrete. The superplasticizer used was Glenium-B 233 supplied by BASF India Ltd. The type of SAP used was a gel polymerized sodium polyacrylate supplied by M/S CHEMZEST ENTERPRISES, Perambur, Chennai. Its water absorption capacity is 24 g of water per g of polymer (provided by manufacturer). They can be added externally pre-saturated with water or they can be added dry to concrete mix.

2.3 Concrete types used

To arrive at the mix proportions of self-compacting concrete (SCC), Nan Su method was used. Trial specimens were cast using the so obtained proportions and tested. When the designed strength was not attained, the proportions were varied by trial and error based on experience and judgment. The total cement content finally required for M70 grade concrete is mentioned in Table II along with the value obtained as per Nan Su design.

TABLE II. TOTAL CEMENT CONTENT FOR M70 GRADE CONCRETE

	Experiment	Nan Su Design
Total cement content (Kg/m^3)	620.70	570.71

In this work, cement was partially replaced by a constant percentage of silica fume in accordance with the mix design in both self-compacting concrete (SCC) and self-compacting and self-curing concrete (SCSCC). 0.15% of SAP was added by weight of cement to self-compacting and self-curing concrete obtaining SCSCC-1. 0.30% of SAP was added by weight of cement to self-compacting and self-curing concrete obtaining SCSCC-2. 10% by weight of coarse aggregate in self-compacting and self-curing concrete was replaced by LWA obtaining SCSCC-3. 15% by weight of coarse aggregate in self-compacting and self-curing concrete was replaced by LWA obtaining SCSCC-4. Superplasticizer was used to achieve the required workability, the dosage being restricted to maximum permissible limit. The details of the various types of concrete used in the present work are given in Table III.

TABLE III. TYPES OF CONCRETE USED

Sl. No.	Concrete Type	Cementitious Material		F.A. Content	C.A. Content		SAP (%)
		Cement (%)	*Silica Fume (%)*	*Sand (%)*	*Crushed stone (%)*	*LWA (%)*	
1	SCC	89	11	100	100	0	0
2	SCSCC-1	89	11	100	100	0	0.15
3	SCSCC-2	89	11	100	100	0	0.3
4	SCSCC-3	89	11	100	90	10	0
5	SCSCC-4	89	11	100	85	15	0

The details of the mix proportions for M70 grade SCC arrived at are given in Table IV.

TABLE IV. INGREDIENTS OF M70 GRADE SCC

Description	Cementitious Material		F.A.	C.A.		SAP	Water	SP
	Cement	*SF*	*Sand*	*Crushed stone*	*LWA*			
Qty kg/m^3	550.9	69.9	893.2	673.9	0	0	205.1	7.17
Ratio	1	0.11	1.44	1.09	0	0	0.33	0.01

11% of cement in Table II was replaced by silica fume and SAP = 0.15% by weight of cement was added to obtain SCSCC-1. The details of the mix proportions for M70 grade SCSCC-1 arrived at are given in Table V.

TABLE V. INGREDIENTS OF M70 GRADE SCSCC-1

Description	Cementitious Material		F.A.	C.A.		SAP	Water	SP
	Cement	*SF*	*Sand*	*Crushed stone*	*LWA*			
Qty kg/m^3	550.9	69.9	893.2	673.9	0	0.93	205.1	7.17
Ratio	1	0.11	1.44	1.09	0	0.0015	0.33	0.01

11% of cement in Table II was replaced by silica fume and SAP 0.30% by weight of cement was added to obtain SCSCC-1. The details of the mix proportions for M70 grade SCSCC-2 arrived at are given in Table VI.

TABLE VI. **INGREDIENTS OF M70 GRADE SCSCC-2**

Description	Cementitious Material		F.A.	C.A.		SAP	Water	SP
	Cement	*SF*	*Sand*	*Crushed stone*	*LWA*			
Qty kg/m^3	550.9	69.9	893.2	673.9	0	1.86	205.06	7.17
Ratio	1	0.11	1.44	1.09	0	0.003	0.33	0.01

11% of cement in Table II was replaced by silica fume and coarse aggregate in Table IV was replaced by 10% of LWA. The details of the mix proportions for M70 grade SCSCC-3
arrived at are given Table VII.

TABLE VII. INGREDIENTS OF M70 GRADE SCSCC-3

Description	Cementitious Material		F.A.	C.A.		SAP	Water	SP
	Cement	*SF*	*Sand*	*Crushed stone*	*LWA*			
Qty kg/m^3	550.9	69.9	893.2	606.49	67.38	0	205.06	7.17
Ratio	1	0.11	1.44	0.98	0.11	0	0.33	0.01

11% of cement in Table II was replaced by silica fume and coarse aggregate in Table IV was replaced by 15% of LWA. The details of the mix proportions for M70 grade SCSCC-4 arrived at are given Table VIII.

TABLE VIII. INGREDIENTS OF M70 GRADE SCSCC-4

Description	Cementitious Material		F.A.	C.A.		SAP	Water	SP
	Cement	*SF*	*Sand*	*Crushed stone*	*LWA*			
Qty kg/m^3	550.9	69.9	893.2	606.5	67.38	0	205.06	7.17
Ratio	1	0.11	1.44	0.98	0.11	0	0.33	0.01

2.4 Tests on Fresh Concrete

The tests conducted on fresh state of self-compacting concrete and self-compacting and self-curing concrete are listed in Table IX.

TABLE IX. TESTS CONDUCTED ON FRESH CONCRETE

Sl. No.	Method	Property
1	Slump-flow by Abrams cone	Filling ability
2	T_{50cm} slump flow	Filling ability
3	J-ring	Passing ability
4	V-funnel	Filling ability
5	L-box	Passing ability
6	U-box	Passing ability

2.5 Compressive Strength Test

Compressive Strength test was carried out on concrete cubes of size 150 mm x 150 mm x 150 mm. The steel cube moulds were coated with oil at inner surfaces and base plate. The amount of cement, silica fume, sand, SAP, LWA and coarse aggregates required for the cubes were weighed. The materials were first dry mixed and then mixed with water and calculated amount of superplasticizer. The top surface was finished using trowel.

After 24 hours concrete cubes were demoulded and the self-compacting concrete (SCC) specimens were kept for curing under water. For self-compacting and self-curing concrete cubes, conventional curing was not required. The cubes were tested in 200 tonnes capacity compression testing machine to get the compressive strength of concrete in accordance with BIS specifications (IS:516-1959). Fig. 3 shows testing of cubes for compressive strength and Fig. 4 shows LWA concrete cube specimens.

Fig.3. Testing Cubes for Compressive Strength

Fig. 4. LWA Concrete Cube Specimens

2.6 Flexural Strength Test

Flexural test was carried out on prism specimens of size 500 mm x 100 mm x 100 mm. The inner surfaces and the base plate of the moulds were coated with oil for easy removal of form and for smooth finish. The amount of cement, silica fume, sand, SAP, LWA and coarse aggregates required for specimens were weighed. The materials were first dry mixed and then mixed with water and calculated amount of superplasticizer. The top surface was finished using trowel. After 24 hours the concrete specimens were demoulded and the self-compacting concrete (SCC) specimens were kept for curing under water. For self-compacting and self-curing concrete, conventional curing is not required. The specimens were tested for flexural strength at 7, 14, 21 and 28 days in accordance with the BIS specifications (IS:516-1959). Fig. 5 shows the test for flexural strength. Fig. 6 shows the LWA prism specimens. Fig.7 shows the SAP prism specimens.

Fig. 5. Testing for Flexural Strength

Fig. 6. LWA Prism Specimens

Fig. 7. SAP Prism Specimens

3. RESULTS AND DISCUSSION

3.1 Tests on Fresh Concrete

The flow properties for SCC, SCSCC-1, SCSCC-2, SCSCC-3 and SCSCC-4 concretes are given in Tables X through XIV.

TABLE X. **FLOW PROPERTIES OF SCC**

Property	Experimental Value	Recommended Range
Slump value (mm)	720	650-800
T50 Slump (sec)	3.5	3-5
J Ring (mm)	8	<10
V Funnel (sec)	8	6-12
L-Box	1	0.8-1
U-Box (mm)	25	<30

TABLE XI. FLOW PROPERTIES OF SCSCC-1

Property	Experimental Value	Recommended Range
Slump value (mm)	710	650-800
T50 Slump (sec)	4	3-5
J Ring (mm)	8	<10
V Funnel (sec)	8	6-12
L-Box	0.9	0.8-1
U-Box (mm)	20	<30

TABLE XII. **FLOW PROPERTIES OF SCSCC-2**

Property	Experimental Value	Recommended Range
Slump value (mm)	690	650-800
T50 Slump (sec)	5	3-5
J Ring (mm)	9	<10
V Funnel (sec)	9	6-12
L-Box	0.86	0.8-1
U-Box (mm)	22.5	<30

TABLE XIII. **FLOW PROPERTIES OF SCSCC-3**

Property	Experimental Value	Recommended Range
Slump value (mm)	680	650-800
T50 Slump (sec)	5	3-5
J Ring (mm)	10	<10
V Funnel (sec)	8	6-12
L-Box	0.9	0.8-1
U-Box (mm)	25	<30

TABLE XIV. FLOW PROPERTIES OF SCSCC-4

Property	Experimental Value	Recommended Range
Slump value (mm)	660	650-800
T50 Slump (sec)	4	3-5
J Ring (mm)	9	<10
V Funnel (sec)	8	6-12
L-Box	0.875	0.8-1
U-Box (mm)	15	<30

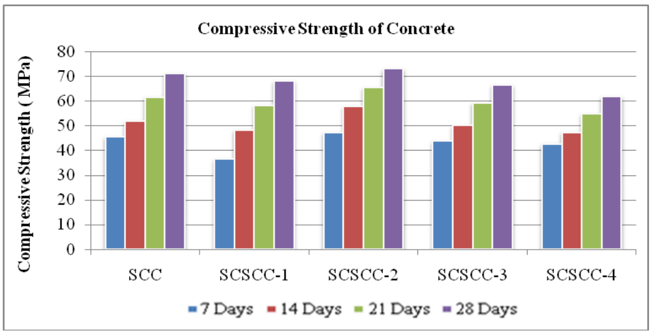
From Tables X through XIV, it is observed that all the concrete types satisfy the flow criteria and hence are self-compacting.

3.2 Compressive Strength Test

The results for the compressive strength at 7, 14, 21 and 28 days for SCC, SCSCC-1, SCSCC-2, SCSCC-3 and SCSCC-4 are given in Table XV. The Bar Chart 1 represents the various compressive strengths pictorially.

TABLE XV. **COMPRESSIVE STRENGTH OF CONCRETE**

Sl.No.	**Concrete Type**	**Compressive Strength (MPa)**			
		7 Days	*14 Days*	*21 Days*	*28 Days*
1	SCC	45.60	52.00	61.70	71.40
2	SCSCC-1	36.66	48.50	58.45	68.40
3	SCSCC-2	47.50	58.00	65.60	73.20
4	SCSCC-3	44.00	50.30	59.45	66.70
5	SCSCC-4	42.90	47.55	55.00	62.00



Bar Chart 1: Compressive Strength of Concrete

The following are observed from Table XV and Bar Chart 1:

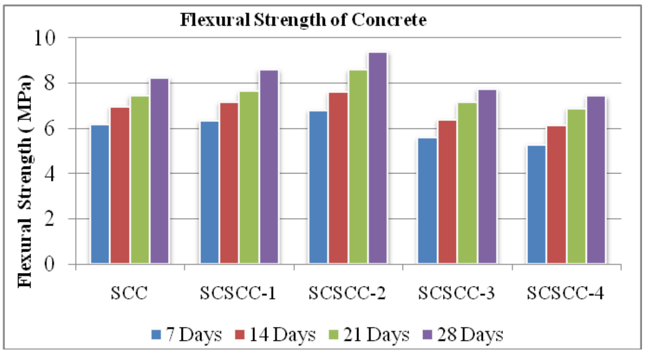
- For all the concrete types, the compressive strength increases with age.
- SCSCC-2 gives highest value for compressive strength at any age compared to others, the next best being SCC.
- SCSCC-4 gives lowest value for compressive strength at any age compared to others. Its strength at 28 days is considerably lower than the target strength. This may be attributed to the lower density of the coarse aggregate combination among others.

3.3 Flexural Strength Test

The results for the flexural strength at 7, 14, 21 and 28 days for SCC, SCSCC-1, SCSCC-2, SCSCC-3 and SCSCC-4 are given in Table XVI. The Bar Chart 2 shows the various flexural strengths pictorially

TABLE XVI. FLEXURAL STRENGTH OF CONCRETE

Sl.No.	Concrete Type	Flexural Strength (MPa)			
		7 Days	14 Days	21 Days	28 Days
1	SCC	6.17	6.97	7.46	8.25
2	SCSCC-1	6.35	7.18	7.65	8.60
3	SCSCC-2	6.80	7.60	8.60	9.40
4	SCSCC-3	5.60	6.40	7.15	7.75
5	SCSCC-4	5.30	6.15	6.90	7.44



Bar Chart 2: Flexural Strength of Concrete

The following are observed from Table XVI and Bar Chart 2:

- For all concrete types, the flexural strength increases with age.
- SCSCC-2 has highest value for flexural strength at all ages compared to the other types, the next best being SCSCC-1.
- Self-compacting and self-curing concretes with SAP (SCSCC-1 and SCSCC-2) have better flexural strengths compared to self-compacting concretes (SCC) and self-compacting and self-curing concretes with LWA (SCSCC-3 and SCSCC-4).

4. CONCLUSIONS

Based on the results of this study, the following conclusions are drawn:

- All the concrete types (SCC, SCSCC-1, SCSCC-2, SCSCC-3 and SCSCC-4) considered in the present study satisfy the flow criteria and hence are self-compacting.
- For all the concrete types, the compressive and the flexural strengths increase with age.
- SCSCC-2 gives highest value for compressive strength at any age compared to others, the next best being SCC.
- SCSCC-2 has highest value for flexural strength at all ages compared to the other types, the next best being SCSCC-1.
- SCSCC-4 gives lowest value for compressive strength and flexural strength at any age compared to others.
- The compressive strength of SCSCC-4 at 28 days is considerably lower than the designed strength. This may be attributed to the lower density of coarse aggregate combination among others.
- Self-compacting and self-curing concretes with SAP (SCSCC-1 and SCSCC-2) have better flexural strengths compared to self-compacting concretes (SCC) and self-compacting and self-curing concretes with LWA (SCSCC-3 and SCSCC-4).

ACKNOWLEDGMENT

All the authors gratefully acknowledge the encouragement and support provided by the Management, Principal and HOD, Civil Engineering Dr. Y. Ramalinga Reddy of Reva Institute of Technology and Management, Bengaluru.

REFERENCES

[1] Kazumasa Ozawa, “Development of Self Compacting Concrete”, EASEC-2, Vol.1.

[2] Cristian Druta and Dr. Linbing Wang, “Tensile Strength and Bonding Characteristics of Self Compacting Concrete”, Polytechnic University of Bucharest (1995), August 2003.

[3] A.A. Maghsoudi, Sh. Mohamadpour and M. Maghsoudi, “Mix Design and Mechanical Properties of Self Compacting Light Weight Concrete”, International Journal of Civil Engineering, Vol. 9, No. 3, September 2011.

[4] Dubey Sanjay Kumar and Chandak Rajeev, “Development of Self Compacting Concrete by Use of Portland Pozzolana Cement, Hydrated Lime and Silica Fume”, ISCA Journal of Engineering Sciences Vol. 1(1), 35-39, July (2012).

[5] Dilraj Singh, Harkamaljeet Singh Gill and Sarvesh Kumar, “An Experimental Investigation on the Fresh Properties of Self-Compacting Concrete Containing Fly Ash, Silica Fume and Lime Powder”, Published in IJREAS Volume 2, Issue 2 (February 2012) ISSN: 2249-3905.

[6] Arivalagan S, “Experimental Analysis of Self Compacting Concrete Incorporating Different Range of High-Volumes of Class F Fly Ash”, Sch. J. Eng. Tech., 2013; 1(3):104-111.

[7] Sumrerng Rukzon and Prinyaka Chindaprasirt, “Use of Rice Husk-Bark as in Producing Self-Compacting Concrete”, Hindawi Publishing Corporation advances in civil engineering volume 2014, article id 429727.

[8] P.Raghuver, S.Chandrashekar Reddy And K.Nagaraju , “Effect of Size of Aggregate On Self Compacting Concrete of M70 Grade”, Civil engineering department GRIET, Hyderabad.

[9] M. Manoj Kumar and D. Maruthachalam, “ Experimental Investigation on Self-Curing Concrete”, International journal of advanced scientific and technical research Issue 3 volume 2, March-April 2013.

[10] C. Chella Gifta, S. Prabavathy and G. Yuvaraj Kumar, “Study on Internal Curing of High Performance Concrete using Super Absorbent Polymers and Light Weight Aggregates” , Asian Journal of Civil Engineering (BHRC) VOL. 14, NO. 5 (2013).

[11] Nagesh Tatoba Suryawanshi, “Assessment of the Properties of Self-Cured Concrete”, *S.B.Patil, College of Engineering, Indapur,(Pune)*portal http://www.engineeringcivil.com /assessment-of-the-properties-of-self-cured-concrete.html.

[12] R. Aarthi and R. Venkatakrishnaiah, “Strength Behavior of Self-Curing Fly Ash Concrete using Steel Fiber”, International Journal of Advanced Research in Civil Engineering and Developing Volume: 2 Issue: 1 08-May-2014,ISSN_NO: 2320-723X.

[13] Magda I. Mousa , Mohamed G. Mahdy , Ahmed H. Abdel-Reheem ,Akram Z. Yehia, “Physical Properties of Self-Curing Concrete”, Published in HBRC journal (2014).

[14] C. Selvamony, M. S. Ravikumar, S. U. Kannan and S. Basil Gnanappa, “Investigations on Self-Compacted Self-Curing Concrete using Limestone Powder and Clinkers”, ARPN Journal of Engineering and Applied Sciences VOL. 5, NO. 3 March 2010.

[15] S. U. Kannan, C. Selvamony, M. S. Ravikumar and S. Basil Gnanappa “Investigations and Study on the Effect of Ar Glass Polymer Fibres in Self-Compacting Self-Curing Concrete” , ARPN Journal of Engineering and Applied Sciences Vol. 5, No. 2 March 2010.

[16] Prof. Nanak J Pamnani, Dr. A.K. Verma, Dr. D.R. Bhatt, “Comparison of Compressive Strength of Medium Strength Self Compacted Concrete by Different Curing Techniques”, International Journal of Engineering Trends and Technology (IJETT) – Volume 4, Issue 5- May 2013.

[17] Moayyad Al-Nasra , “Optimizing the use of Sodium Polyacrylate in Plain Concrete” , International Journal of Engineering Research and Applications ISSN: 2248-9622 Vol. 3, Issue 3, May-June 2013.

[18] Mr. Sanjay Raj A and Yogananda N, “ Experimental Investigation On Self-Curing Self-Compacting Concrete By Replacing Natural Sand By M-Sand And Coarse Aggregates By Light Weight Aggregate For M-40 Grade Concrete” , International Journal of Scientific and Research Publications, Volume 4, Issue 8, August 2014.