Self-Compacting Concrete

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ABSTRACT

Self-compacting concrete is a type of special concrete which do not require vibration for compaction. The self-compacting concrete has a major disadvantage of its cost due to additional usage of chemical admixtures and Portland Cement. The cost of self-compacting concrete can be reduced by replacement of cement by cement replacement materials. In this paper fly ash, wood ash and their combinations are used as cement replacement materials. Fly ash is a mineral admixture that can be used in concrete. The Wood ash containing less Calcium oxide and significant quantity of Silicon dioxide may be used for replacement of cement. The incorporation of these replacement materials reduces the need for viscosity modifying agents. Higher durability and greater mechanical integrity can be achieved by lowering the water content in the concrete. Experimental investigations such as split tensile strength, compressive strength, flexural strength of self-compacting concrete containing cement replacement materials are conducted to determine their Mechanical properties. Workability tests (slump, L-box, V-funnel) on the corresponding mix are also used to study the characteristics. The methodology adopted here is the cement replacement materials are replaced 10% and 20% by weight of ordinary Portland cement and the performance is measured. To improve the workability of the concrete 1.5 % of superplasticizer (glenium B233) by weight of the cement is used as chemical admixture. Guidelines given by EFNARC are followed to design the mix. From this investigation it is observed that the optimum replacement of 10% of wood ash and fly ash in self- compacting concrete increases the compressive strength of the of the concrete mixture.

Keywords: Self-compacting concrete, fly ash, wood ash.

1. INTRODUCTION

Self-Compacting Concrete (SCC) is a special concrete of high performance which has excellent deformability in the fresh state and high resistance to segregation and can be placed and compacted under its self-weight without any vibration. In SCC durability was the main concept and the purpose was to develop a concrete mix that would eliminate the need for vibration to achieve compaction. Self-Compacting Concrete can achieve the above-mentioned characteristics by its unique fresh properties viz.

- Filling ability.
- Passing ability.
- Resistance to segregation.

1.1. SELF-COMPACTING CONCRETE

- ❖ Unlike the conventional concrete, self- compacting concrete doesn't require compacting using external force from mechanical equipment such as an immersion vibrator; instead SCC is designed in such as way that it gets compacted using its own weight and characteristics.
- ❖ Once applied, the self-compacting property enables the concrete to fully reinforce around the steel structures and completely fill the space within the framework. The self-compacting of concrete is achieved without losing any kind of strength, stability, or change in properties.

1.2. ADVANTAGES OF SCC

SCC offers many advantages for the precast, prestressed concrete industry and for cast-in place construction:

- Low noise-level in the plants and construction sites.
- Eliminated problems associated with vibration.
- Less labour involved.
- Faster construction.
- Improved quality and durability.
- Higher strength.
- Improved working environment.
- Architectural complex shapes possible.
- SSC can be placed quickly.
- Re-use and extended use of formwork.

1.3. LIMITATIONS OF SCC

- Proves to be costlier initially compared to conventional concrete. Also costs of admixtures are to be borne.
- No standard test methods are available to check the segregation on site.
- Because of the presence of large quantity of fines in the mix, the plastic shrinkage and creep are more in SCC when compared to conventional concrete.

2. LITERATURE REVIEW

In early 1980s, the problem of the durability of concrete structures was a major topic of interest in Japan. The creation of durable concrete structures requires adequate compaction by skilled workers. Lack of uniform and complete compaction as the primary factor responsible for poor performance of concrete structures. Okamura solved the issue of degrading quality of concrete construction due to lack of compaction by the employment of SCC which is independent of the quality of construction work [4]. Introduced SCC in the late 1980s. Early 1990s limited public knowledge about SCC, mainly in the Japanese language. The prototype of SCC was completed in 1988 with available materials in the market and is shown below.

- Okamura and Ozawa proposed simple mix design method.
- The coarse aggregate content in concrete is fixed at 50% of solid volume.
- The fine aggregate content is fixed at 40% of mortar volume.
- The water-powder ratio in volume is assumed as 0.9 to 1.0, depending on the properties of the powder.
- The SP dosage and the final w/b ratio are determined to ensure self compactability.

Nan Su et al. (2001) Proposed new Mix design method based on experimental investigation carried out in Taiwan [14].

- Packing Factor is used to determine the aggregate contents.
- The volume of fine aggregate is more than coarse aggregate.
- Simpler, easier for implementation and less-time consuming, requires smaller amount of binders and saves cost as compared to the method developed by JRMCA (Japanese Ready-Mixed Concrete Association)

Soo-Duck Hwang et al. (2006) [24] studied the suitability of various test methods for workability assessment and proposed performance specifications.

- 70 CC mixes with w/c ranges of 0.35 and 0.42.
- For structural applications slump flow ranges of 620 to 720mm, L-box ratio (h2/h1)≥0.7, J-Ring flow of 600 to 700mm, V-Funnel Flow time ≤8 sec.

Paratibha Aggarwal et al. (2008) [20] Presented the experimental procedure to obtain the SCC mixes based on Japanese Method of mix design.

- Initially trial mixes, CA – 50% by volume of concrete, FA - 40% by volume of mortar with a w/c ratio of 0.90.
- Later on, by reducing the coarse aggregate from 45% to 37% and increasing fine aggregate contents from 40% to 47.5% to attain the required results in all the tests i.e., slump flow, V-funnel and L-Box.

Dr. Hemant Sood et al. (2009) [2] presented the experimental investigation of SCC using Flyash and Rice husk ash as mineral admixtures and testing rheological properties as per European Standards.

S. Venkateswara Rao et al. (2010) [25] Aims at developing standard and high strength SCC with different sizes of aggregate based on Nan-su‟s mix design procedure.

- The variables involved in the study are size of aggregate, dosage of fly ash and grade of concrete.
- SCC can be developed with all sizes of graded aggregate satisfying the SCC characteristics.
- Noticed that the fresh properties improved with increase in fly ash percentages.
- This study illustrated that the optimum dosages of fly ash were 52% addition in case of standard grade SCC, and it is 31% addition in case of high strength Self Compacting Concrete.

N R Gaywala et al. (2011) [15] studied the strength properties of SCC when cement is replaced by different proportions of fly ash ranging from 15% to 55% and are compared with M25 concrete. The experimental result shows that the 15% fly ash mix gives the better strength characteristics as compared to the other fly ash mixes.

Prof. Shriram H. Mahure et al. (2013) [22] aimed to develop SCS using two industry wastes: cement kiln dust (CKD) and fly ash (FA).

CKD was used to replace the cement content by three various percentages (5, 10 and 15%) and fly ash was kept as constant (20%).

3. EXPERIMENTAL EVALUATION

Table 1: Physical Properties of Cement

S. No.	Characteristics	Values Obtained	Standard values
1.	Normal Consistency	33%	-
2.	Initial Setting time	48 min	Not be less than 30 minutes
3.	Final Setting time	240 min	Not be greater than 600 minutes.
4.	Fineness	4.8 %	<10
5.	Specific gravity	3.09	-
Compressive strength:- Cement : Sand (1:3)			
1.	3 days	24.5 N/mm2	27 N/mm2
2	7 days	38 N/mm2	41 N/mm2
3.	28 days	45 N/mm2	43 /mm2

Table 2: Physical Properties of fine aggregates

S. No.	Characteristics	Value
1.	Specific gravity	2.46
2.	Bulk density	1.4 kg/m3
3.	Fineness modulus	2.56 m2/g
4.	Water absorption	0.85 %
5.	Grading Zone (Based on percentage passing 0.60 mm)	Zone III

Table 3: Sieve analysis of fine aggregates

S. No.	Sieve Size	Mass retained	Percentage Retained	Cumulative Percentage Retained	Percent Passing
1	4.75mm	4.0 g	0.4	0.4	99.6
2	2.36 mm	75.0 g	7.50	7.90	92.1
3	1.18 mm	178.0 g	17.8	25.70	74.3
4	600^m	220.0 g	22.0	47.70	52.3
5	300^m	274.0 g	27.4	75.10	24.9

6	150^m	246.5 g	24.65	99.75	0.25
7			£=256.55		

Total weight taken = 1000gm Fineness Modulus of sand = 2.56

Table 4: Physical properties of C.A

S. No.	Characteristics	Value
1	Type	Crushed
2	Specific Gravity	2.66
3	Total Water Absorption	0.56
4	Fineness Modulus	6.83

Table 5: Sieve Analysis of C.A.

S. No.	**Sieve Size**	**Mass Retained (in gm)**	**Percentage Retained**	**Cumulative Percentage Retained**	**Percent Passing**
1	20 mm	0	0	0	100
2	10 mm	2516	83.89	83.87	16.13
3	4.75 mm	474	15.8	99.67	0.33
4	PAN	10	0.33	£= 183.54	

Total weight taken = 3Kg

FM of Coarse aggregate = [183.54+500] / 100 = 6.83.

GGBS

Ground granulated blast-furnace slag is a non-metallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form glassy sand like material. The granulated material when further ground to less than 45 micron will have specific surface about 400 to 600m2/kg. The chemical composition of blast furnace slag is similar to that of cement clinker. In this investigation, GGBS is brought from steel work at Bellary. Specific gravity of GGBS is 2.62 and its chemical composition is shown in table.

Table 7: Chemical components of GGBS

S. No.	**Parameter**	**Quantity (% wt)**
1	Insoluble residue	0.83
2	Manganese Oxide	0.25

3	Magnesium oxide	10.13
4	Sulphide sulphur	0.75
5	CaO+MgO+1/3Al2O3 SiO2+2/3Al2O3	1.10
6	CaO+MgO+ Al2O3 SiO2	1.84

Table 8: List of test methods for workability properties of SCC

S. No.	Method	Property
1	Slump-flow by Abram‟s cone	Filling ability
2	T50cm slump flow	Filling ability
3	J-ring	Passing ability
4	V-funnel	Filling ability
5	V-funnel at T5 minutes	Segregation resistance
6	L-box	Passing ability
7	U-box	Passing ability

Table 9: Acceptance criteria for Self-compacting Concrete (EFNARC,2005)

S. No.	METHOD	UNIT	TYPICAL RANGE OF VALUES	
			MINIMUM	MAXIMUM
1	Slump flow by Abrams cone	mm	650	800
2	T50cm slump flow	sec	2	5
3	J-ring	mm	0	10
4	V-ring	sec	6	12
5	Time increase, V-funnel at T T 5minutes	sec	0	3
6	L-box	(h2/h1)	0.8	1
7	U-box	(h2-hi) mm	0	30

Table 10: Fault-finding for low results (EFNARC, 2002)

S. No.	Method	Unit	Result less than	Possible cause	
1	Slump flow by Abram‟s cone	Mm	650	a	viscosity too high
				c	yield value too high
2	T50cm slump flow	Sec	2	b	viscosity too low
3	J-ring	Mm	10	a	viscosity too high
				c	yield value too high
				d	segregation
				f	blockage
4	V-funnel	Sec	8	b	viscosity too low
5	Increase in V-funnel at T5min	Sec	0.8	g	doubtful result
6	L-box (h2/hi)			a	viscosity too high
				c	yield value too high
				f	Blockage

Table 11: Fault-finding for high results (EFNARC, 2002)

S. No.	Method	Unit	Result more than	Possible cause	
1	Slump flow by Abrams cone	mm	750	b	osity too low
				D	segregation
2	T50cm slump flow	sec	5	a	:osity too high
				c	value too high

3	J-ring	mm		b	osity too low
				d	Segregation
4	V-funnel	sec	12	a	viscosity too high
				c	yield value too high
				f	blockage
5	Increase in V-funnel at T5min	sec	3	d	segregation
				e	rapid loss in workability
				f	blockage
6	L-box (h2/hi)		1	g	false result

Table 12: Mix composition as per EFNARC guidelines:

CONSTITUENT	**Typical range by mass (kg/m^3)**	**Typical range by Volume (liters/m$^{3)}$**
Powder	380-600	
Paste		300-380
Water	150-210	150-210
Coarse aggregate	750-1000	270-360
Fine aggregate (sand)	counterbalances the volume of the other constituents typically 48-55 % of the total aggregate weight	
Water/powder ratio by volume		0.85-1.1

MIX DESIGN APPROACH

Laboratory trials should be used to verify properties of the initial mix composition with respect to the specified characteristics and classes. If necessary, adjustments to the mix composition should then be made. Once all requirements are fulfilled, the mix should be tested at full scale in the concrete plant and if necessary, at site to verify both the fresh and hardened properties. The mix design is generally based on the approach outlined below:

- Evaluate the water demand and optimize the flow and stability of the paste.
- Determine the proportion of sand and the dose of admixture to give the required robustness.
- Test the sensitivity for small variations in quantities (the robustness).
- Add an appropriate amount of coarse aggregate.
- Produce the fresh SCC in the laboratory mixer, perform the required tests.
- Test the properties of the SCC in the hardened state.
- Produce trial mixes in the plant mixer.

The design process is graphically presented in Figure 8.

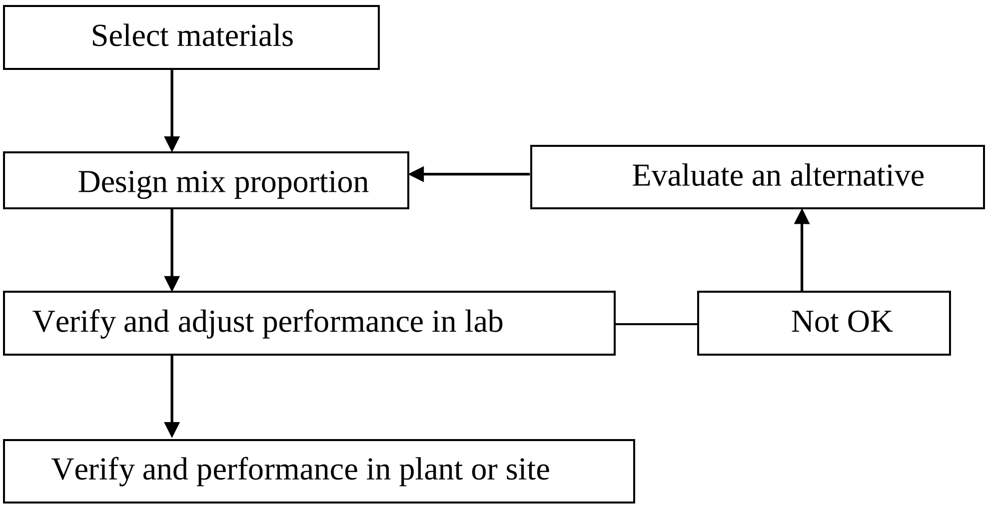


Table 1.13. Fault finding results:

Method	Result less than	Possible cause	Result more than	Possible cause
Slump flow	650 mm	Viscosity too high Yield value too high	750mm	**Viscosity too low Segregation**
T_{50} slump	2 sec	Viscosity too low	5 sec	**Viscosity too high, Yield value too high**
V-funnel	8 sec	Viscosity too low	12 sec	**Viscosity too high, Yield value too high, Blockage**
V-funnel at T_{5min}	Sec	Doubtful result	3 sec	**Segregation Rapid loss in workability Blockage**

L-box test	**0.8**	**Viscosity too high, Yield value too high, Blockage**	**1**	**False result**

Mix Design For M20 Grade:

The concrete mix design has been done as per IS method

Details of materials:

a) Grade of concrete – M20

b) Type of cement – OPC 53 grade

c) Maximum nominal size of Coarse aggregate – 20mm

d) Exposure condition – Severe

e) Degree of Supervision – good

f) Type of aggregate – Angular aggregate

Assuming state of surface to be SSD (Surface Saturated Dry state)

Test data of materials:

g) Specific gravity of OPC- 3.15

h) Specific gravity of Natural Sand – 2.67

i) Specific gravity of quarry dust – 2.67

j) Specific gravity of Coarse aggregate - 2.88

k) Water absorption of sand-2%.

l) Water absorption of coarse aggregate-0.5%.

m) Free moisture content of sand-2%.

n) Free moisture content of coarse aggregate-nil

Sieve analysis:

- Sand – Conforming to zone-111 of IS 383-1970
- Aggregate 20 mm nominal size.

Step-1: Statistical constant = 1.65

Standard deviation=4.6 Fck = fmin + ks = 27.59 N\m^2

Step -2: From table 5 of IS 456: 2000

For severe exposure – Maximum w/c = 0.39

Step-3: From table 2 of IS 10262-2009

Water content = 186 lit (for 25 to 50mm slump, 20mm nominal size aggregate) To maintain slump w/c ratio is taken as 0.39.

Estimated water content = 186 + (3/100 * 186) =191 liter.

Step-4: Cement content = water content / (w/c ratio) = 191 / 0.39 = 489.74 kg/m^3

Step-5: 20mm nominal size aggregates Zone 3 of fine aggregates

The volume of coarse aggregate per unit volume of total aggregate for the w/c ratio is given in Table3 of IS 10262: 2009 as 0.64.

Therefore, volume of fine aggregates per unit volume of Total aggregate = 1- 0.6 = 0.36.

Step-6: Volume of concrete = 1 m^3

(a) Volume of cement = (Mass/specific gravity) x (1/1000) = (489.74/3.15) x (1/1000) = 0.155 m^3

(b) Volume of water = 191 x (1/1000) = 0.191 m^3

(c) Volume of all in Aggregate = [a- (b + c)] = [1- (0.155 + 0.191)] = 0.654 m^3

(d) Mass of coarse Aggregate = d x volume of coarse aggregate x specific gravity of coarse aggregate x 1000 = 0.654 x 0.64 x 2.88 x 1000 = 1205.453 kg/m^3

(e) Mass of fine aggregate = d X volume of coarse aggregate X specific gravity of coarse aggregate x 1000 = 0.654 x 0.36 x 2.67 x 1000 = 628.625 kg/m^3.

Step- 7: Quantity of materials

Table 14. Quantity of materials

S. No.	**INGREDIENT**	**QUANTITY**
1	Cement	489.74 Kg \ M3
2	Fine Aggregate	628.625 Kg \ M3
3	Coarse Aggregate	1205.453 Kg \ M3
4	Water	191 tres

The present investigations are aimed to study the effect of partial replacement of sand with GGBS, Silica Fume in concrete. Project is mainly concentrated on compressive strength, split tensile strength. The program involves casting and testing a total of 60 cube specimens, 60-cylinder specimens. The cubes were casted using standard cubes of (150mm X 150mm X 150 mm) and cylinder specimens were casted using standard cylinders of (150mm diameter & 300mm length).Then curing was done by conventional moist curing. Compression testing machine of 2000 KN capacity was used to test the cubes and cylinder specimens.

- In the first series, the specimens were casted with conventional materials i.e. fine aggregate is natural river sand with M20 grade by using Ordinary Portland cement (OPC).
- In the second series, specimens were casted with M20 grade by replacing 20% of sand with GGBS& Silica fume. In the third series, the specimens were casted with M20 grade by replacing 25% of sand with GGBS & Silica fume.
- In the fourth series, the specimens were casted with M30 grade by replacing 30% of sand with GGBS& Silica Fume.
- In the fifth series, the specimens were casted with M30 grade by replacing 35% of sand with GGBS & Silica Fume

MIXING OF CONCRETE

The performance of concrete is influenced by proper mixing. And good practice of mixing can lead to better performance and good quality of concrete. The design of M20 grade concrete was taken from IS10262-2009. In the present study, the mixing was done in a mechanical drum mixer of 60lts capacity. The test procedure for the process of mixing is as follows.

S. No	Type of Mix	W/C ratio	Proportions of constituent materials		
			Cement	Fine Aggregate	Coarse Aggregate
1	OPC With River Sand	0.39	1	1.28	2.461
2	OPC with 20%replacement of sand with quarry dust	0.39	1	1.28	2.461
3	OPC with 25% replacement of sand with quarry dust	0.39	1	1.28	2.461
4	OPC with 30% replacement of sand with quarry dust	0.39	1	1.28	2.461
5	OPC with 35% replacement of sand with quarry dust	0.39	1	1.28	2.461

All the materials were weighed & prepared as per the proportion of mix design. Before the mix begins, the surface of the mixer is damped with a wet cloth. All the aggregates (fine & coarse) are added into the mixer till the aggregate is uniformly distributed throughout the mixer. The cement is then added into the mixer containing the aggregates. Then it is mixed for about 3minutes from the point of addition of water and then the mixer is switched off. The handle of the miller is held down to fill the concrete into the pan.

Placing, Compacting and Casting of specimens

Before the placing of, the mould must be oiled for the ease of concrete specimen stripping. Once the workability test is done, the fresh concrete is placed into concrete moulds to prepare specimens for hardened properties. Cubes of 150 X 150 X 150mm and Cylinders of 150mm diameter were casted, compacted by hand compaction. After filling of the mould is completed, care should be taken to level the surface.

Table 15: Materials Quantities obtained as per design method:

Materials	**Quantities(kg/m^3)**
Cement	454
Fine aggregate	1047.28
Coarse aggregate	700.8
Water	200

These mixes are further adjusted using EFNARC guidelines as explained earlier and the final quantities are used in the mix proportions.

Table 16: Materials quantities after adjustments as per EFNARC guidelines:

Materials	**Quantities (kg/m^3)**
Cement	390
Fine aggregate	1047.28
Coarse aggregate	700.8
Water	200
Fly ash	140
Super plasticizer	100 ml
Viscosity modifying agent	6 ml
Water / powder ratio	1.05

CASTING OF TEST SPECIMENS

The cubes are casted with the same mix proportion and placed at a temperature of 27^{o}c and 90 % humidity for 24 hours. Then the cubes are demolded and placed in clean water till the date of testing.

Table 17: Fresh properties test results

S. No.	Fresh properties	Test results
1	Slump Flow	650mm
2	T 50 Slump	5sec
3	V-Funnel	3sec
4	V-Funnel at T 5 min	5.6 sec
5	L-Box	
a)	H2/H1	0.9
b)	T_{20}	1 sec
c)	T_{40}	3 sec

Table 18: Ratio of Mix proportions by weight for M 20 Mix

Mix	Cement	F.A	C.A	Fly ash	W/C	W/p
M20 SCC	1	2.68	1.79	0.35	0.51	1.05

Table 19: Ratios of various contents

Ratio	C.A/T.A	F.A/T.A	C.A/F.A	C.A/total
Value (%)	40	60	66.29	28.27

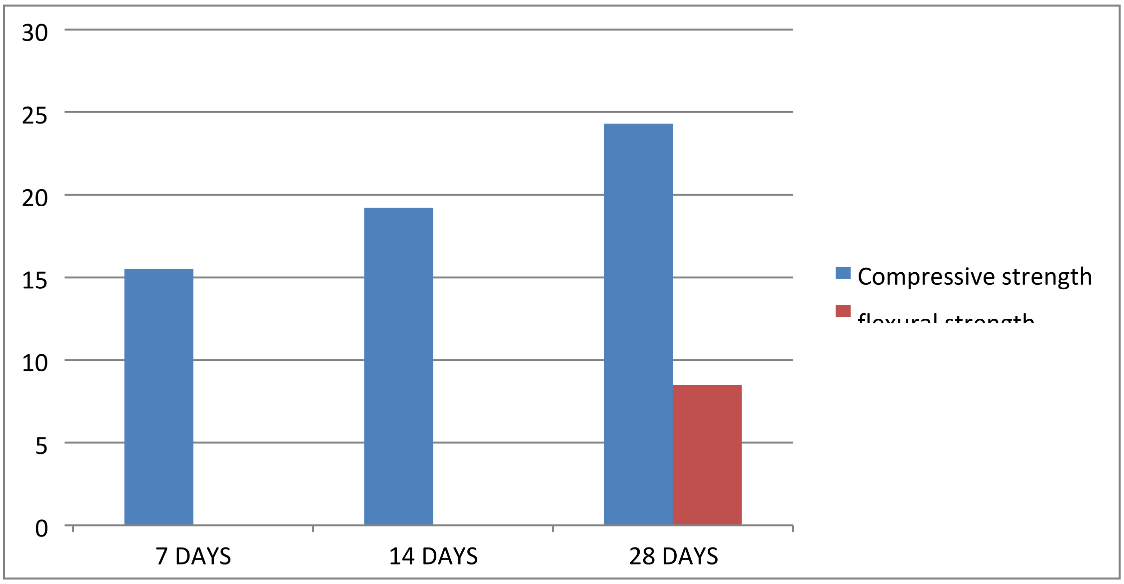
Table 20: Compressive strength results of SCC at 7, 14, and 28 Days

S. No.	Days	Compressive Strength(Mpa)
1.	7	15.5
2.	14	19.2
3.	28	24.3

Table 21: Flexural strength of casted beam specimens

S. No.	Days	Load (kN)	Flexural strength (N/mm^2)
1.	28	385	8.5

Graph 2: Compressive and Flexural Strength of SCC



4. RESULTS AND DISCUSSIONS

In this experiment we aimed to arrive at the mix proportions of M35 grade self- compacting concrete using locally available materials. In the mix, fly ash of about 39 % of the cement content is taken with VMA of 6ml and the fresh properties are tested. For the mix adopted the fresh properties like slump flow, V-funnel, L-box are satisfied. The cube and beam specimens are casted in the laboratory. The casted specimens are tested for 7 days, 14 days and 28 days compressive strengths.

5. CONCLUSIONS

At the water/powder ratio of 1.05, slump flow test, V-funnel test and L-box test results were found to be satisfactory, i.e. passing ability, filling ability and segregation resistance are well within the limits. By using Ordinary Portland cement, normal strength of 50.60 MPa is obtained at 28 days, keeping the cement content 390 kg/m^3. As SCC technology is now being adopted in many countries throughout the world, in absence of suitable standardized test methods it is necessary to examine the existing test methods and identify or, when necessary to develop test methods suitable for acceptance as International Standards. Such test methods must be capable of a rapid and reliable assessment of key properties of fresh SCC on a construction site. At the same time, testing equipment should be reliable, easily portable, and inexpensive. A single operator should carry out the test procedure and the test results must be interpreted with a minimum of training. In addition, the results must be defined and specify different SCC mixes. One primary application of these test methods would be in verification of compliance on sites and in concrete production plants, if self-compacting concrete is to be manufactured in large quantities.

REFERENCES

[1] Japan Society of Civil Engineers, „Recommendations for Design and Construction of Antiwashout Underwater Concrete", Concrete library of JSCE, 19 (1992) 89.

[2] Peterson, Ö., Billberg, P., Van, B.K., „A model for self-compacting Concrete", Proceedings of International RILEM Conference on „Production Methods and Workability of Concrete", edited by P.J.M. Bartos, et al. (Chapman & Hall/E & FN Spon) (Paisley, 1996) 483-490.

[3] Bartos, P.J.M., „An appraisal of the Orimet Test as a Method for On-site Assessment of Fresh

SCC Concrete‟, Proceedings of International Workshop on Self-Compacting Concrete, (Japan, August 1998) 121-135.

[4] Haykawa, M., „Development and Application of Super Workable Concrete‟, Proceedings of International RILEM Workshop on „Special Concretes - Workability and Mixing‟, edited by Prof.P.J.M. Bartos, (Paisley, 1993) 183-190.

[5] Ozawa, K., Sakata, N., Okamura, H., „Evaluation of Self-Compactibility of Fresh Concrete Using The Funnel Test‟, Concrete Library of JSCE, (25) (June 1995) 59-75.

[6] Rooney, M., Bartos, P.M.J., „Development of the settlement column segregation test for fresh self-compacting concrete (SCC)‟, to appear in the second international symposium on SCC, Tokyo, Japan (2001).

[7] Brite-EuRam programme: BE96-3801/BRPR-CT96-0366, „Rational production and improved Working environment through using self-compacting concrete‟.

[8] Henderson N A, Baldwin N J R, McKibbins L D, Winsor D S, & Shanghavi H B, 'Concrete technology for foundation applications', CIRIA Report C569: 2002.

[9] M. S. SHETTY Concrete Technology, by S. CHAND Publisher.

[10] EFNARC (www.efnarc.org)

[11] SUBRAMNIAN. S. CHATTOPADHYAY. D. "Experiments for mix- proportioning of self-compacting concrete", The Indian Concrete Journal, Jan 2002.

[12] Indian Standard Codes for Concrete & Guidelines.

[13] CHAMPION, J. M. and JOST, P., 'Self-compacting concrete: Expanding the possibility of Concrete Design and Placement', Concrete International, Vol.22, No.4, pp. 159-178, June 1998.

[14] HEINE, HANS J. "Saving Dollars through Sand Reclamation - Part 1," Foundry Management and Technology. (May, 1983), pp.

[15] KAMESWARA RAO, C.V.S (1983) "Analysis of Some Common Workability Tests". Indian Concrete Journal.

[16] KATHY STANFIELD, "Self-compacting concrete a Growth area", The Str.Engg., Vol. 76, No‟s 23 and 24

[17] NAGATAKI, S. and FUJIWARA, H. "Self-compacting property of Highly-Flowable Concrete" ICI Journal July-September 2002.

[18] KLAUS HOLSCHEMACHER, "Structural Aspects of Self- compacting concrete", NBM & CW, July 2002.

[19] MAHINDRAKAR A.B. Research work Study on Red Mud by, KLESCET, Belgaum, 1999.

[20] MEHTA, P.K., 'Concrete structure: Properties and materials', Prentice Hall, 1986. ICI Journal July-Sep 2002.

[21] MICHEAL J. CAMPION and PHILLIPPE JOST, "Self-compacting concrete", Concrete Int. 2000.

[22] OKAMURA (1997), "Self-Compacting High Performance concrete", Concrete International, Vol. 19, No. 7