INFLUENCE OF AGGREGATE SIZE ON SCC

B. Chandraiah[1], C.Krishnama Raju[2], S.Talha Zaid[3]

[1]Post-Graduate Student, [2]Associate Professor, [3]Assistant Professor, School of Civil Engineering,

Rajeev Gandhi College of Engineering and Technology (Autonomous), Nandyal.

ABSTRACT

Self Compacting Concrete (SCC) is a highly workable concrete, it spreads easily even in the presence of congested reinforcement due to its self weight. Generally, SCC is made of cement, fine aggregate, coarse aggregate, mineral admixtures, super plasticizers and viscosity modifying agents. In this paper, an experimental study has been carried out for M40 grade SCC. Nan-Su mix design method is used. SCC mixes are prepared by using mineral admixtures Fly Ash and GGBS in 7:3 ratio, Conplast-SP430 as super plasticizer, Auramix V100 as viscosity modifying agent and ordinary Portland cement of 53 grade with different sizes of coarse aggregates (10, 12.5, 16 and 20 mm). Fresh concrete properties are determined by conducting Slump flow, T50 slump flow, V-funnel, L-box and J-Ring tests. Fresh concrete properties obtained confirms to EFNARC specifications. Compressive strength of mixes is determined at ages of 3, 7, 28 and 56-days. Split tensile strength and Flexural strength is determined at the age of 28 days. 16 mm coarse aggregate yielded better mechanical properties compared other sizes of aggregates.

KEY WORDS: *Fly Ash, GGBS, Super plasticizers, workability properties, Nan-Su method, EFNARC specifications.*

1. INDRODUCTION:

Self Compacting Concrete(SCC) is a special type of concrete which provides greater workability, strength, durability and it resists segregation and it have a passing ability. This concrete was first introduced in Japan by professor Okamura in 1986. The mix design was proposed by Nan-Su et.al in 2001. Specifications and guide lines for SCC are given in EFNARC 2002 and 2005. These guide lines gives the specifications for workability.

In India, during last decade SCC utilization is increased. In Delhi metro project about 10, 000 m^3 of SCC is used. Rich content fly ash SCC is introduced by Hindustan Construction Company for the construction of power plant in Rajasthan.

INFLUENCE OF AGGREGATES

The influence of fine aggregate on fresh concrete properties of SCC is significantly greater than that of coarse aggregate. Both crushed and river sands are suitable for SCC. In principle, all types of coarse aggregates are suitable to produce SCC. Light weight aggregates are successfully used for SCC, although the aggregate may migrate to the surface if the paste viscosity is low. The particle size distribution and the shape of coarse aggregate directly influence the flow and passing ability of SCC. The more spherical the aggregate particles the less they are likely to cause blocking and the greater the flow because of reduced internal friction. However, crushed aggregates tend to improve the strength because of the interlocking of the angular particles. EFNARC (2005) specifies a typical volume content of coarse aggregate that ranged from 28% to 35% by volume of mix [1].Nan-Su et al.(2001) proposes that the aggregate packing factor (i.e., the ratio of mass of tightly packed state in SCC to that of loosely packed state in air) determines the aggregate content, and influences the strength, flowability and self compacting ability. They also indicated volume ratio of fine aggregate to total aggregates ranges from 50% to 57% [2].Shakir et al., (2001) indicated that the flowability of SCC decreases with the increase of coarse aggregate from 10-20 mm. Although the mechanical properties of SCC containing 10 mm maximum size of coarse aggregate are higher than mixes with 20 mm maximum size of coarse aggregate [3].Collepardi et al (2005) indicated that the volume and maximum size of the coarse aggregate must be lower than 340 L/m^3 and 25 mm respectively, in order to avoid segregation collision among aggregate particles, which can block the concrete flow [4]. Okamura and Quchi (2003) indicate that if the coarse aggregate content in SCC a mixture exceeds a certain limit, blockage would occur independently of viscosity of mortar. Super plasticizer and water content are then determined to ensure desired self- compacting characteristics. It is also suggested to increase passing ability, it is better to reduce volume of coarse aggregate in SCC [5]. Dr K. Pandurangan et al.,(2012) investigated Low Volume Fly ash(LVF) SCC and High Volume Fly ash(HVF) SCC with 10, 12.5, 16 and 20 mm size coarse aggregates. The compressive strength of HVF SCC is more compared to LVF SCC. Also 16 mm coarse aggregate HVF SCC mix had better compressive strength compared to other sizes of coarse aggregate HVF SCC mixes. But 20 mm coarse aggregate LVF SCC mix had better compressive strength compared to other sizes of coarse aggregate LVF SCC mixes [6].

2. MATERIALS USED:

In this investigation, the SCC is made of Cement, Fine aggregate, Coarse aggregate, Fly ash, Ground Granulated Blast Furnace Slag, Super-Plasticizers (ConplastSP-430) and Viscosity Modifying Agent (Auramix V-100).

2.1 CEMENT:

The cement used is OPC 53 grade. The properties of cement are shown in table 1.

Table-1 Test Results on Cement

Property	**Test results**
Fineness	4%
Normal consistency	32%
Setting times Initial Final	 61min 302min
Soundness	3 mm
Specific gravity	3.01
Compressive strength 3 days 7days 28days	 27.9Mpa 37.9Mpa 54.81Mpa

- All the properties of cement are satisfied as per IS:12269-1987

2.2 FINE AGGREGATE:

In this investigation locally available Natural River sand was used as fine aggregate. The following properties of fine aggregate are shown in table 2.

Table-2 Test Results on Fine aggregate

Property	**Test Results**
Fineness modulus	2.735
Specific gravity	2.66
Zone of Fine Aggregate	II
Bulking of sand	21%

- All the properties of Fine aggregate are satisfied as per IS:383-1970.

2.3 COARSE AGGREGATE:

The different sizes of coarse aggregate are 10 mm, 12.5 mm, 16 mm, 20 mm were used. The properties of Coarse aggregate as show in table 3.

Table-3 Test Results on Coarse aggregate

Property	**Test Results**
Specific Gravity	2.66
Impact Value	12%
Crushing Value	16%
Elongation index	24.64%
Flakiness index	20.98%

- All the properties of Coarse aggregate are satisfied as per IS: 383-1970.

2.4 MINERAL ADMIXTURES

In this investigation, two types of mineral admixtures are considered. They are

1. Fly Ash
2. Ground Granulated Blast Furnace Slag

2.4.1 FLY ASH AND GROUND GRANULATED BLAST FURNACE SLAG (GGBS):

The Fly Ash considered in this investigation was collected from Rayalaseema Thermal power plant (RTTP), near kadapa.A.P. The GGBS is used as another mineral admixture and it was collected from JSW

Cements, Gadivemula, Nandyal, AP. The chemical composition of Fly ash and GGBS as shown in table 4.

The Chemical composition, it can be said that the considered Fly ash and GGBS satisfies the codal provision IS: 3812-2003 and IS: 12089-1987

Table-4 Chemical properties of Fly Ash and GGBS

Property	Test results of Fly Ash	Test results of GGBS
Moisture	0.2%	0.15%
loss on ignition	4.00%	1.56%
$SiO_2+Al_2O_3+Fe_2O_3$	89.8%	78.53%
Sodium dioxide(SiO_2)	60.7%	34.20%
Calcium oxide(CaO)	9.02%	37.06%
Reactive silica	52.32%	--
Magnesium oxide(MgO)	0.65%	7.2%
Total sulphur as sulphur Trioxide(SO_3)	0.17%	--
Available Alkali as Na_2O	0.32%	--
Total chlorides	<0.01%	0.007%
Glass content	--	92.6%
Specific gravity	2.1	2.89

2.5 SUPER PLASICIZERS:

In this investigation Conplast SP-430 and Viscosity Modifying Agent (AuramixV-100) were used as chemical admixtures.

2.6 WATER:

Locally available water is used for mixing and curing.

3. MIX PROPORTIONING:

The grade of concrete is M40 grade and the mix design adopted is Nan-Su mix design method as shown in table-5.

Table-5 Mix proportion by Nan-Su Method

Cement (Kg/m^3)	Fly ash (Kg/m^3)	GGBS (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	SP dosage (l/m^3)	VMA in % of concrete volume	W/C ratio	W/P ratio
348	83.02	35.58	1005.4	736.1	8.39	0.2%	0.42	0.41

4. RESULTS AND DISCUSSION

In this investigation, Fresh concrete was tested for workability to know its different characteristics like passing ability and filling ability. Slump flow test, T50 slump flow test, V-funnel test were conducted to know the filling ability of the manufactured fresh concrete-Ring, L-Box tests were considered to know the passing ability of the manufactured fresh concrete.

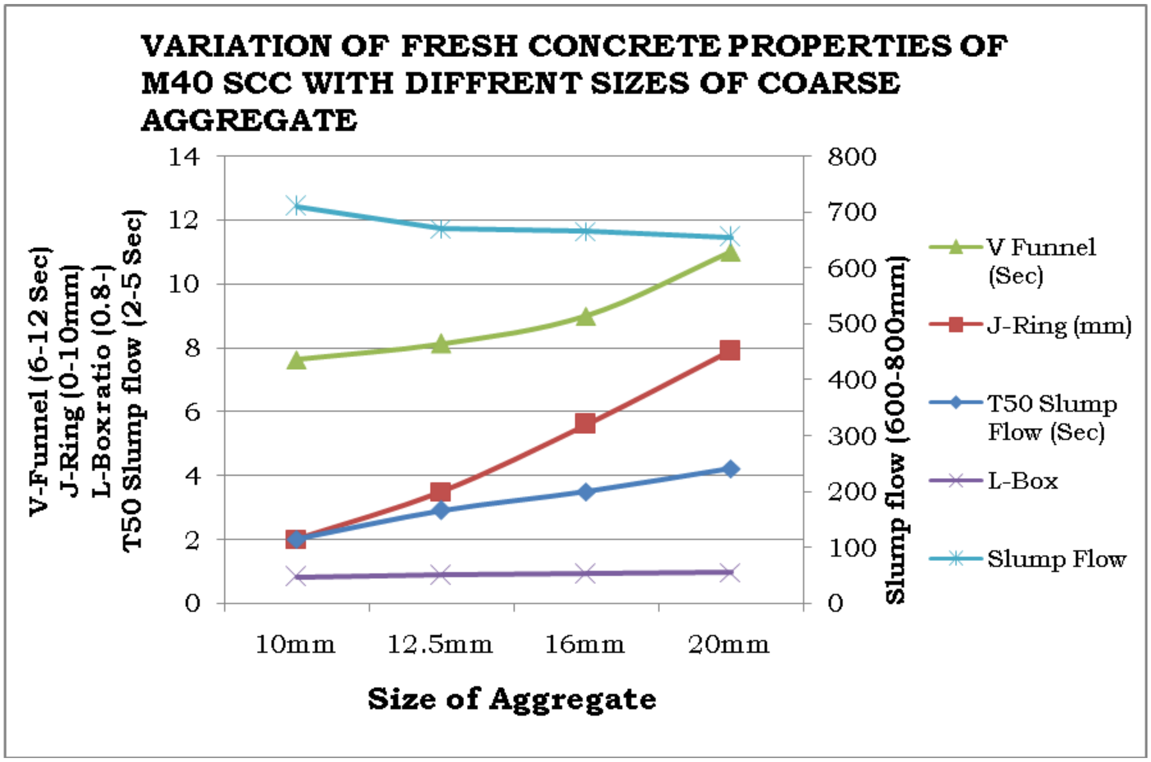
Tests were conducted on hardened concrete to determine its compressive strength for different sizes of coarse aggregate, different mixes were made, casting of concrete cubes was done and cured for 3,7, 28 and 56 days. The tensile strength also be tested at 28days of curing.

4.1 WORKABILITY TEST RESULTS OF FRESH SELF COMPACTING CONCRETE:

To determine the Filling and Passing ability of the fresh SCC, its workability characteristics were determined and the fresh results are shown in table 6.

Table-6 Workability test results

Size of the aggregate	10 mm	12.5 mm	16 mm	20 mm	EFNARC Limits
Slump flow(mm)	710	670	665	655	600-800mm
T50Slump flow(sec)	2	2.9	3.5	4.21	2-5 sec
J-Ring(mm)	2	3.5	5.6	7.9	0-10mm
V-Funnel(sec)	7.62	8.12	9	11	6-12sec
L-Box	0.815	0.873	0.914	0.963	0.8-1



Graph-1; Slump flow, T50 Slump flow ,J-Ring, V-Funnel ,L-Box tests.

From graph-1 ; The Slump flow value decreases with the increasing in the aggregate size.The other workability properties os SCC increases with increase of aggregate size.

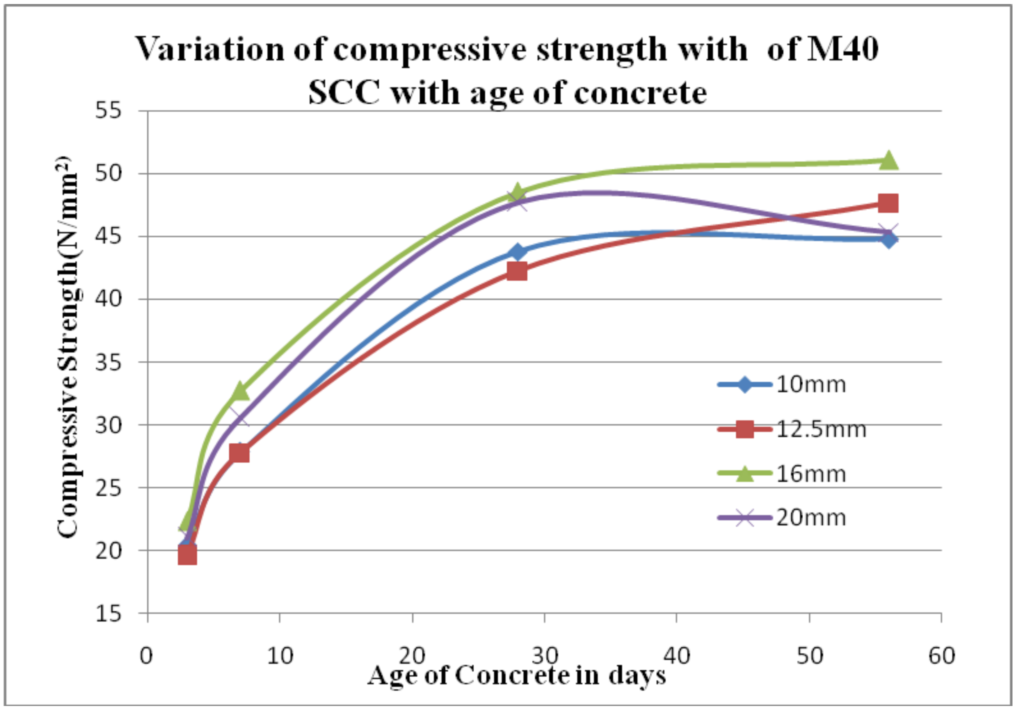
4.2 TESTS ON HARDENED CONCRETE

4.2.1 COMPRESSIVE STRENGTHOF SCC:

Concrete cubes are casted for different sizes of coarse aggregate SCC mixes and cured for 3, 7, 28 and 56 days. Compressive strength of cubes is determined at different ages and is shown in table 7.

Table-7 Compressive Strength vs Size of the aggregate

Size of the aggregate	Compressive strength of SCC at different ages			
	3 Days	7 Days	28 Days	56 Days
10 mm	20.36	27.8	43.8	44.78
12.5 mm	19.59	27.79	42.24	47.65
16 mm	22.32	32.7	48.51	51.1
20 mm	20.97	30.6	47.71	45.3



Graph-3: Compressive strength

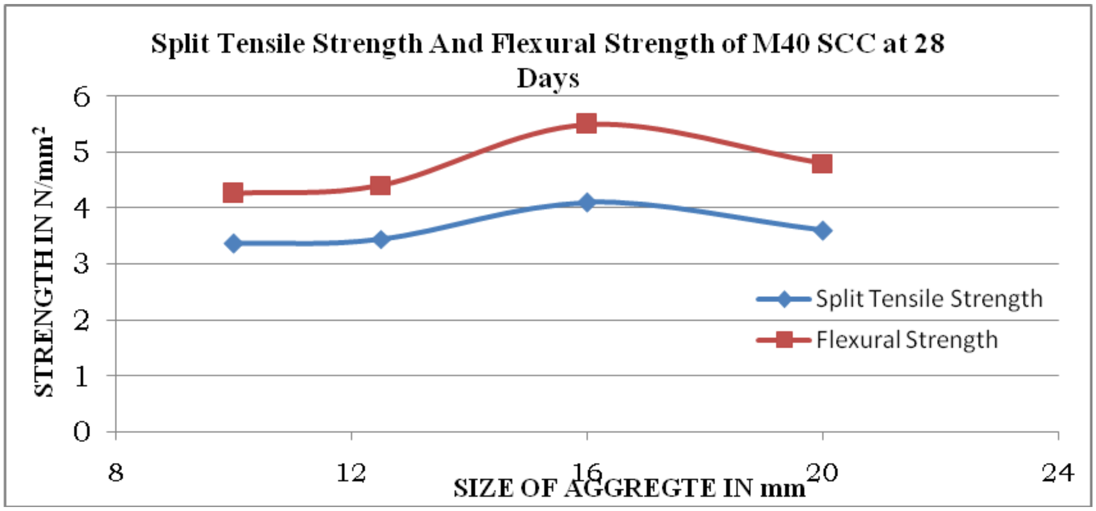
Graph 3 shows that the compressive strength of 16 mm aggregate SCC mix is more compared other sizes of aggregated mixes at all ages. Also the compressive strength of 20 mm aggregate SCC mix is more compared 10 mm aggregated mix at all ages.

4.2.2 SPLIT TENSILE STRENGTH AND FLEXURAL STRENGTHOF SCC

Concrete cylinders and Beams were casted for different mixes and cured for 28 days and the test results of split tensile strength (cylinders) and flexural strength (Beams) are as shown in table 8.

Table -8: Split Tensile Strength & Flexural Strength of M40 SCC

Size of the Aggregate	Split Tensile Strength at 28 Days (N/mm^2)	Flexural Strength at 28 Days (N/mm^2)
10 mm	3.37	4.26
12.5 mm	3.44	4.41
16 mm	4.1	5.5
20 mm	3.6	4.8



Graph-4 Split Tensile Strength and flexural strength of SCCat 28 days curing.

The split tensile strength and flexural strength of 16 mm aggregate SCC mix is more compared to other sizes of aggregated SCC mixes. Also the split tensile strength of 20 mm aggregate SCC mix is more compared 10 mm aggregated SCC mix.

4.3 NON-DESTRUCTIVE TESTS:

Rebound hammer and Ultrasonic pulse velocity instruments are used as nondestructive tests. From Rebound hammer test compressive strength can be found out and the quality of SCC ca be found from Ultrasonic pulse velocity.

4.3.1NON DESTRUCTIVE TESTS ON BEAMS:

SINO	Size of Coarse aggregate (mm)	Average Compressive strength of beam (N/mm^2) at 28 days from RH test		Quality of Concrete from UPV test (IS:13311 PART-1)	
		Rebound number	Strength	Velocity (m/s)	Quality of SCC
1	10	33	36	4328	Good
2	12.5	34	38	4608	Excellent
3	16	35	40	4619	Excellent
4	20	33	36	4069	Good

4.3.2 NON DESTRUCTIVE TESTS ON CYLINDERS:

SINO	Size of Coarse aggregate (mm)	Average Compressive strength of cylinder (N/mm^2) at 28 days from RH test		Quality of Concrete from UPV test (IS:13311 PART-1)	
		Rebound number	Strength	Velocity (m/s)	Quality of SCC
1	10	32	34	4657	Excellent
2	12.5	33	36	4675	Excellent
3	16	35	40	4750	Excellent
4	20	31	30	4613	Excellent

4.3.3 NON DESTRUCTIVE TESTS ON CUBES:

SINO	Size of Coarse aggregate (mm)	Average Compressive strength of cubes (N/mm^2) at 28 days from RH test		Quality of Concrete from UPV test (IS:13311 PART-1)	
		Rebound number	Strength	Velocity (m/s)	Quality of SCC
1	10	42.0	43.80	4712	Excellent
2	12.5	48.3	42.24	4832	Excellent
3	16	49.3	48.51	4861	Excellent
4	20	48.6	47.71	4613	Excellent

5. CONCLUSION

From the above investigation the following conclusions are drawn

1. Nan-Su mix design method can be used to design SCC mixes.
2. Fresh concrete properties obtained satisfy the EFNARC guide lines.
3. Mix prepared with 16 mm size of coarse aggregate gives better compressive strength compared with mixes prepared with other size of mixes for all ages.
4. Mix prepared with 16 mm size of coarse aggregate gives better split tensile strength compared with mixes prepared with other size of mixes.
5. 16 mm size coarse aggregate SCC mix has 1.67% more compressive strength, 13.8% more split tensile strength and22.78% more flexural strength compared to 20 mm size coarse aggregate SCC mix.
6. From Non-Destructive tests also gives better compressive strength for 16mm size of coarse aggregate.

REFRENCES

[1] EFNARC May-2005. European Guidelines for Self Compacting Concrete, Specification, Production and Use.

[2] Nan-Su, Kung-Chung Hsu, His-Wen Chai " Simple Mix Design Method for Self Compacting Concrete'', 2001

[3] SHAKIR A. A Data Base for Self-Compacting Concrete in Iraq, Engineering & Technology journal, Vol 27, No.6,2009.

[4] M. COLLEPARDI A., BORSOI S. AND COLLEPARDI R.TROLI,Recent Developments of Special SSCC's in Europe-proceedings of Seventh CANMET/ACCI International conference on Recent Advances in Concrete Tecgnology,Las Vegas, USA, 26-29 May2004.pp.1-18.

[5] OKAMURA H. and QUCHI M. Self Compacting Concrete, journal of advanced concrete technology,vol.31,2003,pp.5-15.

[6] Krishnamurthy Pandurangan and Kothandaraman "Effect of Coarse Aggregate Size and Shape on the Strength and Flow Characteristics of Self Compacting Concrete''2012

[7] Properties of Concrete Text Book by Neville

[8]Concrete Technology Theory and Practice Text Book by M.S.Shetty.

[9]IS12269-1987, "Ordinary Portland Cement 53 Grade-Specification'' Of Indian Standards, ManakBhavan, 9Bahadur Shah Zafar Marg,, New Delhi-110 002

[10] IS2386(Part-1)-1963, Methods Of Test For Aggregate, ,Bureau Of Indian Standards,Manak Bhavan,9Bahadur Shah Zafar Marg,,New Delhi-110 002

[11]IS3812-1981,"Specification for Fly ash For Use as Pozzolana and Admixture'', Of Indian Standards,Manak Bhavan,9Bahadur Shah Zafar Marg,,New Delhi-110 002