Global Journal of Researches in Engineering: E
Civil And Structural Engineering
Volume 14 Issue 3 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Durability Characteristics of SCC: Influence of Manufacturing Type i.e. Powder Type, VMA Type and Combined Powder and VMA Type

By Manoj R. Vyawahare & Dr. V. M. Mohitkar
SGB Amravati University, India

Abstract- Self-Consolidating Concrete (SCC) often known as self compacting concrete is becoming more widely used in construction in recent years due to its favourable attributes, such as productivity improvements, reduced labour costs, improved work environment and safety and improved product quality. The self consolidating concrete can be obtained by using high powder content or by Viscosity Modifying Agents (VMA), or a combination of both. Keeping in view the possible effect of manufacturing process on the performance of the SCC this study was carried out. Silica Fume (SF) was used as additional powder in powder type and combined powder and VMA type SCC. The fresh properties, strength and durability characteristics were studied. The compressive strength was compared to study the strength and durability relations. The chloride ingress, sorptivity and resistance to acid attack were investigated to assess the durability performance. In all the tests implied in this investigation combined powder and VMA type SCC exhibited the excellent performance among all the three categories of the SCC.

Keywords: SCC, powder, silica fume, durability of SCC.

GJRE-E Classification : FOR Code: 090599

DURABILITYCHARACTERISTICSOFSCCINFLUENCEOFMANUFACTURINGTYPEIEPOWDERTYPEVMATYPEANDCOMBINEDPOWDERANDVMATYPE

Strictly as per the compliance and regulations of :

Open Association of Research Society, USA
Research | Diversity | Ethics

© 2014. Manoj R. Vyawahare & Dr. V. M. Mohitkar. This is a research/review paper, distributed under the terms of the Creative Commons Attribution-Noncommercial 3.0 Unported License http://creativecommons.org/ licenses/by-nc/3.0/), permitting all non commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Durability Characteristics of SCC: Influence of Manufacturing Type i.e. Powder Type, VMA Type and Combined Powder and VMA Type

Manoj R. Vyawahare [α] & Dr. V. M. Mohitkar [σ]

Abstract- Self-Consolidating Concrete (SCC) often known as self compacting concrete is becoming more widely used in construction in recent years due to its favourable attributes, such as productivity improvements, reduced labour costs, improved work environment and safety and improved product quality. The self consolidating concrete can be obtained by using high powder content or by Viscosity Modifying Agents (VMA), or a combination of both. Keeping in view the possible effect of manufacturing process on the performance of the SCC this study was carried out. Silica Fume (SF) was used as additional powder in powder type and combined powder and VMA type SCC. The fresh properties, strength and durability characteristics were studied. The compressive strength was compared to study the strength and durability relations. The chloride ingress, sorptivity and resistance to acid attack were investigated to assess the durability performance. In all the tests implied in this investigation combined powder and VMA type SCC exhibited the excellent performance among all the three categories of the SCC.

Keywords: SCC, powder, silica fume, durability of SCC.

I. Introduction

According to the American Concrete Institute (ACI) Committee 237(2007), SCC is defined as 'a highly flowable, non-segregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation'. Another definition according to the European Guidelines for SCC (EFNARC 2002) is 'a concrete that is able to flow and consolidate under its own weight, completely fill the formwork even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for any additional compaction'.

Due to special requirements for SCC in its fresh state, the procedures for mix proportioning commonly used for normal concretes had to be modified. The SCC mix can be obtained by using high powder content or by Viscosity Modifying Agents (VMA), or a combination of both, in addition to a higher dose of the superplasticiser as compared to ordinary concretes. The mixture proportioning method suggested by Nan Su et al. (2001) has been used in this investigation. This method takes into account the required strength of the SCC. The same has been used to obtain other types of SCC by varying the powder content and cement content so as to obtain required strength. All the mix proportioning methods suggested in the literature deal only with powder type SCC. All the research that has taken place to study durability of SCC considered only the powder type SCC. The influence of manufacturing process i.e. powder type, combined powder and VMA type which is mentioned as combined type SCC hereafter and VMA type SCC on the durability of SCC was however not studied. The effect of manufacturing process does affect the choice of type of SCC in prevailing conditions. Hence it was decided to study the durability through performance of various types of SCC in acid attack, chloride attack and the capillary water absorption. The SCC is more vulnerable to H_2SO_4 than other acidic environments (Al-Tamimi and Sonebi M. 2003). The parameters studied for resistance to acid attack were the loss in strength and mass after immersing the specimens in 3% H_2SO_4 for 90 days. The penetration of chloride ions increases the risk of corrosion in reinforced concrete structures. The depth of chloride ingress was hence measured using colorimetric technique (Stanish K. D. Et al 1997). Kazim Turk et al. (2007) studied the effect of curing regime and pozzolanic admixtures on sorptivity of SCC as one of the durability characteristics of SCC. The capillary water absorption of all categories of SCC was measured in this study with the help of sorptivity test.

II. Experimental Programme

a) Materials

i. Cement

Ordinary Portland cement of grade 53 conforming to the IS 8112:1989 with specific gravity 3.12 was used for all the mixes.

ii. Fine Aggregate

River sand conforming to zone II of IS 383:1970 having a specific gravity 2.52 was used as fine aggregate (F A).

iii. Coarse Aggregate

The coarse aggregate (C A) had a maximum size of 16 mm. The fractions of coarse aggregate used were: 10 percent of it was passing through 10 mm IS sieve and retaining on 4.75 mm IS sieve, 60 percent of it

Author α: Associate Professor, Depart. of Civil Engineering, B.N. College of Engineering, Pusad 445204, India.
e-mail: m.r.vyawahare@gmail.com
Author σ: Secretary, Maharashtra State Board of Technical Education, Mumbai-51, India.

© 2014 Global Journals Inc. (US)

was passing through 12.5 mm IS sieve and retaining on 10 mm IS sieve and 30 percent of it was passing through 16 mm IS sieve and retaining on 12.5 mm IS sieve. The specific gravity of the coarse aggregate was 2.67.

iv. *Superplasticiser*

The superplasticiser used in this study was Glenium B233 procured from BASF. It is based on modified polycarboxylic ether. It complies with ASTM C494 Types F and IS 9103:1999.

v. *Viscosity Modifying Agent*

The Viscosity Modifying Agent reduces the possibility of segregation and becomes essential ingredient when adequate paste volume is not present in the SCC. The VMA used to manufacture VMA type of SCC and combined type SCC was Glenium Stream 2 procured from BASF.

vi. *Water*

Clean potable water available in the laboratory was used for mixing the concrete.

vii. *Silica Fume*

Silica fume imparts very good improvement to rheological, mechanical and chemical properties. It improves the durability of the concrete by reinforcing the microstructure through filler effect and reduces segregation and bleeding. It also helps in achieving high early strength. Silica fume of specific gravity 2.2 was used in this study. Chemical composition of silica fume is given in table 1. Silica fume was obtained from ELKEM India, Mumbai.

Table 1 : Chemical composition of Silica fume

Sr. No.	Constituents	Quantity (%)
1.	SiO_2	91.03
2.	Al_2O_3	0.39
3.	Fe_2O_3	2.11
4.	CaO	1.5
5.	LOI	4.05

III. Mix Proportioning of Self Consolidating Concrete

Three types of SCCs viz. powder type, VMA type and combined type were manufactured for three strength categories M25, M35 and M45. Method suggested by Nan Su et al (2001) was referred for obtaining powder type SCC. Silica fume was used as filler in this type. For obtaining combined type SCC the filler content was almost halved. The modifications were necessary for each SCC mix to achieve the self consolidating properties as well as required strength. For obtaining VMA type SCC the cement content was increased as compared to the same in other two types of SCC mixes keeping all other ingredients in same proportions in each strength category. The final mixture proportions are given in Table 2.

Table 2 : Mix proportions in kg per cubic meter of SCC

Type of SCC	Specimen	Grade	Cement	S. F.	F A	C A	Water	SP	VMA
Powder type	AS1	M25	258	205	960	813	208	5.74	0
	AS2	M35	311	166	960	813	190	7.87	0
	AS3	M45	357	125	960	813	165	8.96	0
Combined powder & VMA type	BS1	M25	258	102	960	813	162	5.04	0.108
	BS2	M35	311	83	960	813	156	7.36	0.079
	BS3	M45	357	63	960	813	147	8.06	0.084
VMA type	CV1	M25	305	0	960	813	137	6.1	0.183
	CV2	M35	348	0	960	813	139	8.0	0.209
	CV3	M45	393	0	960	813	137	10.21	0.235

IV. Specimen Preparation

The mixing of all mixes was done in pan type of concrete mixer. The powder and the aggregates were mixed in dry state for one minute then 70% of calculated water was added in the mixer which was then mixed for 3 minutes. Then 30% of water was mixed with the super plasticizer and added in the powder type concrete mixes. Wherein for VMA type and combined type SCC mixes, out of remaining 30% water 20% was mixed with super-plasticiser and poured in the mixer and mixed for three minutes. Finally VMA was added in the last 10% of water and then poured in the mixer and mixed for one minute. During mixing process the doses of superplasticiser and VMA were adjusted to achieve required plasticity and viscosity of each mix.

Then every mix was checked for self consolidating ability by slump flow test, v-funnel test and L-box test. The results of fresh concrete properties of all the mixes satisfying the self compacting ability have been shown in Table 4. The EFNARC specifications for self consolidating ability have been shown in Table 3. These mixes exhibited horizontal slump flow without signs of bleeding even at the outer boundary. This visual

© 2014 Global Journals Inc. (US)

inspection confirmed the segregation resistance of the SCC mixes. After checking the self consolidating ability of the mix it was poured into the cube moulds of different sizes. The moulds were covered with wet gunny bags for 24 hours after casting and the specimens were then immersed in water for curing after demoulding. Cubes of 150×150×150mm were cast for test of compressive strength. All durability tests were performed on 100×100×100mm cube specimens.

Table 3 : Requirements of self consolidating ability as per the EFNARC specifications

Method	Properties	Range of values
Slump flow	Filling ability	650-800 mm
V-funnel	Viscosity	6-12 sec.
L-box ratio	Passing ability	0.8-1.0

a) Test Procedure

i. *Compressive Strength*

Cube specimens of size 150×150×150mm were tested for average compressive strength at 3 days, 7 days and 28 days according to IS 516. Three specimens were tested per test.

ii. *Durability Tests*

The durability tests were carried out on cube specimens after 28 days of curing. For each test of each mix three specimens were tested and average of the three has been shown.

iii. *Sorptivity Test*

The test for water absorption by capillary action (sorptivity) was carried out to determine the sorptivity coefficient of concrete specimens which were preconditioned in oven at 105^{0}C for 24 hr. and then allowed to cool down at room temperature for 24hr to achieve a constant moisture level. Then, four sides of the concrete specimens were sealed by electrical tape keeping two opposite sides exposed to avoid evaporative effect as well as to maintain uniaxial water flow during the test. Before locating the specimens on water, their initial weight was recorded. One face of specimen was in contact with water. Only 5mm depth of the specimen was submerged in water. The water absorption at predefined intervals was noted by taking weight. Procedure was repeated, consecutively at various time intervals like 15 min., 30 min., 1 hr, 2 hr, 4 hr, 6 hr, 24 hr, 48 hr and 72 hr. Sorptivity coefficient was calculated by the following expression. It is given by the slope of the sorptivity curve when it gets stabilised.

$S = (Q/A)/\sqrt{t}$

Where,

S = Sorptivity (cm/s$^{1/2}$)

Q = Vol. of water absorbed in cm^3

A = Surface area in contact with water in cm^2

t = the time (s)

b) Acid Attack

As reported by Girardi & Di Maggio (2011) sulphuric acid first attacks the calcium hydroxide, and then C–S–H too as soon as portlandite is no longer available, making the calcium hydroxide form gypsum and the calcium silicate hydrate (C–S–H) form both anhydrous gypsum and an incoherent mass of hydrated silicate. In a second step, calcium aluminate hydrate reacts with the sodium sulphate ions from the sulphuric acid, forming ettringite (3CaO_Al2O3_3CaSO4_32H2O). Ettringite having higher volume causes increase in volume of concrete and even the disrupture of concrete. The percentage loss in mass and compressive strength was thus determined for the test specimens of both type of SCC in following manner. The cube specimens after curing in water for 28 days were taken out of curing tank. The specimens were then placed in solution of 3% H_2SO_4. The pH of the solution was regularly monitored and adjusted to keep it constant. The consumed solution was replaced with freshly prepared solution every week. The cubes were immersed in acid for 90 days and the assessment of performance in acid attack was made from

- Mass loss
- % loss in compressive strength.

c) The Chloride Ingress

In the presence of chloride ions the steel reinforcing bars are more prone to corrosion. The test for chloride ingress was hence carried out in this study. A colorimetric technique was adopted. The cube specimens after 28 days curing were immersed in 3% NaCl solution for another 28 days representing the exposure to saline or sea water. The cubes were then taken out of chloride solution and split. The $AgNO_3$ solution was sprayed on the exposed area after splitting. When silver nitrate solution was sprayed on a concrete containing chloride ions, a chemical reaction occurred. The chlorides bind with the silver to produce silver chloride, a whitish substance. In the absence of chlorides, the silver instead bonds with the hydroxides present in the concrete creating a brownish colour. A whitish colour at the border of specimen shows the depth of penetration. It was measured with the help of Vernier Calliper along all four borders of each specimen and the average was taken. The depth of chloride ingress measured by this method is only a quantitative measure and does not give any idea about the chloride ion concentration.

V. Results and Discussions

a) Fresh Properties

The test results of fresh properties have been shown in Table 4. It can be observed that the powder type as well as combined type SCC has shown better results than VMA type in fresh state. The slump value of

Global Journal of Researches in Engineering (E) Volume XIV Issue III Version I Year 2014

© 2014 Global Journals Inc. (US)

VMA type ranged between 665 to 682 mm while the same for other two types ranged between 664 to 712mm. There was no significance difference in V-funnel time. The L-Box ratio of VMA type was between 0.81 and 0.85 and for other two types it was between 0.88 and 0.93. The better performance of powder type and combined type SCC in fresh state can be attributed to of higher powder content of these mixes.

b) Compressive Strength

The compressive strength results of all the mixes of SCC have been shown in Figure 1. and table 5.

Table 4 : Fresh properties of SCC

Type of SCC	Specimen Type	Slump Flow (mm)	V-Funnel (sec)	L-Box h^1/h^2
Powder type	AS1	705	9.2	0.93
	AS2	689	10.1	0.91
	AS3	664	11	0.88
Combined type	BS1	712	9.5	0.91
	BS2	684	10.7	0.89
	BS3	692	10.3	0.93
VMA type	CV1	674	10.6	0.83
	CV2	665	11.2	0.81
	CV3	682	10	0.85

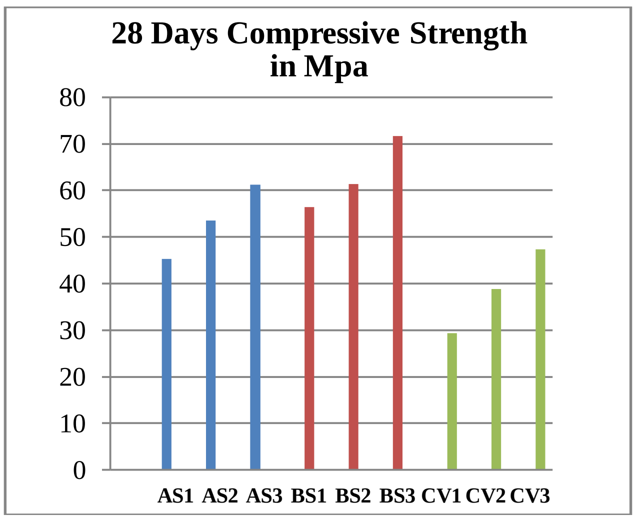

Figure 1

The compressive strength of VMA type of mixes for all grades was just achieved. The powder type mixes showed much better strength than VMA type and the combined powder and VMA type mixes showed maximum strength for all grades. In case of M25 grade mixes the strength achieved by powder type i.e. AS1 mix was 1.54 times the same for VMA mix i.e. CV1 and in M45 category the strength of AS3 was 1.29 times the strength of CV3. The combined type i.e. BS1 mix had compressive strength 1.91 times CV1 and BS3 had compressive strength 1.51 times the strength of VMA3. Both powder type and the combined type SCCs had shown higher strength because of dense structure caused by the higher powder content and pozzolanic reactivity of silica fume. The content of silica fume was more in powder type mixes than the combined type mixes and still their strength was slightly less, this can be due to more quantity of unhydrated silica fume particles remained at the end of 28 days of curing.

Table 5 : Results of strength and durability tests

Type of SCC	Specimen	Grade	Compressive strength in Mpa	Sorptivity cm/√sec	% mass loss in 3% H_2SO_4	% loss in comp strength in 3% H_2SO_4	Chloride ingress in mm
Powder type	AS1	M25	45.31	0.00283	1.42	4.78	1.8
	AS2	M35	53.45	0.00268	1.33	4.51	1.5
	AS3	M45	61.22	0.00253	1.22	3.93	0.9
Combined type	BS1	M25	56.35	0.00253	1.32	4.35	1.6
	BS2	M35	61.32	0.00239	1.26	4.13	1.2
	BS3	M45	71.67	0.00164	1.025	3.6	0.8
VMA type	CV1	M25	29.38	0.00449	2.81	17.13	24
	CV2	M35	38.84	0.00395	2.59	14.71	17.4
	CV3	M45	47.32	0.00354	2.21	12.46	10.8

© 2014 Global Journals Inc. (US)

c) Durability Results

i. *Sorptivity*

The sorptivity coefficient of combined powder and VMA type SCCs was least among all the types of SCCs. It was 11% to 36% less than powder type SCCs and 44% to 54% less than VMA type SCCs. The performance of all the SCCs in sorptivity test is almost similar to that in compressive strength tests. The results have been shown in Table 5 and Fig2.

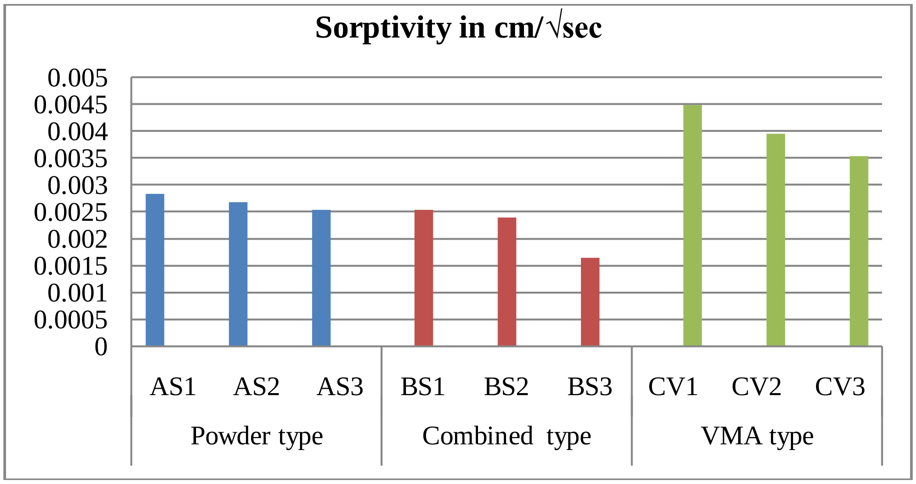

Figure 2

d) Acid Attack

The performance of all the types of SCCs was evaluated on the basis of percentage mass loss and percentage loss in compressive strength. The VMA type of SCC was found to be most vulnerable to acid attack. The resistance of powder type SCCs was better and of combined type was the best in all strength categories. The mass loss was almost half in case of powder type mixes as compared to VMA type and the loss in compressive strength was in the range of only 28 to 31% to that of VMA type. The mass loss in case of combined type was in the range of 46 to 47% of that in VMA type mixes and the loss in compressive strength was only 25 to 29% of that in VMA type mixes. The better performance of powder and combined type mixes should be attributed to less permeability than VMA type mixes. The results have been shown in Table 5 and figure 3.

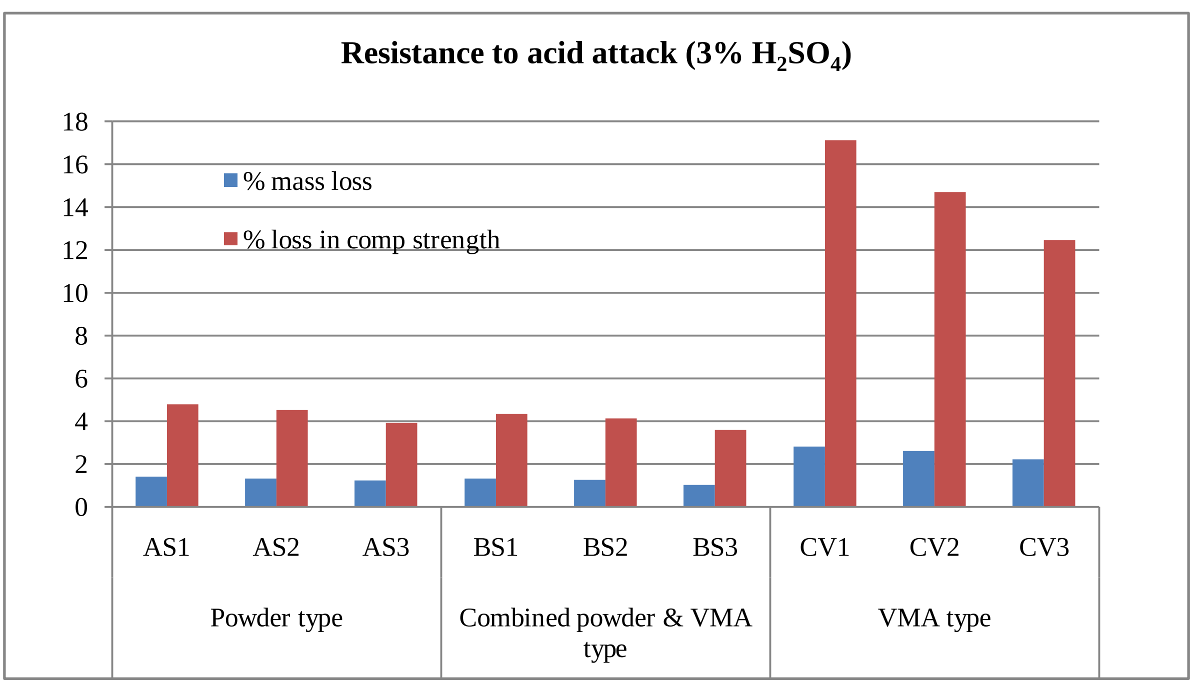

Figure 3

Global Journal of Researches in Engineering (E) Volume XIV Issue III Version I Year 2014

© 2014 Global Journals Inc. (US)

VI. Chloride Ingress

The combined type of SCC mixes showed least ingress of chlorides. The chloride ingress was very small in both powder type and combined type as compared with that in VMA type SCCs. It was only in the range of 0.8 to 1.6 mm in combined type, 0.9 to 1.8 mm in powder type and as large as 10.8 to 24 mm in VMA type SCCs. The large difference of chloride ingress in VMA type and other two types of SCCs must be due to dense structure and improved microstructure in the powder and combined type SCCs. The pozzolanic effect and very fine size of silica fume particles must have played the important role in exhibiting excellent durability characteristics. The results have been shown in Table 5.

VII. Conclusions

The combined powder and VMA type SCCs produced highest strength, excellent resistance to acid attack, least sorptivity and least amount of chloride ingress. Though there was marginal difference in durability performance of powder type SCCs and combined type SCCs the difference in strength was significant. The combined powder type SCC is hence concluded to be the best type of SCC for any strength category. The reasons for the best performance may be the finest size of filler particles, less amount of unhydrated particles, better microstructure of hydrated products and very dense structure of SCC produced. EFNARC (2002) (European Federation of national trade associations representing producers and applicators of specialist building products), Specification and Guidelines for self-compacting concrete, Hampshire, U.K.

References Références Referencias

1. EFNARC (2002) (European Federation of national trade associations representing producers and applicators of specialist building products), Specification and Guidelines for self-compacting concrete, Hampshire, U.K.
2. ACI Committee 237. (ACI 237) (2007). *Self-Consolidating Concrete.* American Concrete Institute (ACI).
3. Kazim Turk, Mehmet Karatas and Tahir Gonen (2013) "Effect of Fly Ash and Silica Fume on Compressive Strength, Sorptivity and Carbonation of SCC", *KSCE Journal of Civil Engineering* 17(1):pp202-209.
4. Al-Tamemi, A. K. and Sonebi, M. (2003) "Assessment of Self Compacting Concrete Immersed in Acidic Solutions", *Journal of Materials in Civil Engineering ©ASCE* pp 354-357.
5. Stanish K. D., Hooton R. D. and. Thomas M.D.A (1997) "Testing the Chloride Penetration Resistance of Concrete: A Literature Review" FHWA Contract DTFH61-97-R-00022, University of Toronto, Ontario, Canada.
6. Luiz Antonio Pereira de Oliveira, João Paulo de Castro Gomes & Cristiana Nadir Gonilho Pereira (2006): "Study of sorptivity of self-compacting concrete with mineral additives", *Journal of Civil Engineering and Management*, Vol. XII, No 3, 12:3, pp 215-220.
7. Nan Su, Kung-Chung Hsu and His-Wen Chai, (2001) "A simple mix design method for self compacting concrete", *Cement and Concrete Research*, 31, pp. 1799-1807.
8. Karjinni, Vilas and Anadinni, Shrishail, (2009) "Mixture proportion procedure for SCC", *The Indian Concrete Journal*, pp 35-41.
9. Girardi, F., Di Maggio, R. (2011) "Resistance of concrete mixtures to cyclic sulfuric acid exposure and mixed sulfates: Effect of the type of aggregate". *Cement and Concrete Composites*, 33, pp. 276-285.

© 2014 Global Journals Inc. (US)