ISCA Journal of Engineering Sciences ______________________________________ *ISCA J. Engineering Sci.*
Vol. **1(1),** 35-39, July **(2012)**

Development of Self Compacting Concrete by use of Portland Pozzolana Cement, Hydrated Lime and Silica Fume

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Available online at: www.isca.in
Received 14th June 2012, revised 18th June 2012, accepted 20th June 2012

Abstract

Concrete is the most widely used construction material because of its mould ability into any required structural form and shape due to its fluid behavior at early ages.. 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 strength 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. Self compacted concrete is used as a special concrete in place of standard concrete due to lack of mix design procedures. The paper presents to develop self compacted concrete by using portland Pozzolana cement, hydrated lime and silica fume. Lime is used as filler material. SF improved aggregate-matrix bond resulting from the formation of a less porous transition zone in concrete. The test results for acceptance characteristics of self-compacting concrete such as slump flow; V-funnel and L-Box are presented. Further, compressive strength at the ages of 7, 28, and 60 days was also determined and results are included here.

Keywords: Self-compacting concrete, lime powder, silica fume, fresh properties, hardened concrete properties and compressive strength.

Introduction

Self-compacting concrete (SCC) was first developed in late1980 in Japan as a mean to create uniformity in the quality of concrete by controlling the ever present problem of insufficient compaction by a workforce that was losing skilled labor and by the increased complexity of designs and reinforcement details in modern structural members. Durability was the main concern and the purpose was to develop a concrete mix that would reduce or eliminate the need for vibration to achieve consolidation. Self- compacting concrete achieves this by its unique fresh state properties[1].

In the plastic state, it flows under its own weight through restricted sections without segregation and bleeding maintains homogeneity while completely filling any formwork and passing around congested reinforcement. In the hardened state, it equals or excels standard concrete with respect to strength and durability. Such concrete should have a relatively low yield value to ensure high flow ability, a moderate viscosity to resist segregation and bleeding, and must maintain its homogeneity during transportation, placing and curing to ensure adequate structural performance and long term durability. The successful development of SCC must ensure a good balance between deformability and stability. Researchers have set some guidelines for mixture proportioning of SCC, which include: i. Reducing the volume ratio of aggregate to cementitious material[1]. ii. Increasing the paste volume and water-cement ratio, iii. Carefully controlling the maximum coarse aggregate particle size and total volume and iv. Using various viscosity enhancing admixtures (VEA)[1].

The viscosity of cement-based material can be improved by decreasing the water/ cementitious material ratio (w/p) or using a viscosity-enhancing agent[2]. It can also be improved by increasing the cohesiveness of the paste through the addition of filler, such as limestone. However, excessive addition of fine particles can result in a considerable increase in the specific surface area of the powder, which results in an increase of water demand to achieve a given consistency. On the other hand, for fixed water content, high powder volume increases inter particle friction due to solid-solid contact. This may affect the ability of the mixture to deform under its own weight and pass through obstacles[2]. The use of limestone powder can enhance many aspects of cement-based systems through physical or chemical effects. Some physical effects are associated with the small size of lime- stone particles, which can enhance the packing density of powder and reduce the interstitial void, thus decreasing entrapped water in the system. For example, the use of a continuously graded skeleton of powder is reported to reduce the required powder volume to ensure adequate deformability for concrete. Chemical factors include the effect of limestone filler in supplying ions into the phase solution, thus modifying the kinetics of hydration and the morphology of hydration products. Partial replacement of cement by an equal volume of limestone powder with a specific surface area ranging between 500 and 1000 m^2/kg resulted in an enhancement in fluidity and a reduction of the yield. Stress of highly flow able mortar

Other investigations have shown that partial replacement of cement by an equal volume of limestone powder varying from 5% to 20% resulted in an enhancement of the fluidity of high-performance concrete having a W/C ratio ranging between 0.5 and 0.7. This improvement may be due to the increase in W/C or in paste volume. Indeed, for given water content, partial replacement of cement by an equal volume of a filler results in an increase in W/C. On the other hand, partial replacement of cement by an equal mass of limestone powder results in an increase of powder content, i.e. an increase in paste volume. For example, the partial substitution of cement by 40% (by mass of limestone filler) having a specific gravity of 2.7 yields to a 17% increase in powder volume.

For improving strength and durability properties; limestone powders produce a more com-pact structure by pore-filling effect. In the case of SF and FA, it also reacts with cement by binding Ca $(OH)_2$ with free silica by a pozzolanic reaction forming a non-soluble CSH structure.

The main objective of the present study was to develop self compacting concrete using silica fume and hydraulic lime in varying combination for use in Indian condition satisfying European standard for rheological properties of concrete in fresh state.

Definition: SCC which stands for self-consolidating concrete, or self-compacting concrete, has many other names. It is also called high-workability concrete, self-leveling concrete or flowing concrete[3]. All the above terms are used to describe a highly workable concrete that needs little to no vibration during placement. The guiding principle behind the self-compaction is that "the sedimentation velocity of a particle is inversely proportional to the viscosity of the floating medium in which the particle exists".

Material of SCC: The constituent material used for the production of SCC is discussed as follows:

Cement: Most of research work on SCC in India is done by use of ordinary portland cement (53 grade) and (43grade) conforming to IS 8112 but due to increasing use PPC we use ultratech cement confirming to IS1489[4] 1991. The different laboratory tests were conducted on cement to determine standard consistency, initial and final setting time, and compressive strength as per IS 4031[5] and IS 269-1967. The results are tabulated in table-1. The results conforms to the IS recommendation

Fine Aggregate: Natural sand crushed and rounded sand and manufactured sand is suitable for SCC. River sand of specific gravity 2.58 and confirming to zone II of IS383-1970 was used for present study[6]. The particle size distribution is given in table -2

Table-1
Properties of cement

Test conducted	Result
Standard consistency	32%
Initial setting time	60 minutes
Final setting time	430 minutes
7day compressive strength	17.0 N/mm^2
28 day compressive strength	34.60 N/mm^2

Coarse Aggregate: The shape and particle size distribution of the aggregate is very important as it affects the packing void content, water absorption, grading of all aggregate should be closely and continuously monitored and must be taken in account in order to produce SCC of constant quality .Coarse aggregate used in this study has maximum size of 20 mm. specific gravity of coarse aggregate used was 2.80. The particle size distribution is given in table -3

Water-Ordinary potable water available in the laboratory was used.

Chemical Admixtures: Superplasticizers or high range water reducing admixtures are an essential component of SCC. FAIR FLO RMC (M) was used as superplasticiser. It is carboxylated acrylic ether co-polymer based superplasticiser confirm to BS 5075 part 3 and ASTM C-494 type and IS9103, 1999.

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 thus reduces segregation and bleeding. Silica fume of specific gravity 2.34 was used in this study. Silica fume is supplied by Oriental Trexim Pvt. Ltd,Navi Mumbai. The chemical composition of silica fume is given in table-6.

Table-2
Sieve analysis of fine aggregate

IS sieve(mm)	Weight retained	Cumulative weight retained	Cumulative % weight retained	% passing
10.0	0.0	0.0	00	100
4.75	0.0	0.0	0.00	100
2.36	2.254	2.254	18.26	81.74
1.18	1.449	3.703	29.99	70.01
0.6	2.299	6.002	48.62	51.38
0.3	3.906	9.908	80.26	19.74
0.15	1.819	11.727	95.00	5.0

Lime Powder-Hydrated lime is used as filler material of specific gravity 2.4.

Methodology

Tests on fresh concrete were performed to study the workability of concrete with various combinations of lime and silica fume. The test conducted are listed below: Different methods have been developing to characterize the rheological properties of SSC. 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 different workability parameter.

Slump flow test (total spread and T-50 time) Primary to assess the filling ability, suitable for laboratory and site use[7].

L-Box test: Primary to assess the passing ability, suitable for laboratory and site use.

J-Ring test: Primary to assess the passing ability, suitable for laboratory and site use[7].

V-Funnel test: Partially indicate filling ability and blocking, suitable for laboratory and site use[7].

The acceptance criteria for the fresh properties of SCC are listed in table-5[8]. Tests on hardened concrete were also conducted for mixes with various proportions of silica fume and lime.

Using Japanese method of mix design and recommendation made by EFNARC the proposed study was carried at coarse aggregate content272 l/m^3(270-360 l/m^3) and fine aggregate content 970 kg /m^3 55%(48-55) of total aggregate weight[8-9]. Minimum value of coarse aggregate and maximum value of fine aggregate is adopted to keep minimum quantity of cement.

To proceed forward achieving SCC trial mix TR-1 was prepared with cement content 330 kg /m^{3}and lime content 90 kg /m^3 with powder content 420 kg /m3(400-600 kg /m^3) w / p ratio 1.17. The dosages of super plasticizer were estimated to be from 1.5 to 3.0 % of powder content (cement, lime). However unsatisfying slump flow was obtained in trial mix and on increasing w/p ratio the segregation and bleeding occur. Mix also not satisfying V funnel test.

To achieve SCC trial mix TR-2 was prepared by increasing cement content 360 kg /m^{3}and lime content 90 kg /m^3 by adjusting F.A content 935 kg /m3 with powder content 450 kg /m^3 again mix not satisfied the rheological properties test.

To procede further SCC1 was formed by increasing the powder content 480 kg /m^3, cement content by 360 kg /m^3 and lime content 120 kg/m^3. Dosage of super plasticizer is fixed by trials 2.2% of powder. Cement is replaced by equal weight of SF i.e.4%,8%,12% of weight of cement, keeping total powder content 480 kg /m^3 SCC2,SCC3, SCC4 is prepared. Quantity of water used is kept constant for SCC1toSCC4. All the mix fulfills slump flow, V funnel, L box test. Further study is made to know the effect of lime and SF the cement content is decreased by 330 kg/m^3 and lime content is increased to 150kg/m^3. Cement is replaced by equal weight of SF i.e.4%,8%,12% of weight of cement, keeping total powder content 480 kg /m^{3}SCC5, SCC6, SCC7, SCC8 is prepared.SCC9 is prepared by decreasing the cement content by 300 kg /m^{3}and increasing the lime content by150 kg /m^3. SCC10, SCC11, SCC12 are prepared with 4%, 8%, 12% replacement of cement by silica fume.

Compressive strength of concrete is tested after 7, 28, and 60 days[10]. Mix proportions are shown in table-6

Table-3
Sieve analysis of coarse aggregate

IS sieve(mm)	Weight retained	Cumulative weight retained	Cumulative % weight retained	% passing
20	0.00	0.00	0.0	100
10.0	2.88	2.88	57.6	42.4
4.75	2.084	4.964	99.28	0.72
2.36	0.036	5.0	100	0.0
1.18	-	-	100	0.0
0.6	-	-	100	0.0
0.3	-	-	100	0.0
0.15	-	-	100	0.0

Fineness modulus = 6.57, Dry rodded Bulk density = 1.63g/cc

Table 4
Chemical composition of silica fume

Constituents	Quantity (%)
SiO_2	92
$Al2O_3$	2.0
$Fe2O_3$	1.0
CaO	1.2
LOI	3.0

Table-5
Acceptance criteria for SCC

Method	Unit	Typical range of values	
		Minimum	Maximum
Slump-flow	mm	650	800
T50 slump flow	Sec	2	5
J-ring	mm	0	10
V-funnel	Sec	8	12
V-funnel at T5minutes	Sec	0	+3
L-Box	(h/h1)	0.8	1.0
U-Box	(h2/hj)	0	30
Fill Box	%	90	100
GTM Screen stability test	%	0	15
Orimet	Sec	0	5

Table-6
Mix Proportions

Mix	Cement	Lime	Silica Fume	Coarse Aggregate	Fine aggregate	Water	Super Plasticizer.	Water to powder ratio
	(Kg/m^3)	(Kg/m^3)	(Kg/m^3	(Kg/m^3)	(Kg/m^3)	(Kg/m^3)	(%)	
TR1	330	90	nil	764	970	189	2.2	1.17
TR2	360	90	nil	764	935	193.5	2.2	1.14
SCC1	360	120	nil	764	917	192	2.2	1.05
SCC2	345.6	120	14.4	764	917	192	2.2	1.04
SCC3	331.2	120	28.8	764	917	192	2.2	1.036
SCC4	316.8	120	43.2	764	917	192	2.2	1.027
SCC5	330	150	nil	764	917	192	2.2	1.037
SCC6	316.8	150	13.2	764	917	192	2.2	1.029
SCC7	303.6	150	26.4	764	917	192	2.2	1.022
SCC8	290.4	150	39.6	764	917	192	2.2	1.014
SCC9	300	180	Nil	764	917	192	2.2	1.021
SCC10	288	180	12	764	917	192	2.2	1.014
SCC11	276	180	24	764	917	192	2.2	1.01
SCC12	264	180	36	764	917	192	2.2	1.00

Table- 7
Workability and compressive strength results

Mix	Slump flow (mm)	^{T} 50cm (sec)	V-funnel Tf ^{b} (sec)	L-box H_2/H_1	7-days (MPa)	28-days (MPa)	60-days (MPa)
TR1	540	9.2	Nil	nil	nil	nil	Nil
TR2	580	7.6	nil	nil	Nil	nil	nil
SCC1	645	5.5	10.4	0.82	26	43	51
SCC2	650	4.9	10.8	0.85	27	46	54
SCC3	660	4.81	11.6	0.91	29	51.5	59
SCC4	668	4.9	13.5	0.92	29	52	59
SCC5	660	4.6	8.9	0.85	23	40	47
SCC6	670	4.5	9.4	0.90	24	43	49
SCC7	680	4.4	10.6	0.92	26	48	55
SCC8	685	4.4	12.3	0.93	26.5	49	55
SCC9	680	4.5	7.2	0.87	19	32	37
SCC10	690	4.1	8.4	0.91	23	33	38
SCC11	705	3.75	9.5	0.95	25	35	40
SCC12	715	3.70	12	0.96	25	36	39

T_{50}cm: time taken for concrete to reach the 500 mm spread circle, V-funnel time the concrete in funnel for10 sec.

H_1, H_2: Heights of the concrete at both ends of horizontal section of L-box after allowing the concrete to flow

Results and Discussion

As mentioned earlier mix TR1 and TR2 did not fulfill the requirement of SCC. The rheological characteristics of SCC1 to SCC9 are discussed below. The slump flow characteristics of mix are between 600 to740 mm. The flow improves due to addition silica fume and lime content. As far as filling ability of mixes is concern, the results of V funnel satisfied the standard requirement. V funnel time increased as increase in silica fume and decrease in lime content. The blocking ratio in the L box was as per the requirement of SCC mixes as laid by EFNARC guidelines. 7 days compressive strength indicates no significant difference in compressive strength of concrete means effect of replacement of cement by silica fume starts from 7 days. 28 days compressive results show 8% replacement of cement by silica fume increases the strength about 20 %. From 7days, 28days and 60 days compressive strength result indicate increase in compressive strength by replacement by silica fume and decrease in strength by replacement by hydraulic lime. The lime has no significant effect on compressive strength of concrete. The results show that there is slow rate of gain in strength up to seven days, medium rate of gain of strength up to 28 and 60 days.

Conclusion

Self compacting concrete could be prepared without using viscosity modifying agent as was done in the study. Portland Pozzolana cement can be used for development of Self compacting concrete. Silica fume provide mechanical strength to SSC, 8% replacement of cement by silica fume have best effect on compressive strength of concrete. Addition of silica fume and lime develop filling and passing ability of concrete. There is continuous gain of strength up to sixty days due to slow pozzalanic reactions of Portland Pozzolana cement. Different types of SCC having different compressive strength can be prepared by different combination of cement, lime and silica fume.

Acknowledgement

The author acknowledges SSANGYONG Engineering and Construction Co. Ltd Branch Sagar M.P. for providing super plasticizer and hydrated lime.

References

1. Nagamoto N. and Ozawa K., Mixture properties of Self-Compacting, High-Performance Concrete, Proceedings, *Third* Canmet/ACI International Conferences on Design and Materials and Recent Advances in Concrete Technology, SP-172, V. M. Malhotra, American Concrete Institute, Farmington Hills, Mich. 623-637 **(1997)**

2. Ravikumar M.S., Selvamony C, Kannan S.U. et al. Behaviour of self compacting self curing kiln ash concrete with various admixtures, *ARPN journal of engineering and applied science,* **4(8),** 25-30 (**2009**)

3. Frances Yang A report on self consolidating concrete **3-21(2004)**

4. IS: 1489 (Part-1), Indian standard specification for Portland Pozzolana cementPart1Fly ash based Bureau of Indian Standards, New Delhi, India **(1991)**

5. IS:4031(Part-iv,v), Indian standard code of practice for Methods of tests for Properties of cement Bureau of Indian Standards, New Delhi, India **(1988)**

6. IS: 383-1970, Specifications for Coarse and Fine aggregates from Natural sources for Concrete, Bureau of Indian Standards, New Delhi, India **(1970)**

7. Schutter G. DE Guideline for Testing Fresh Self Compacting, 4-19 (**2005**)

8. EFNARC (European Federation of national trade associations representing producers and applicators of specialist building products), Specification and Guidelines for self- compacting concrete, Hampshire, U.K. **(2002)**

9. Gambhir M.L., Book of Concrete Technology, 511-537 (**2011**)

10. IS 516-1959, Indian Standard code of practice for Methods of tests for strength of concrete, Bureau of Indian Standards, New Delhi **(1999)**