Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 15	No. 1	pp. 285-290	2016

Original Research Paper

Effective Utilization of Industrial Wastes in Self Compacting Concrete for Environmental Protection

S. Suchithra*† and R. Malathy**
*Kongu Engineering College, Perundurai, Tamil Nadu, India
**Sona College of Technology, Salem, Tamil Nadu, India
†Corresponding author: S. Suchithra

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 23-03-2015
Accepted: 01-05-2015

Key Words:
Fly ash
Silica fume
Rice husk ash
Self compacting concrete

ABSTRACT

An experimental study on the workability of self-compacting concrete (SCC) with three mineral admixtures which are obtained as waste products from industries were studied. The materials used for the study are fly ash (FA), Silica fume (SF), rice husk ash (RHA) along with OPC cement. Self compacting concrete is a special concrete, which can be placed and compacted under its own weight with little or no vibration effect, and which is at the same time cohesive enough to be handled without segregation or bleeding. The work involves four types of mixes, the first consisting of fly ash, the second uses FA and silica fume the third uses a mixture of FA and rice husk ash and the fourth, a combination of fly ash, silica fume and rice husk ash. After each mix proportion was arrived, its workability was checked and cubes were cast, cured and strength check made. The results show that SCC with 10% of SF and 20% fly ash combination gives higher values of compressive strength than those with 30% replacement of FA.

INTRODUCTION

Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact load, the tensile strength is approximately just one tenth of its compressive strength. Hence, for these characteristics, the flexural members cannot support such loads that usually take place during their service life. The term self-compacting concrete (SCC) refers to a "new" special type of concrete mixture, which has high resistance to segregation that can be cast without compaction or vibration. Development of self-compacting concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Skarendahl & Petersson (2000) says SCC is not affected by the shape and the amount of reinforcing bars, the skills of workers or the arrangement of a structure.

Findings of Bilodeau et al. (1994) indicate that among the materials used, fly ash, a by-product of thermal power plants, is found to improve the mechanical properties and durability of concrete when used as a cement replacement material. Previous investigations done by BouzoubaaÃa (2001) show that the use of fly ash and blast furnace slag in SCC reduces, the dosage of superplasticizer needed to obtain similar slump flow compared to concrete made with Portland cement only. Also, Kurita et al. (1998) paper's findings say that the use of fly ash improves the rheological properties and reduces cracking of concrete due to the heat of hydration of the cement. Studies carried by Mohamed (2011) show that higher the percentage of fly ash, the higher the values of concrete compressive strength until 30% of FA replacement. Rice husk ash (RHA) has been used as a highly reactive pozzolanic material to improve the microstructure of the interfacial transition zone (ITZ) between the cement paste and the aggregate in self compacting concrete. This was mentioned by Wee et al. (1995). Krishna (2012) asserted that the production and use of rice husk ash (RHA) in India should be considerably increased given the fact that RHA contributes significantly to a green building. It reduces the consumption of cement due to blending but also solves the waste disposal problem. Naik et al. (2013) investigated that depending upon the mineral admixture and curing conditions, the result indicates that the mineral admixture addition helps in gain of compressive strength, especially silica fume (SF). Pai et al. (2005) finding says that significant improvement in various strengths is observed with the inclusion of steel fibres and silica fumes in the mix. However, it appears that maximum gain in the strength of SFRSCC is found to depend on the fibre content and optimum dosage of SF. SF user's manual (2005) gives the guidance for its usage in concrete. Memona et al. (2011) findings mentioned that the fresh concrete and the different concrete mix have slump flow in the range of 595-795 mm, L-box ratio ranging from 0 (stucked) to 1 and flow time ranging from 2.2 to 29.3 s.

The compressive strengths developed by the SCC mixes with RHA were comparable to the control concrete. Analysis of cost showed that the cost of ingredients of specific SCC mix is 42.47% less than that of control concrete.

OBJECTIVE OF THE WORK

The experiment was carried out with different proportioning of mineral admixtures such as fly ash, silica fume and rice husk ash, which are obtained as waste and by products along with ordinary Portland cement. Till now no proper mix design method was developed for designing SCC. Here, an attempt was made to develop M30 grade SCC and tests were conducted for the fresh and hardened properties of SCC.

INDIAN SCENARIO

As per 3rd Annual International Summit FlyAsh Utilization, 2013, the annual generation of fly ash is expected to be around 175 million tonnes by the end of XIth Five Year Plan and around 500 million tonnes by 2031-32. The generation of fly ash is expected to increase to 190 million tonnes per year (2011-12), 300 million tonnes per year (2016-17) and 700 million tonnes per year (2031-32). 180 billion tonnes of clay brick production per year consumes 540 million tonnes of clay, which makes 65000 acres of land barren, and consumes approximately 30 million tonnes of coal equivalent, and generates approximately 26 million tonnes of CO_2. A 10% switch-over to fly ash bricks will use about 30 million tonnes of fly ash every year, and can save environment and coal. This can yield a benefit of 300 crores by way of reduction in brick cost production.

Silica fume is a very fine non-crystalline silica produced in electric furnaces as a by-product of the production of elemental silicon or alloys containing silicon-ACI116R. As per USGS figures, India has a production of 68,000 tonnes per annum. Similar to the above two admixtures, silica fume disposal is also a big problem. Silica fume is commercially available as small quantities for research.

India is a major rice producing country, and the husk generated is mostly used as a fuel in the boilers for processing paddy. Approximately 20 million tons of RHA are produced annually. This creates a great environmental threat causing damage to the land and the surrounding area in which it is dumped. Lot of ways are being thought for disposing it by making commercial use of this RHA. The annual rice husk production in India is approximately 120 million tons. Construction industry is one of the fastest growing sectors in India. This leads to the shortfall of traditional building materials. Cement, sand, bricks, and wood are now becoming scarce materials. The demand for good quality of building materials to replace the traditional materials and the need for cost effective and durable materials for the low cost housing has necessitated the researchers to develop a variety of new and innovative building materials.

ADVANTAGES OF USING SCC

The use of SCC is considered to have a number of advantages such as faster placement, better consolidation around reinforcement and can be easily placed in the walled element. It improves the quality, durability and reliability of the concrete structures and reduces the total time of the construction and the cost.

When compared to normal concrete, SCC contains large powder content in terms of cement, which can be partially replaced by fly ash, silica fume, rice husk ash, GGBS, quarry dust and lime stone. The above mentioned mineral admixtures are mostly obtained as industrial wastes which create high pollution and disposal problems.

Due to its intrinsic low porosity, SCC has high performance properties also in the terms of mechanical behaviour and durability. SCC often contains a large quantity of powder materials which is required to maintain sufficiently low yield stress to provide flow ability at a plastic viscosity which is high enough to effectively avoid segregation. As, the use of a large quantity of cement increases cost and results in large temperature rise, the use of mineral admixtures such as fly ash, silica fume and rice husk ash could increase the slump of the concrete mixture without increasing its cost. The fine content provides stability of the mix, resulting in resistance against bleeding and segregation.

EXPERIMENTAL WORK

For the present study three trial mixes were prepared as per EFNARC and IS 10262:2009 by varying the powder content. Along with cement, fine aggregate, coarse aggregate and water, fly ash, silica fume and rice husk ash were used in varying proportions. The characteristics of the three admixtures used are given below. Superplasticizer, Conplast SP 430 which improves the workability of concrete was also used.

Fly ash: Fly ash of Class F (as per ASTM C 618), collected from the Mettur thermal power plant, was used for the work and the tests were conducted with the facilities in the laboratory at the room temperature. The physical property details are given in Table 1.

Silica fume: Silica fume gives very good improvement to mechanical, rheological and chemical properties. The durability of the concrete is improved by reinforcing the microstructure through filler effect and reduces segregation and bleeding. Silica fume also helps in achieving high early

Table 1: Physical properties of fly ash.

Physical Properties	Test Values
Specific surface area (cm^2/g)	3200
Specific gravity	2.6
Bulk density (kg/m^3)	750
Physical form	Powder form

Table 2: Physical properties of silica fume.

Physical Properties	Test Values
Specific surface area (m^2/g)	20.9
Specific gravity	2.2
Bulk density D (kg/m^3)	600-700 (when packed)
Bulk density U (kg/m^3)	200-35 (when packed)

Table 3: Chemical properties of mineral admixtures.

Chemical properties (% by mass)	Fly ash	Silica fume	Rice husk ash
SiO_2	60.3	92	88.32
Al_2O_3	2.23	0.56	0.46
Fe_2O_3	0.9	0.70	0.67
CaO	0.35	0.47	0.67
MgO	0.87	0.80	0.44
Na_2O_3	0.2	0.21	0.12
K_2O	0.6	0.43	2.91
LOI	3.6	2.1	5.81

Table 4: Slump flow (650-800mm).

Test mixes	Mix 1	Mix 2	Mix 3
CC	795	795	795
SCFA	800	795	792
SCFSF	795	786	780
SCFSFRH	795	787	782
SCFARH	798	795	792

Table 5: L box (0.8 -1).

Test Mixes	Mix 1	Mix 2	Mix 3
CC	6	6	6
SCFA	6	6	6
SCFSF	6	7	7
SCFSFRH	6	6	7
SCFARH	6	6	7

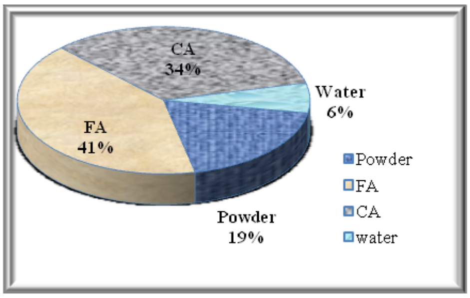

Fig. 1: Mix ratio.

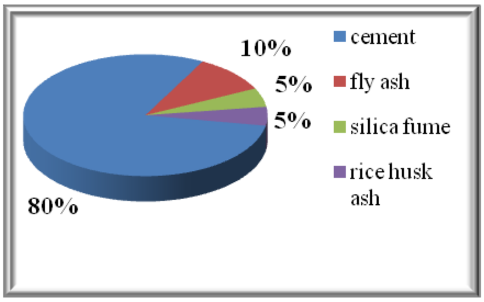

Fig. 2: Ratio of maximum powder content replacement for Mix 1.

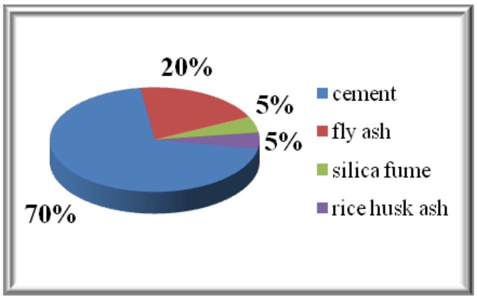

Fig. 3: Ratio of maximum powder content replacement for Mix 2.

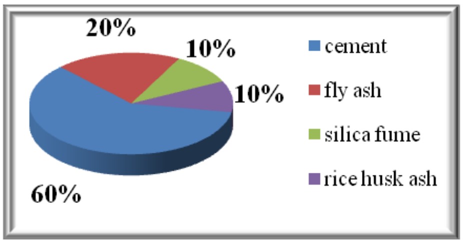

Fig. 4: Ratio of maximum powder content replacement for Mix 3.

strength. Silica fume was obtained from ELKEM materials, Mumbai. The properties of silica fume are given in Table 2.

Rice husk ash (RHA): RHA is finer than cement having a very small particle size of around 25 microns, that it fills the interstices between the cement in the aggregate. Rice husk ash is produced by burning the outer shell of the paddy that comes out as a waste product during milling of rice. Each ton of paddy makes about 210 kg of husk and this rice husk can be effectively converted through controlled burning. At 500°C a valuable siliceous product that can enhance the durability of concrete in the chemical composition of rice husk ash is obtained. The temperature variations in the burning much above or below will drastically alter the silica content of the ash. It has been found that one fifth of the five hundred million tons of world annual paddy production is available as rice husks. From this, only a small quantity of rice

Table 6: V-funnel (6-12 sec).

Test Mixes	Mix 1	Mix 2	Mix 3
CC	1	1	1
SCFA	1	1	0.98
SCFSF	1	0.98	0.96
SCFSFRH	1	1	0.97
SCFARH	1	1	0.98

Table 7: U tube (0-30mm).

Test Mixes	Mix 1	Mix 2	Mix 3
CC	3	3	3
SCFA	3	3	5
SCFSF	3	4	5
SCFSFRH	4	5	5
SCFARH	4	4	5

Table 8: J- Ring test (0-10mm).

Test Mixes	Mix 1	Mix 2	Mix 3
CC	3	3	3
SCFA	4	4	5
SCFSF	5	5	6
SCFSFRH	4	5	5
SCFARH	4	4	5

Table 9: Comparison of cost.

Mix	Savings (%)
SCFA1	5
SCFSF1	7
SCFSFRH1	5
SCFARH1	5
SCFA2	10
SCFSF2	14
SCFSFRH2	10
SCFARH2	10
SCFA3	15
SCFSF3	20
SCFSFRH3	15
SCFARH3	15

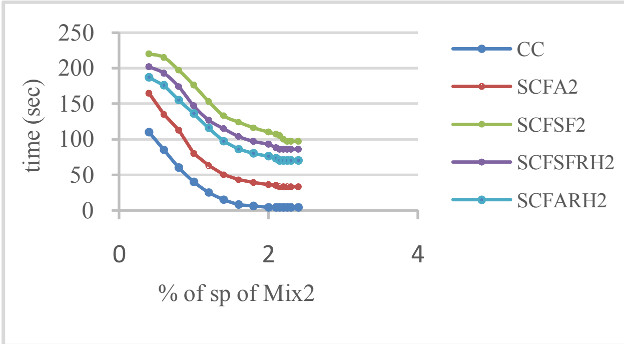

Fig. 5(a): Optimum dosage of SP for mix 1.

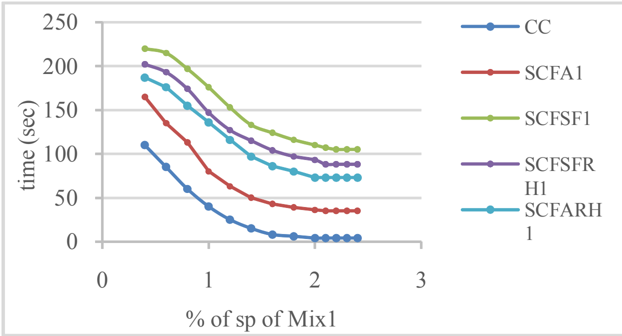

Fig. 5(b): Optimum dosage of SP for mix 2.

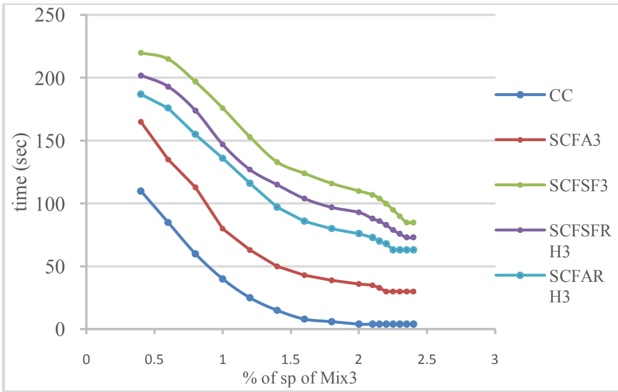

Fig. 5(c): Optimum dosage of SP for mix 3.

husk is used in agricultural field as a fertilizer, or used in stabilization of black cotton soils. In the present study, RHA is used in powder form with specific gravity of 2.11.

A comparison of chemical properties of mineral admixtures is given in Table 3. It is evident that all the three admixtures have similar chemical composition as cement and this characteristic is used in the present study as a replacement for cement.

MIX COMPOSITION

The mix proportion was done based on the method proposed by Malathy & Govindasamy (2006) and later the ratio was improved to satisfy the EFNARC workability conditions. The mix trials were carried out for concrete grade M30. This method was preferred as it has the advantage of considering the strengths of the SCC mix. Fig. 1 shows the percentage of the ingredients of M30 mix. Figs. 2, 3 and 4 show the maximum replacement of admixtures for the three mixes.

WORKABILITY TESTS

The workability of the concrete mixes is important as the name suggests as self compacting concrete. As the powder

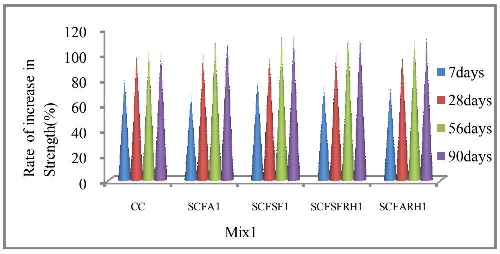

Fig. 6(a): Rate of increase in strength of Mix 1.

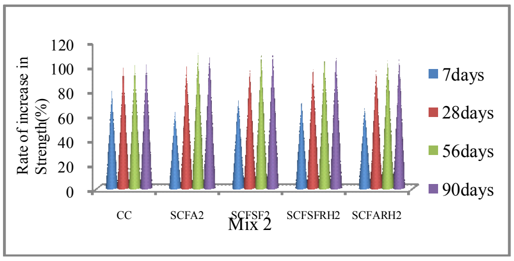

Fig. 6(b): Rate of increase in strength of Mix 2.

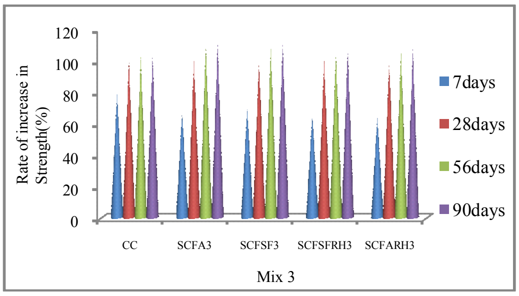

Fig. 6(c): Rate of increase in strength of Mix 3.

content is more than normal concrete, the passing ability, filling ability, resistance to segregation are to be confirmed. The workability is checked mainly by tests, namely, Slump flow test, L-Box test, V-Funnel test, J- Ring test and U- Box test. It was found that all the mixes satisfy the EFNARC limits for the all four tests. The results of the tests are given in Tables 4-8. Permissible limits are mentioned in brackets.

HARDENED PROPERTY RESULTS

All the mixes satisfied the acceptance criteria for self compacting concrete. Hence, these mixes were chosen as the successful mixes. The cube specimens of size 150 × 150 × 150 mm were cast for the successful mixes and tested for the 28-day compressive strength. Also, cylindrical specimens of size 300mm height and 150mm diameter were cast and tested for 28-day split tensile strength. Flexural strength test was conducted as per the recommendations of IS: 516-1959. In this test, beams of size 100 × 100 × 500 mm were cast and tested for 28 days.

Table 10: Energy savings.

Mix	Global warming potential per ft^2 (kg CO_2eq)	Ozone depletion potential per ft2 (mg CFC-11 eq)
SCFA1	13.35	0.02
SCFSF1	14.98	0.021
SCFSFRH1	13.24	0.021
SCFARH1	13.33	0.02
SCFA2	8.75	0.02
SCFSF2	6.12	0.022
SCFSFRH2	8.56	0.021
SCFARH2	8.35	0.02
SCFA3	4.55	0.02
SCFSF3	5.13	0.025
SCFSFRH3	6.23	0.02
SCFARH3	5.34	0.022

COMPARATIVE STUDY

Cost comparison: Table 9 shows the cost comparison of different mixes with normal concrete per m^3 of concrete used in the study.

Energy savings: Table 10 shows the comparative study of energy savings of various mixes with the normal concrete. Global warming potential gives the measurement of greenhouse gases created. It is measured in mass equivalent of carbon dioxide equivalents. The estimated amount of ozone depleting substances are measured in mass unit CFC-11 equivalent.

RESULTS AND DISCUSSION

Fresh concrete properties: Workability of concrete is assured by using optimum percentage usage of super plasticizer. This is done by conducting Marsh cone test. From the test, it was found that optimum percentage of super plasticizer varies from 2% to 3.8% by weight of powder content for three mixes. The results are presented in Figs. 5(a), 5(b) and 5(c). The results of workability tests show that when the percentage of replacement of admixtures are increased, the workability is reduced. But this reduction does not affect the workability of concrete. The slump flow test results show that workability of SCFSF is the least for all the trials. For the other tests also, this mix shows the least workability. The reason for decreasing the workability of the mixes can be attributed to the very fine particle size of silica fume that causes some of the super plasticizers being adsorbed on its surface.

Hardened concrete properties: The compressive strength of the self-compacting concrete mixes increased as the powder content is increased to a certain level and after that there is reduction in the strength. The Figs. 6(a), 6(b) and 6(c) show the compressive strength achievements of Mix1, Mix2 and Mix3 of concrete with various proportions of admixture replacement at various curing periods. The strength achievement is higher at an early period and it is also noted that it is increased for SCFSF3, SCFSFRH2, SCFARH1 and SCFA1 concrete when compared to the other mixes intended to achieve M30 grade.

CONCLUSIONS

- The use of mineral admixtures which are treated as wastes are utilized satisfactorily in the mixes without any compromise to the strength.
- For the mixes, the optimum dosage of super plasticizer was found out.
- The addition of mineral admixtures does not affect the workability of concrete.
- Cost comparison study shows that the addition of fly ash, silica fume, rice husk ash gives a savings varying from 5% to 20%.
- There is a considerable amount of energy reduction by adding the mineral admixtures obtained as industrial wastes.
- The strength of mix is linearly related to optimum replacement of admixtures to the mix.

REFERENCES

Bilodeau, A., Sivasundaram, V., Painter, K.E. and Malhotra, V.M. 1994. Durability of concrete incorporating high volumes of fly ash from sources in US. ACI Mater. J., 91: 3-12.

BouzoubaaÃa, N. and Lachemib, M. 2001. Self-compacting concrete incorporating high volumes of class F fly ash-preliminary results. Cement and Concrete Research, 31(3): 413-420.

Heba, A. Mohamed 2011. Effect of fly ash and silica fume on compressive strength of self-compacting concrete under different curing conditions. Ain Shams Engineering Journal, 2(2): 79-86.

Kurita, M. and Nomura, T. 1998. Highly-flowable steel fiber-reinforced concrete containing fly ash. ACI Special Publication, 178.

Krishna, R.N. 2012. Rice husk ash-an ideal admixture for concrete in aggressive environments. Recycling construction waste for sustainable development. Organized by CREAM, UiTM, ACCI and CSM, Kuala Lumpur.

Malathy, R. and Givindasamy, T. 2006. Development of mix design chart for various grades of self compacting concrete, ICI Journal, 6: 19-23.

Memona, S.A., Shaikh, M.A. and Hassan, A. 2011. Utilization of rice husk ash as viscosity modifying agent in self compacting concrete. Construction Building Materials, 25: 1044-48.

Pai, A.B.H.V. and Sujith Kumar, C.P. 2009. Experimental study on steel fiber reinforced self compacting concrete with silica fume as filler material. 34th Conference on Our World In Concrete & Structures, Singapore.

Priyanka, P. and Naik, M. R. Vyawahare 2013. Comparative study of effect of silica fume and quarry dust on strength of self compacting concrete. International Journal of Engineering Research and Applications, 3(3): 1497-1500.

Skarendahl, A. and Petersson, O. 2000. Self-compacting concrete: state of the art report of RILEM TC 174-SCC, Report 23, RILEM Publishers, Cachan, France.

Silica Fume User's Manual, April 2005. Silica Fume Association.

Wee, T.H., Matsunga, Y., Watanabe, Y. and Sahai, E. 1995. Production and properties of high-strength concrete containing various mineral admixtures. Cement and Concrete Research, 25(4): 709-714.