Incorporating European Standards for Testing Self Compacting Concrete in Indian Conditions

Dr. Hemant Sood[1], Dr.R.K.Khitoliya[2] and S. S. Pathak[1]
[1]Dept. of Civil Engineering, N.I.T.T.T.R; Chandigarh, INDIA
sood_hemant@yahoo.co.in
[2]Dept. of Civil Engineering, Panjab Engg. College, Chandigarh, INDIA
r_khit_2000@yahoo.com, sspathak28@gmail.com

Abstract— **Concrete is a vital ingredient in infrastructure development with its versatile and extensive applications. The Indian construction industry today is consuming about 400 million tons of concrete every year and is expected to reach a billion tons in less than a decade. It is the most widely used construction material because of its mouldability into any required structural form and shape due to its fluid behaviour at early ages. However, there is a limit to the fluid behaviour of normal fresh concrete. Thorough compaction, using vibration, is normally essential for achieving workability, the required strength and durability of concrete. Inadequate compaction of concrete results in large number of voids, affecting performance and long term durability of structures. Self-compacting concrete (SCC) provides a solution to these problems. As the name signifies, it is able to compact itself without any additional vibration or compactive effort. However, wide spread applications of SCC have been restricted due to lack of standard mix design procedure and testing methods. It is pertinent to mention that only features of SCC have been included in Indian Standard Code for the present. Slump flow test, L-box test, V-funnel test, U-box test, Orimet test & GTM Screen test are recommended by EFNARC (European Federation for Specialist Construction Chemicals and Concrete system) for determining properties of SCC in fresh state. This paper highlights the use of European standards by various researchers for testing Self compacting concrete in Indian conditions. The paper presents the experimental investigation of Self Compacting Concrete using Flyash and Rice husk ash as mineral admixtures and testing rheological properties as per European Standards**

Index Terms—**Self compacting concrete, Rice husk ash, Flyash**

I. Introduction

With growing population, industrialization, urbanization and globalization, there is corresponding growth in the demand for infrastructure. During the 20th century, concrete has emerged as the material of choice for modern infrastructural needs. It has occupied a unique position among modern construction materials. It gives considerable freedom to the architect to mould structural elements to any shape. Almost all concretes rely critically on being fully compacted. Insufficient compaction dramatically lowers ultimate performance of concrete inspite of good mix design. As concrete is produced and placed at construction sites, under conditions far from ideal, it often ends up with unpleasant results.

Concrete that is capable of compaction under its own weight and can occupy all the spaces in the forms, which self-levels, does not segregate and does not entrap air is termed self-compacting concrete (SCC).

For concrete to be self-compacting it should have filling ability, passing ability and resistance against segregation. Self compactability is obtained by limiting the coarse aggregate content and using lower water–powder ratio together with superplasticizers (SP).

II. Testing of SCC

Inspite of excellent rheological and durability properties wide spread applications of SCC have been restricted due to lack of standard mix design procedure and testing methods. It is important to mention that none of the test methods for SCC have yet been standardised and included in Indian Standard Code for the present. The following are some of the features of self compacting concrete mentioned in Indian Standard code IS 456-2000.

1. Slump flow: Minimum 600 mm.
2. Sufficient amount of fines (<0.125 mm) preferably in the range of 400 kg/m^3 to 600 kg/m^3. This can be achieved by having sand content more than 38% and using mineral admixture to the order of 25 to 50% by mass of cementitious materials.
3. Use of high range water reducing (HRWR) admixture and viscosity modifying agent (VMA) in appropriate dosages is permitted.

In Norway "Guidelines for production and use of self-compacting concrete-2002" is used for development of SCC. In Sweden "Self-compacting concrete Recommendations for use-2002" is referred for development of SCC. Germany has developed "Self Compacting Concrete-2001" as guidelines for SCC. "The European Guidelines for SCC- 2005"were developed by EFNARC (European Federation of Specialist Construction Chemicals and Concrete Systems.). Kai Westphal [1] has carried out comparison of these guidelines which are reproduced under Table I.

European guidelines [2] for testing, covers number of parameters ranging from material selection, mixture designs and testing methods like Slump flow test, L-box test, V-funnel test, U-box test, Orimet test and GTM screen stability test as recommended by EFNARC for determining properties of SCC in fresh state. Most of Indian researchers are following these guidelines to determine the rheological properties of SCC mixes.

TABLE I
COMPARISON OF GUIDELINES FOR SCC

Sr. No.	Description ↓ / Country →	ENFARC	Norway	Sweden	Germany
1	Slump Flow (mm)	550-850	600-750	NA	>750
2	V Funnel (Sec)	2-5	NA	NA	NA
3	L- Box (h_2/h_1)	0.8 -1	NA	0.8-0.85	NA
4	U- Box (h_2-h_1)	0-30 (mm)	NA	NA	NA
5	Orimet Test (Second)	0-5	NA	NA	NA
6	GTM-Stability (%)	0-15	NA	NA	NA
7	Aggregate Size (mm)	12-20	$\leq$ 16	$\leq$ 16	$\leq$ 16

*NA- Not Available

III. INDIAN SCENARIO OF SCC

In India, the development of concrete possessing self-compacting properties is still very much in its infancy. During the last couple of years, few attempts were made using European Guidelines for testing SCC in the laboratories and in the field. As mentioned by M. S. Shetty [3] SCC was used by Nuclear Power Corporation of India Ltd. at Tarapur, Kaiga and Rajasthan Atomic Power Project (RAPP). Some pioneering efforts have been made in Delhi Metro Project. Debashis Das et al. [4] have carried out experimental investigation of SCC using Micro-silica and flyash from Thermal Power Plant, Dadari (Delhi).Vengala et al. [5] developed SCC using flyash from Thermal Power Station, Silchar (Karnataka, India). Naveen Kumar et al. [6] developed SCC using blend of flyash and metakaolin. Praveen Kumar et al. [7] used stone crusher dust partially replacing aggregates to obtain SCC. In all the above investigations European standards were followed for determining rheological properties of Self compacting concrete. Results of above mentioned investigations are reproduced in Table II.

IV. TESTING METHODS OF SCC

Different methods have been developed to characterize the rheological properties of SCC. No single method has been found until date, which characterizes all the relevant workability aspects. Each mix has been tested by more than one test method for the different workability parameters. Following are the tests recommended by European guidelines.

A. *Slump flow Test* - The slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions. The test also indicates resistance to segregation. On lifting the slump cone, filled with concrete the average diameter of spread of the concrete is measured. It indicates the filling ability of the concrete.

B. *V-Funnel Test*- The flowability of the fresh concrete can be tested with the V-funnel test, whereby the flow time is measured. The funnel is filled with about 12 litres of concrete and the time taken for it to flow through the apparatus is measured. Shorter flow time indicate greater flowability.

C. *L-Box Test* - This is a widely used test, suitable for laboratory and site use. It assesses filling and passing ability of SCC and serious lack of stability (segregation) can be detected visually. The vertical section of the L-Box is filled with concrete, and then the gate is lifted to let the concrete flow into the horizontal section. Blocking ratio (i.e. is ratio of the height of the concrete at the end of the horizontal section (h_2) to height of concrete at beginning of horizontal section (h_1)) is determined.

TABLE II
COMPARISON OF SELF COMPACTING CONCRETE CASE STUDIES IN INDIA

Sr. No.	Particulars	Delhi Metro Project	Tarapur Project	Kaiga Project	RAPP 5&6	Debashis Das et al.	Vengala et al.	Naveen Kumar et al.	Praveen Kumar et al.
1	Cement (Kg/m^3)	330	300	225	225	291.2	431	450	250
2	Flyash (Kg/m^3)	150	200	225	225	291.2	163.78	66	350
3	Micro Silica (Kg/m^3)	0	25	0	0	14.6	0	0	18.75
4	Metakaolin (Kg/m^3)	0	0	0	0	0	0	82	0
4	Sand (Kg/m^3)	917	976	1024	988	1062.2	849	789	935
5	Aggregate (Kg/m^3)	764	664	762	624	455.2	650	664	623
6	Water (Kg/m^3)	163	175	165	180	186.3	241	225	160.9
7	Superplasticizer	2.4 %	2.4 %	1.80 Kg/m^3	4.0	10 Kg/m^3	0.65%	0.5%	2.3%
Rheological Properties									
8	Slump Flow(mm)	680	686	700	735	670	635	720	630
9	V Funnel Test (Seconds)	8	14	8.3	7.6	14	3.5	6.3	-
10	L- Box Test	0.91	0.95	0.92	0.8	-	0.85	10	6.2
11	U- Box Test (mm)	NA	10	9.6	12	10	12.2	0.9	10
Compressive Strength									
12	7 Days Strength(MPa)	33	48.06	40	36.22	30	38	25.27	23.5
13	28 days Strength (MPa)	44	56.93	51.3	43.69	50.1	51.2	47.57	32.6

It indicates passing ability of concrete or the degree to which the passage of concrete through the bars is restricted.

D. *U-Box Test*- The test is used to measure the filling and passing ability of self-compacting concrete. The apparatus consists of a U shape vessel that is divided by a middle wall into two compartments. The U-box test indicates degree of compactability in terms of filling height i.e. (h_1-h_2), difference of height of concrete attained in two compartment of U-box.

E. *Orimet Test*- Orimet test is able to simulate the flow of fresh concrete during actual placing on sites. The Orimet apparatus is filled with about 8 litres of concrete and the time taken for it to flow through the apparatus is measured.

F. *GTM Screen Stability Test*- GTM screen stability test is a very effective way of assessing the stability of SCC. It consists of taking a sample of 10 litre of concrete, allowing it to stand for a period to allow any internal segregation to occur, then pouring it on to a 5mm sieve of 350mm diameter. After two minutes, the mortar which passed through the sieve is weighed and expressed as a percentage of the weight of the original sample on the sieve (i.e. Segregation Ratio).

V. Proposed Work And Experimental Investigation

Presently self compacting concrete is used as a special concrete rather than standard concrete all over the world. One of the bottlenecks in the use of self compacting concrete as a standard concrete is its economical viability. Self compacting concrete requires large quantity of powder or filler material. In order to arrive at the economical SCC, it is proposed to incorporate industrial by products as filler which will limit the use of Portland cement. It shall not only reduce the cost of SCC but shall provide solution to disposal problems and other environmental pollution created by these wastes.

The proposed study is being carried out to develop self compacting concrete using Rice husk ash and flyash in varying combinations for use in the Indian conditions satisfying European Standards for rheological properties of concrete in fresh state. OPC 43 grade cement, flyash from Guru Gobindsingh Super Thermal Power Station, Ropar, India and Rice Husk Ash (RHA) from Punjab Industrial area are being used for experimental investigation. Specific gravity of flyash and RHA determined was 2.08 and 2.06 respectively. The chemical characteristics of flyash and RHA are given in Table III.

TABLE III
CHEMICAL COMPOSITION OF RHA AND FLYASH

Constituents	Rice Husk Ash (%)	Flyash From GGSTP, Ropar (%)
SiO_2	86.01	60.53
Al_2O_3	01.40	27.27
Fe_2O_3	00.01	04.18
CaO	01.90	01.04
MgO	0	00.40
Loss on ignition	05.66	2.11

TABLE IV
PHYSICAL PROPERTIES OF AGGREGATES

Sr. No.	Property	Results Obtained	
		Coarse Aggregate	Fine Aggregate
1	Specific Gravity	2.68	2.62
2	Loose Bulk Density (Kg/m^3)	1480	1525
3	Packed Bulk Density (Kg/m^3)	1604	1629

Flyash and RHA used for investigation have 5 % fines passing through 45 micron sieve size. Locally available natural sand with 4.75 mm maximum size has been used as fine aggregate, with properties like specific gravity and bulk density as given in Table IV. The physical properties of crushed stone aggregate (coarse aggregate) having 20mm maximum size are given in Table IV. A polycarboxylic based ether based superplasticizer Glenium B233 has been used in present research work.

Scanning electron microscopy (SEM) has been used to study the surface structure of the flyash and Rice husk ash. The smooth and clean surface of flyash ash (Figure 1) is clearly visible in micrograph. Presence of ample number of small spherical particles of flyash enhances the flowability of concrete. The scanning electron micrograph of Rice husk (Figure 2) shows angular particles having a rough texture which may affect the flowability of SCC.

Using Japanese method of mix design as reference, initial mix design for the proposed study was carried out at coarse aggregate content of 37% by volume of concrete and fine aggregate content of 47% by volume of mortar in concrete, the water/powder(W/P) ratio was kept at 0.78 (by volume). The dosage of superplasticizer was estimated to be from 1.5 to 3.0 % of powder content (Cement, Flyash and Rice husk ash) from Flow Cone test trials on cement mortar containing flyash and rice husk ash. On this basis trial mix SCC1 was designed with superplasticizer content of 1.5%. However, unsatisfactory

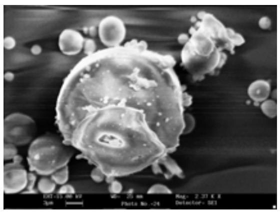

Figure 1: Scanning Electron Micrograph of Flyash

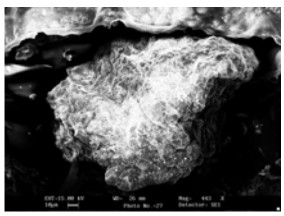

Figure 2: Scanning Electron Micrograph of Rice Husk Ash

slump flow and high segregation was observed in the trial mix. Mix could not satisfy V-funnel and L-box tests. Hence, superplasticizer content for subsequent mixes was increased to 2 % with increased water powder ratio till all mixes satisfied acceptance criteria for rheological properties of SCC as laid down by EFNARC. Total powder content (Cement, Flyash and Rice husk ash) was kept constant at 600 Kg/m^3 with varying content of flyash and RHA. The mix proportion used in the proposed study are shown in Table V.

As per EFNARC guidelines Slump flow test, V-funnel test, L-box test and GTM screen stability test stability test are being carried out to determine the properties of SCC in fresh state. Compressive strength at the ages of 7, and 28 days was also determined. The properties of SCC mixes as obtained in trial mixes are reproduced in Table VI.

VI. Results And Discussions

As mentioned earlier Mix SCC1 did not fulfill the requirement of SCC. The rheological characteristics of mixes SCC2 to SCC6 are discussed below.

The slump flow characteristics of the mixtures are between 615 and 750 mm, which satisfies the EFNARC requirement. Slump flow improves with the increase in Flyash and decrease in Rice husk ash content. As far as filling ability of the mixes was concerned, the results of V-funnel test satisfied the standard requirements. V-Funnel time increases from 8 to 12 seconds with increasing Rice husk ash content indicating increase in viscosity of concrete. The blocking ratios in the L - box test were as per the requirement of SCC mixes as laid down by EFNARC guidelines. Segregation ratio of trial mixes were from 5 to 15 % as per requirements of SCC. From 7 days and 28 days compressive strength results, it has been observed that increase in Rice husk ash content in mixes (SCC2 to SCC5) from 7.5 kg/m^3 to 30 kg/m^3 increases water requirement of mixes, decreasing 7 days strength from 28 to 23.56 MPa and 28 days the strength of concrete from 38 MPa to 27 MPa.The ambient temperature during study was in the range of 10^0 to 12^{0}C. This retards strength gain of concrete. Higher ambient temperature conditions could have been helped in better gain in concrete strength. Hence, higher strength could have been achieved in case of normal temperature of 27^{0}C.

TABLE V
MIX PROPORTIONS OF SCC

SCC Mix	Cement	FLA	RHA	FA	CA	Water	W/P Ratio (By Volume)
SCC1	360	216	24	951	583	180	0.78
SCC2	450	142.5	7.5	920	614	210	0.98
SCC3	450	135	15	920	614	215	1.00
SCC4	450	127.5	22.5	920	614	225	1.05
SCC5	450	120	30	920	614	225	1.05
SCC6	420	162	18	951	583	240	1.09

* FLA-Fly Ash, RHA- Rice Husk Ash, FA- Fine Aggregate, CA- Coarse Aggregate,

TABLE VI
PROPERTIES OF SCC

SCC Mix	Slump Flow mm	V-funnel Flow Time in Second	L-box h_2/h_1	GTM Screen Test (SR) %	*Compressive strength (MPa)*	
					7 days	*28 days*
SCC1	400	15	0.78	20	14	*24*
SCC2	735	8	1.0	15	28	*38*
SCC3	670	9	0.95	12	25	*37*
SCC4	650	10	0.90	10	24	*28*
SCC5	615	12	0.89	5	23.56	*27*
SCC6	*750*	*10*	*0.90*	*10*	*25*	*41*

*SR-Segregation Ratio

From the above discussions, it can be concluded that Mix SCC1 does not fulfill all the requirements of the SCC mix whereas SCC2 to SCC6 satisfy all the properties of SCC mixes. Addition of flyash in mix increases filling and passing ability of concrete, whereas rice husk ash imparts viscosity to concrete improving segregation resistance of concrete mix. Flyash and RHA blend well to improve the rheological properties of Self compacting concrete.

VII. Conclusion

Based on this experimentation, following conclusions are drawn.

1. Establishment of standard mix design procedure and appropriate testing methods is essential for widespread use of SCC. Most of Indian researchers have followed European guidelines for testing SCC. Other countries are adopting these guidelines with slight modifications as per their local conditions.
2. Addition of flyash in SCC increases filling and passing ability of concrete, whereas rice husk ash imparts viscosity to concrete improving segregation resistance of concrete mix. From this experimental study it can be inferred that Flyash and RHA blend well improving overall workability, which is the prime important characteristics of SCC.
3. Increase in Rice husk ash content in SCC increases water demand reducing compressive strength of concrete. In the present investigation increase in Rice husk ash content from 7.5 kg/m^3 to 30 kg/m^3, raises the water requirement of mix, thereby decreasing the 28 days the strength of concrete from 38 MPa to 27 MPa.
4. Rice husk ash is agro waste where as flyash is industrial waste from thermal power station. Utilization of these waste products as cement replacement will not only help to achieve economical SCC mix, but it is envisaged that it may improve the microstructure and consequently the durability of concrete. This provides solution to disposal problems and other environmental pollution created by these waste.

5. Utilization of flyash and Rice husk ash as cement replacement avoids the environmental and ecological damages caused by quarrying and exploitation of raw materials like limestone for making cement. Substitution of these waste materials with cement shall also help to conserve the valuable natural resources.

ACKNOWLEDGMENT

The authors acknowledge D-BASF Pvt. Ltd, Chandigarh Branch for providing superplasticizers for the experimental work.

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