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Effect of silica fume and fly ash on fresh and hardened state of self compacting concrete

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ABSTRACT

This study presents an experimental investigation on self-compacting concrete with two mineral admixtures such as silica fume and fly ash. With low water-binder ratio, we had achieved higher grade of self-compacting concrete. The water-binder ratio was maintained to 0.36 for all the SCC mixes. This research includes the following studies: (i) Develop a suitable design mix for SCC that would satisfies all the acceptance criteria of EFNARC (ii) A study has been made for the rheology properties of SCC.The main requirements of fresh properties of SCC are filling ability, passing ability, and high segregation resistance, which can be investigated by slump flow, T50 slump flow, J ring, V-funnel, L box test. (iii) concrete samples were casted and tested for its compressive strength and Young's modulus. The results show that SCC with 10% of SF gives higher values of compressive strength than those with 15% of FA.

Introduction

Self-Compacting Concrete (SCC) is a concrete that is consolidated only through its self-weight, hence no additional compaction processes are needed. The intention behind developing such type of concrete was to address the concerns regarding homogeneity and compaction of cast in-place concrete. SCC mixes usually contain superplasticizer, high content of fines. Whilst the use of superplasticizer maintains the fluidity, the fine content provides stability of the mix resulting in resistance against bleeding and segregation Development of Self-compacting concrete is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Vibrating concrete in congested locations may cause some risk to labour and there are always doubts about the strength and durability of concrete placed in such locations, one solution for that is Self-compacting concrete.

In this study, the cement was partially replaced with mineral admixtures such as silica fume and fly ash. By employing Self-compacting concrete, the cost of chemical and mineral admixtures is compensated by the elimination of compaction and work done to level the surface of normal concrete.

Objectives of the study

The main objective of the research work is to study the fresh and hardened properties of self-compacting concrete.

- To design a higher grade of Self-Compacting Concrete with less water-binder ratio.
- To study the fresh properties (filling ability, passing ability, segregation resistance) of Self-Compacting Concrete for various replacement levels of silica fume and fly ash.
- To study the effect on compressive strength for various replacement levels of silica fume and fly ash. To study the effect of accelerated curing in self-compacting concrete.
- To find the young's modulus and Poisson's ratio for the self-compacting concrete.

Materials used

OPC confining to IS: 8112-1989, Silica fume and fly ash are used. Super plasticizer of modified polycarboxylic ether GLENIUM B233 is used and Viscosity modifying agent of brand name strene 2 is used. Fine aggregate of zone II sand confining to IS: 383-1970 and coarse aggregate of 12.5mm are used.

Mix design

In this study Aitcin method is adopted for mix design. The method follows the same approach as ACI 211-1-1991 standard practice for selecting proportional for Normal and Heavyweight concrete. The water contributed by the super plasticizer is considered as part of the mixing water.

- A suggestion of water/binder ratio can be found by a nomogram (from 40 to 160 MPa at 28 days)
- Estimation of minimum water dosage, according to the super plasticizer saturation point
- The super plasticizer dosage can be deducted from Marsh cone test.
- Water-binder ratio and VMA content kept constant for all the replacement levels of SCC mixes.
- The coarse aggregate content can be found according to its shape. If its shape is not known, a content of 1000 kg/m^3 of coarse aggregate can be used to start with.
- An entrapped air content of 1.5% was adopted in the design mix.
- After arriving the basic mix proportion, the final mix proportions have been formulated by performing numerous trials. For SCC the packing of coarse aggregate is approximately 50% and that of fine aggregate in mortar is 60%.

Table 1 shows the mix proportion for the Self-Compacting Concrete mix which is used for this research work.

Experimental investigation

Fresh concrete tests

Table 2 shows the acceptance criteria's for Self-Compacting Concrete as per EFNARC guidelines.

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Table 1 Mix proportion

Water (l/m^3)	Cement (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	SP (l/m^3)	VMA (l/m^3)
0.36	1	2.14	1.97	0.013	0.001

Table 2 Acceptance criteria's for self-compacting concrete

Sl.No	Method	Unit	Typical range of value	
			Minimum	Maximum
1.	Slump flow by Abrams cone	mm	650	800
2.	T50 slump flow	Sec	2	5
3.	J-ring	mm	0	10
4.	V-funnel	sec	6	12
5.	L-box	h_2/h_1	0.8	1.0

Slump flow

Introduction

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete.

Figure 1 shows the slump flow test using Abram's cone. This slump flow is within the EFNARC standard

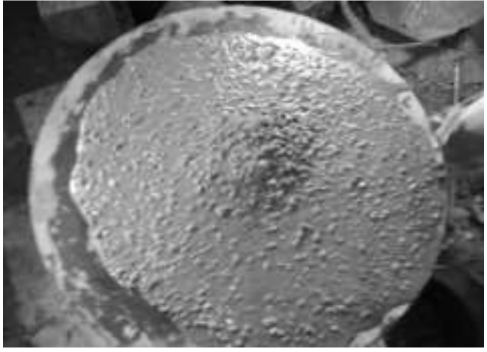

Figure 1 Slump flow test using Abrams cone

Interpretation of result

The higher the slump flow value, the greater its ability to fill formwork under its own weight. A value of at least 650mm is required for SCC. There is no generally accepted advice on what are reasonable tolerances about a specified value, though ± 50mm, as with the related flow table test, might be appropriate.

J Ring test

Introduction

The J-ring test aims at investigating both the filling ability and the passing ability of SCC. It can also be used to investigate the resistance of SCC to segregation by comparing test results from two different portions of sample. The J-ring test measures flow spread and blocking step. The J-ring flow spread indicates the restricted deformability of SCC due to blocking effect of reinforcement bars and the flow time T50J indicates the rate of deformation within a defined flow distance. The blocking step quantifies the effect of blocking.

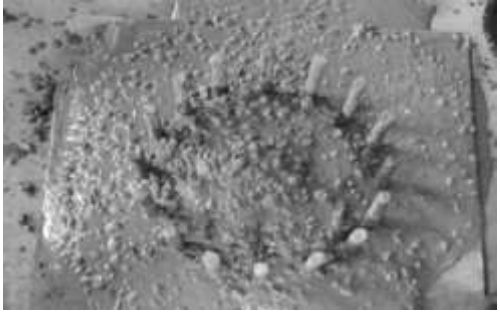

Figure 2 J Ring Test

Interpretation of result

This tests measure flow and passing ability, the results are not independent. The measured flow is certainly affected by the degree to which the concrete movement is blocked by the reinforcing bars. The extent of blocking is much less affected by the flow characteristics, the greater the difference in height, the less the passing ability of the concrete. The result can be expressed as, flow spread $S_j=(d_{max}+d_{perp})/2$

The J-ring blocking step B_J is calculated using equation,

$$B_J=\frac{(\Delta hx1+\Delta hx2+\Delta hy1+\Delta hy2)}{4}-\Delta hx0$$

V-Funnel test

Introduction

V-funnel test is used to determine the filling ability (flow ability) of the concrete with a maximum aggregate size of 20mm. The funnel is filled with about 12 litres of concrete and the time taken for it to flow through the apparatus measured.

Figure 3 V-Funnel Test

Interpretation of result

This test measures the ease of flow of the concrete; shorter flow times indicate greater flow ability. For SCC a flow time of 10 seconds is considered appropriate

L-Box test

Introduction

The test assesses the flow of the concrete, and also the extent to which it is subject to blocking by reinforcement. The apparatus consists of a rectangular-section box in the shape of an 'L', with a vertical and horizontal section, separated by a moveable gate, in front of which vertical lengths of reinforcement bar are fitted. The vertical section is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (H2/H1). It indicates the slope of the concrete when at rest.

Figure 4 L-Box Test

Interpretation of result

If the concrete flows as freely as water, at rest it will be horizontal, so H2/H1 = 1. Therefore the nearer this test value, the 'blocking ratio', is to unity, the better the flow of the concrete.

Test methods on concrete in hardened state

Compressive strength test on cubes

Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The cube moulds of the size 150mm × 150mm × 150mm as specified in the code had been used. Compression testing machine was used for performing the test. Figure 5 shows the test setup of compressive strength test.

Young's Modulus Test

Modulus of Elasticity is determined by subjecting a cylinder specimen to uni-axial compression and measuring the deformation by means of dial gauges fixed between certain gauge lengths. The dial gauge reading divided by gauge length will give the strain and load applied divided by area of cross-section will give the stress. In this study, the test specimen consists of concrete cylinder 15 cm in diameter and 30cm long were used.

Figure 5 Young's Modulus Test

Poisson's Ratio

Poisson's Ratio is the ratio between lateral strain to the longitudinal strain. It is generally represented by µ.It is found by using both compressometer and extensometer.

Poisson's ratio is determined by subjecting a cube or cylinder specimen to uni axial compression and measuring the deformation by means of dial gauge fixed between certain gauge lengths. The dial gauge reading divided by gauge length will give the strain and load applied divided by area of cross-section will give the stress. In this study, the test specimen consists of concrete cylinder 15cm in diameter and 30 cm long were used.

The extensometer gives the readings for the lateral strain while the compressometer gives the readings of the longitudinal strain. The diametrical strain characteristics of concrete are evaluated while undergoing compressive testing. Dial gauge has a least count of 0.00025mm.

Results and Discussion

- This section discusses the results obtained in the experimental studies. Tests performed on materials had already been discussed. Test were performed on the concrete mixes to the study the properties in fresh and hardened states.

Table 3 Workability Test results on SCC

Mix	Replacement level in %	Slump flow test		J Ring test	V-funnel test	L-box test
		Spread (mm)	T50 (sec)	Blocking step B_J(mm)	T_f(sec)	h_2/h_1
M1	0	725	2.32	10	9	0.916
M2	2.5% SF	680	2.45	10	9.54	0.843
M3	5% SF	661	2.48	9	10.11	0.820
M4	7.5 % SF	655	2.55	9	10.61	0.880
M5	10 % SF	611	3.81	9.5	11.55	0.940
M6	5 % FA	671	2.84	9	10.80	0.880
M7	10 % FA	677	2.80	9.5	9.74	0.930
M8	15 % FA	682	2.72	8	9.61	0.950

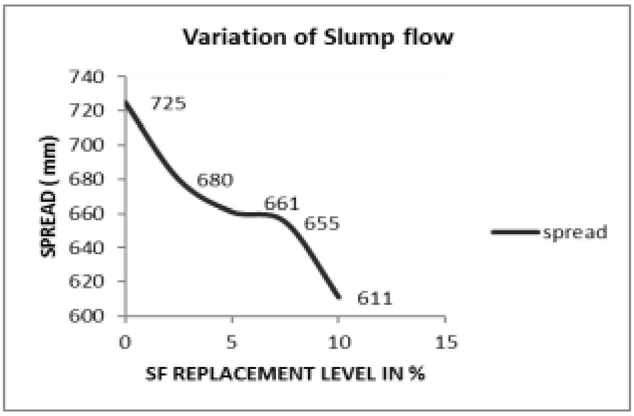

Figure 6 Variation of slump flow with increase in replacement of silica fume

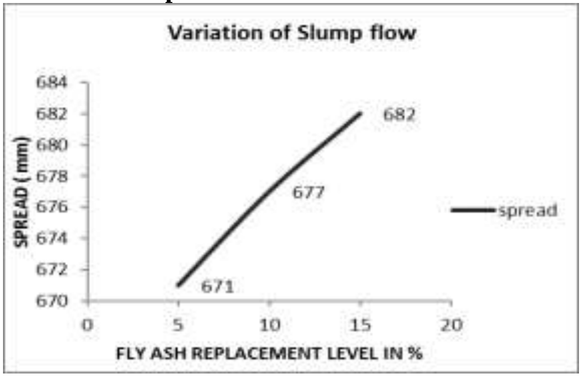

Figure 7 Variation of slump flow with increase in replacement of Fly ash

- The curves shows the variation of slump flow with incremental replacement of cement by silica fume in Figure 6 and Fly ash in Figure 7 .It can be noted from the above plots that the slump flow decrease with the addition of silica fume and increases with addition of Fly ash but remains within the permissible limit.

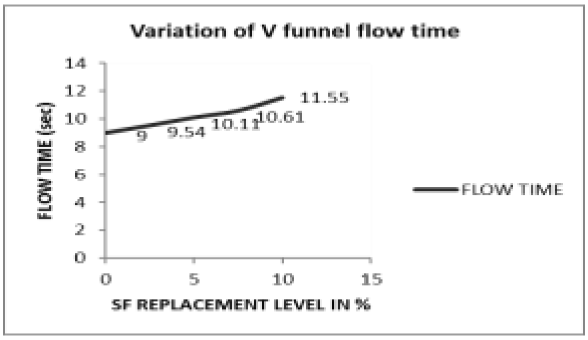

Figure 8 Variation of V funnel flow time with increase in replacement of SF

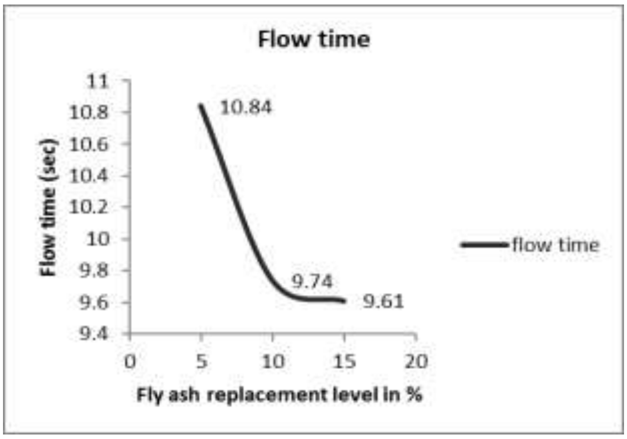

Figure 9 Variation of V funnel flow time with increase in replacement of FA

- The figure 8 and 9 plot represents the variation of V funnel flow time with increased addition of silica fume and fly ash. The curves show the increase in the time required for the complete discharge with increased addition of silica fume and reduction in the time in increased addition of fly ash.

Table 4 Compressive strength test results for SF and FA replaced SCC mixes

MIX	Replacement Level in %	Accelerated curing strength(MPa)	7 Day strength (Mpa)	28 Day strength(Mpa)
M1	0	42.11	43.34	61.79
M2	2.5%SF	42.40	43.20	62.48
M3	5%SF	42.38	43.87	64.85
M4	7.5%SF	42.70	43.90	64.95
M5	10%SF	43.70	44.14	65.60
M6	5% FA	43.20	42.70	62.20
M7	10%FA	42.10	43.30	63.40
M8	15%FA	43.40	45.10	63.90

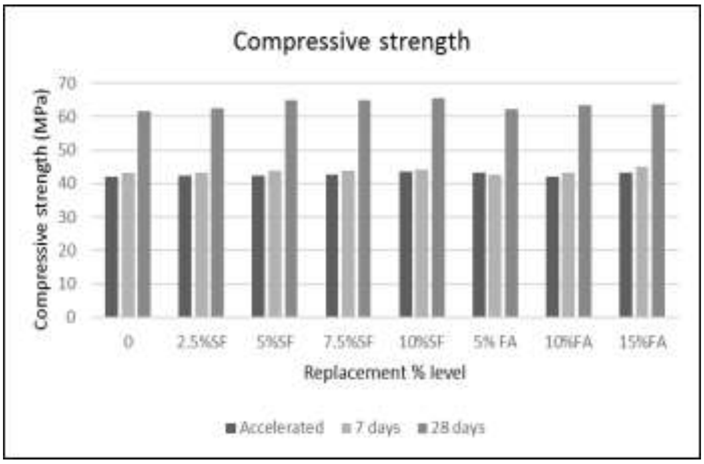

Figure 10 Compressive strength variations for SF and FA replaced SCC mixes

- The chart 10 shows the variation of compressive strength of the different mixes. The variation of strength with incremental replacement shows fluctuation in accelerated curing and 7 day strength, but the variation is steady for 28 days. It can be seen that the highest compressive strength obtained is for the replacement of 10% silica fume and 15% replacement level of Fly ash.

Table 5 Young's modulus and Poisson's ratio results for SF and FA replaced SCC mix

MIX	Young's Modulus (GPa)	Poisson's ratio
0	30.13	0.273
2.5%SF	32.06	0.248
5%SF	32.86	0.250
7.5%SF	33.07	0.224
10%SF	34.41	0.200
5%FA	30.52	0.268
10%FA	31.73	0.251
15%FA	32.98	0.221

- The Young's modulus and Poisson's ratio of various mixes of SCC projected in Table 5. The Value of Young's modulus goes on increasing with increase in replacement of silica fume and fly ash and Poisson's ratio decreases with increase in replacement of silica fume and fly ash.

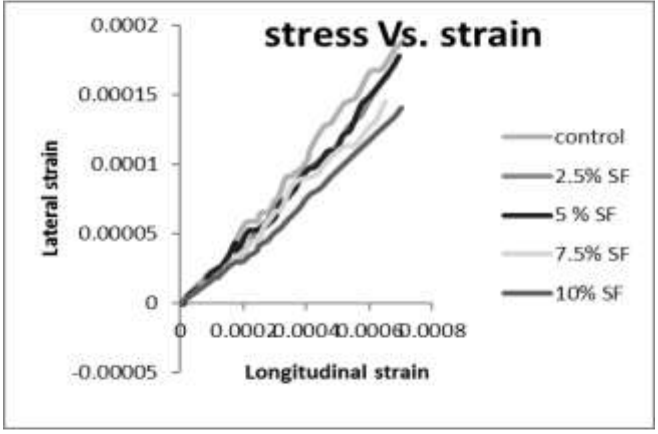

Figure 11. Stress Vs. strain curves for SF replaced SCC

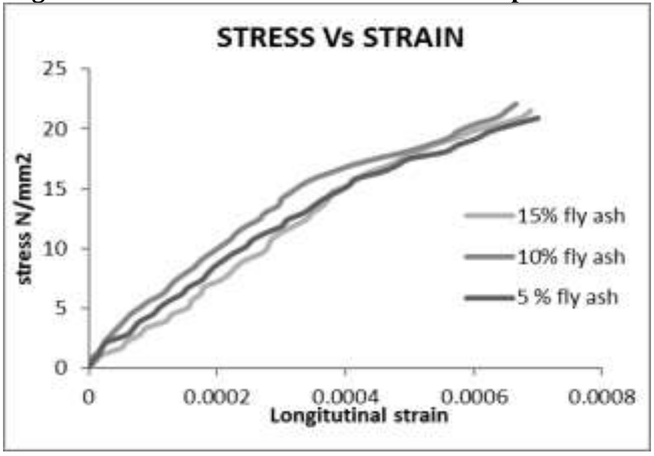

Figure 12. Stress Vs strain curves for FA replaced SCC

- Figure 11 and 12 shows the stress strain curve for SF and FA replaced SCC mixes.

Conclusion

Based on the experimental investigations, the following conclusions are arrived,

- SCC with silica fume (SF) exhibited satisfactory results because of its smaller particle size and larger surface area. The spread in slump flow is 680 mm for 2.5 % replacement of SF, which is the maximum. Partially replacement of cement by SF decreases the filling, flowing, passing ability. But all the mixes are within the EFNARC standard.
- The maximum slum flow is 682 mm and V-funnel flow time is 2.72 sec for 15% replacement of fly ash. The results of L box test shows that increase in fly ash increases the passing ability. The optimum value of fly ash was found to be 15%.Increase in fly ash content beyond that shows decrease in filling, flowing

and passing ability. Thus concluded that addition of fly ash in smaller quantity increases the amount of workability.

- The presence of SF improved both early ages and long-term compressive strength. It can be seen that the highest compressive strength of 65.6 Mpa obtained for the replacement of 10% silica fume.
- For fly ash replaced SCC, the maximum value of compressive strength achieved is 63.90 MPa for 15% fly ash replacement. The value of compressive strength is increasing gradually when increasing the percentage of replacement of fly ash up to 15 %, beyond that strength may reduce, because higher percentage of fly ash replacement results in lowering of cement content.
- The young's modulus and Poisson's ratio for 10% SF replaced SCC is 34.41GPa and 0.2 respectively. The young's modulus and Poisson's ratio for 15% fly ash replaced SCC is 32.98 GPa and 0.221 respectively.
- The compressive strength of both SF and fly ash replaced SCC are merely equal. Addition of fly ash as a replacement of cement content is more economical for making self-compacting concrete as the fly ash is available freely.

References

1. Hajime Okamura and Masahiro Ouchi. Development of self-compacting concrete.2003; Journal of Advanced Concrete Technology. Vol.1; pp. 5-15.
2. BertilPersson. Comparison between mechanical properties of self-compacting concrete and the corresponding properties of Normal Concrete.2003; Cement and Concrete Research. Vol.31; pp. 193-198.
3. Domone P.L. A review of hardened mechanical properties of self-compacting concrete. 2007; Cement& Concrete Composites. Vol.29; pp. 1-12.
4. Jagadish Vengala and Ranganath R. V. Mixture proportioning procedures for self-compacting concrete.2004; The Indian Concrete Journal, August; pp. 13-21.
5. Anirwan Sengupta and Manu Santhanam. Influence of Aggregate characteristics on uniformity of SCC.2009; The Indian Concrete Journal.June; pp. 50-60.
6. ZordanGrdic, IvaDespotovic, Gordana Toplicic Curcic. Properties of self-compacting concrete with different types of Additives.2008; Architecture and Civil Engineering. Vol.6; pp.173-177.
7. Khayat K.H. Workability, Testing, and performance of self-consolidating concrete.2009;ACI materials Journal. May-June; pp.346-353.
8. Wenzhong Zhu and Peter J.M Bartos. Permeation properties of self-compacting concrete.2003;Cement and Concrete Research. Vol.33; pp.921-926.
9. Subramanian S. and Chattopadhyay, D. Experiments for mix proportioning of self-compacting concrete.2002;The Indian Concrete Journal. January; pp.13-20.
10. Karen L Scrivener and James Kirkpatrick, R. Innovation in use and research on cementitious material.2008*; Cement and Concrete Research*. Vol.38, pp.128-136.
11. Okamura and Ozawa. Mix design for self-compacting concrete.1995;Concrete Library of JSCE.June; pp.107-120.
12. Bouzoubaa N. and Lachemi M. Self-Compacting Concrete incorporating high volumes of class-F fly ash preliminary results.2001; Cement and Concrete Research. Vol.31; pp.413-420.
13. Nan Sua, Kung-Chung Hsub, His-Wen Chai. A simple mix design method for self-compacting concrete.2001;Cement and Concrete Research, Vol.31; pp.1799-1807.
14. Janusz Szwabowski and Beata Lazniewska-Piekarczyk. Air Entrainment problem in Self-Compacting Concrete.2009;Journal of Civil Engineering and Management. Vol.15; pp.137-147.
15. Domone P.L. Self-Compacting Concrete: An analysis of 11 years of case studies.2006; *Cement and Concrete Composites*. Vol.28; pp.197-208.
16. Hajime Okamura. Self- Compacting High-Performance Concrete.1997;Concrete International, July; pp. 50-54
17. Wenzhong Zhu, John C Gibbs, and PeterBartos J. M. Uniformity of in situ properties of Self-Compacting concrete in full-scale structural elements.2001;Cement and Concrete Composites. Vol.23, pp.57-64.