Experimental Study of Self Compacting Concrete using Portland Cement and Mineral Admixture

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Abstract:- Self-Compacting Concrete is generally termed as very effective for congested spaces, having dense reinforcement and narrow formwork. A lot of researches and executed construction activities with SCC indicate its unique properties of self-flowing ability, passing ability and self-compaction with its own weight. Though to obtain these fresh properties of SCC, the mix should have optimum viscosity so that in the process of flow and passing through congested areas, the paste and aggregates do not separate from each other. Fresh properties of SCC such as segregation resistance, viscosity, flow ability and passing ability largely depend upon paste thickness, which is again governed by type of mineral admixtures (i.e. fly ash, GGBS, Micro silica etc.) used as binders, water binder ratio and chemical agents such as Viscosity modifying agents, admixtures/superplasticisers. Objective of this research paper is to study the fresh and hardened properties of SCC if designed with Ordinary Portland Cement (PPC) Moreover the external addition of mineral admixture fly ash with OPC was also considered to produce more cost effective and environment friendly SCC.

Keywords:- *Self Compacting Concrete, Design Mix, Flow Ability, Passing Ability, Viscosity.*

I. INTRODUCTION

SCC has extended the global recognition of construction industry in last two decades. Self-Compacting Concrete has unique ability to flow with its own weight and due to this SCC can fill the congested farm work spaces, dense reinforcement and flow easily through narrow spaces without vibration. The fresh properties of SCC mix can be determined by tests such as slump flow, V Funnel, J-Ring, L -Box and U-Box. These tests are conducted to evaluated the passing ability, filling ability and flowing ability. SCC behaves as visco-plastic fluid or Binghum fluid. Therefore, the rheological properties of paste, mainly plastic viscosity and yield stress are of paramount importance and should be studied thoroughly. Studies indicate that, with respect to conventional concrete shear yield stress of SCC observed on lower side. However large variations in plastic viscosity are also pragmatic.

The Self Compacting Concrete (SCC) has large variations in its fresh properties if compared to conventional concrete. When comparted to SCC, the tests conducted for fresh properties of conventional concrete are very few i.e. slump measurement, air content, compaction factor, Vee-Bee Consistency tests etc. Contrary to conventional concrete there are number of mix design methods available for SCC. Majorly the methods direct towards higher packing density of aggregate matrix and optimize the paste volume to fill the void content and generate the excess paste volume to provide the desired mobility to SCC mix. The hardened properties of SCC, such as compressive strength, tensile strength etc. are more or less same as conventional concrete.

In order to utilize the mineral admixtures for improvement in fresh properties, Fly Ash, GGBS, Micro Silica are widely used. The usage of mineral admixtures may result into lower early strength but 28 days or later strength are higher for these composite mixes.

A number of previous studies have been conducted to investigate the effect of FA, GGBS on the properties of the SCC, it was found that the incorporation of FA, GGBS improved the rheological properties, appreciably lessened the formwork lateral pressure of the SCC, greatly prolonged the setting times of cement pastes (Ponikiewski and Golaszewski., 2014; Kim et al., 2010; Erhan et al., 2009).

II. EXPERIMENTAL STUDY

1.1 Materials

1.1.1 Cement

In this study Ordinary Portland Cement of 43 grade is used, which conforms the physical and chemical requirements as per IS 269-2015 (Part-1). Physical and chemical properties are presented in Table-1.

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Table-1: Physical and Chemical properties of OPC and Fly ash

Chemical Requirements for Cement		
S. No.	**Parameters**	**OPC**
1.	Loss of Ignition, % by weight	2.30
2.	Insoluble residue, % by weight	3.50
3.	Ratio of percentage of lime to percentages of silica, alumina and iron oxide, when calculated by the formula	0.89
4.	Ratio of percentage of alumina to that of iron oxide, Min	0.27
5.	Magnesium Oxide (as MgO), % by weight	1.58
6.	Total Sulphur Content as Sulphuric Anhydride (SO_3), % by weight	2.01
7.	Total Chlorides	0.01

Physical Properties		**OPC**	**Fly Ash**
1	Specific Gravity	3.11	2.20
2	Blaine's Fineness (m^2/kg)	275	16700
3	Normal Consistency (%)	31	Confirms the suitability requirements to be used in concrete as per IS 3812:2013 (Part-1).
4	Compressive Strength (MPa)		
	3 days	24.20	
	7 days	35.20	
	28 days	44.57	
5	Initial Setting time (minutes)	140	
6	Final Setting time (minutes)	290	

1.1.2 Mineral Admixture

Fly ash was used as mineral admixture for present study. The physical properties of Fly ash are presented in Table-1.

1.1.3 Aggregates

River sand (Zone- II) and natural crushed stone (max. aggregate size 10 mm) were used as fine and coarse aggregate. Gradation Curve for coarse and fine aggregate is presented as Fig.1. Physical properties of fine and coarse aggregate are presented in Table-2.

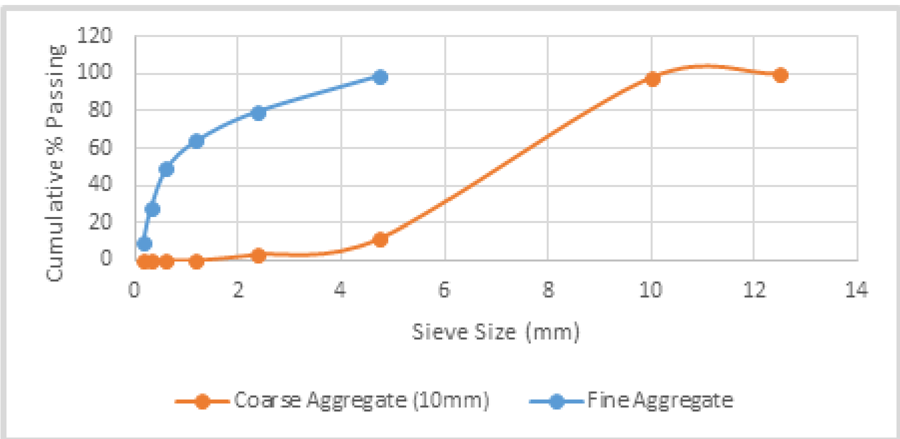

Fig.1: Gradation of Coarse and Fine Aggregate

Table-2: Physical properties of fine and coarse aggregate

Physical Properties	**Fine Aggregate**	**Coarse Aggregate**
Impact Value (%)	-	19.70
Crushing Value (%)	-	23.70
Abrasion Value (%)	-	22.45
Water Absorption (%)	1.52	0.95
Specific Gravity	2.70	2.71

1.1.4 Super plasticizer

PC based high-performance super plasticiser Master Gillenium Sky, which is free from chloride and low alkali content has been used for production of self compacting concrete.

1.1.5 Design Mixes

In the present study total six nos. of SCC trials were conducted for M35 grade of concrete. These trials consist 03 nos. of controlled SCC mixes and 03 nos. of mixes having mineral admixture viz. fly ash in addition. The binder content for these trials ranges from 415 kg to 615 kg, water powder ratio ranges from 1.01 to 1.39. The maximum coarse aggregate content used is 755 kg. The weight ratio of fine aggregate to total aggregate varies from 56.50 % to 60.00 %. The details of trial mixes are given in table-3. To determine the properties of fresh SCC various tests as per EFNARC 2005 standard were conducted prior to casting of test specimens. Curing of test specimens were ensured as per IS 516.

Table-3: Details of SCC design mixes

Description	CT 1A	CT 1B	CT 1C	MA 1D	MA 1E	MA 1F
Cement (Kg)	415	425	450	515	480	455
FA (Kg)	981	980	970	950	966	942
CA (Kg)	755	750	735	637	644	711
Water (Litre)	202	201	200	198	194	190
Admix (litre)	4.2	4.3	4.6	5.5	5.4	5.03
Fly Ash (Kg)	0	0	0	100	130	155

III. TESTS METHODS FOR FRESH PROPERTIES OF SCC

As per EFNARC guidelines fresh properties of SCC may be determined by number of laboratory investigations such as Slump Flow, L-Box, U -Box, V-Funnel, J-Ring, Segregation Resistance and Box-test etc. In the present study Slump Flow, L Box, U Box and V Funnel were conducted for evaluation of fresh properties of SCC.

3.1 Slump Flow

Slump Flow measurement indicates about the flowing ability of SCC. As per EFNARC guidelines for normal reinforcement and semi congested area of formwork slump flow value between 550mm-650mm is considered within acceptable limits. Studies show that for a given powder content, slump flow increases with increase in water-powder ratio. During the test special attention should be given to the mixes which are bleeding. With optimum dosage of Viscosity modifying agent (VMA) the viscosity of these mixes can be improved and bleeding can be controlled.

The slump flow value calculated as the mean diameter value of SCC after lifting the standard slump cone and T500 was represented as the time elapsed in between lifting of slump cone and when SCC first touched the 500mm circle mark on circular base plate.

3.2 V Funnel

The V-funnel passing time is very crucial as it indirectly indicates about the viscosity of the paste. The viscosity of paste largely depends upon the water content. Hence while performing this test the adjustment in water content should be made appropriately. Otherwise, the mixes with higher powder content and low water-powder ratio may get stacked into the narrow opening of funnel bottom. To analyze the viscosity of the mix, the variations of V-funnel passing time may be studied with respect to the water content.

3.3 L-Box

This test indicates about the passing ability of self-compacting concrete through narrow reinforcement. The height ratio of SCC once stable after flow is the determining parameter in this test. Many studies were conducted in past to establish the co-relation between L-box and other parameters such as W/P, paste volume, water content. However, few of the researches could not establish any co-relation between L-box value and other parameters.

3.4 U-Box

The U-box test or sometimes called box test signifies about the filling ability of self-compacting concrete. The deciding parameter in case of U-box test is the height difference in between two chambers. The test requires a SCC mix having filling and passing ability so that it can lift up through the congested reinforcement and narrow formwork.

IV. MECHANICAL PROPERTIES

4.1 Compressive Strength

Cube specimens of 150mm size were prepared during each trial. Compressive strength test for cube specimens were carried out at the age of 7days and 28days as per IS 516. The Compressive strength testing and curing arrangements for cube specimen are shown in Fig.2 below:

Fig.2 : Compressive Strength testing and curing arrangements of cube specimen (150mm)

V. RESULTS AND DISCUSSION

5.1 Fresh Properties

The Slump flow variations with respect to paste volume were studied and shown in Fig.3 below. The graph shows a good corelation between the two parameters, as with increase in paste volume, slump flow value is increasing in a linear pattern.

The value of T_{500} shows the reverse trends as the flow ability of SCC got increased it took lesser time to achieve the circle marked 500mm on base plate. The corelation between T_{500} passing time and slump flow (mm) in shown in Fig.4. The test results indicate that the mixes with higher slump flow are having lower T_{500} time. The value also indicates about the viscosity, as a mix having lower viscosity initially flows faster but stops intermittently rather than mix having higher viscosity flows slower initially but spreads into a larger diameter with lower T_{500} time.

Fig.3: Relationship between slump flow & paste volume

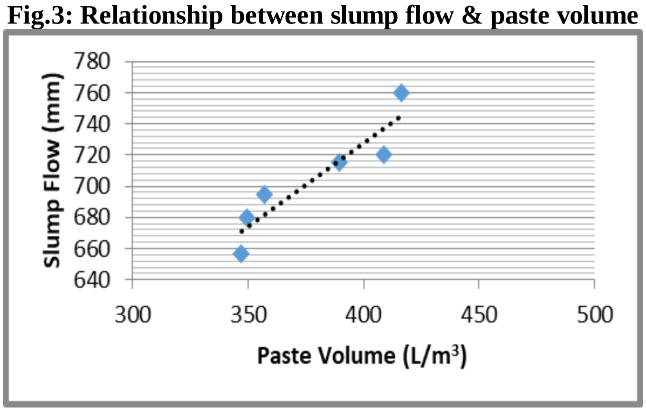

Fig.4: Relationship between slump flow and T_{500}

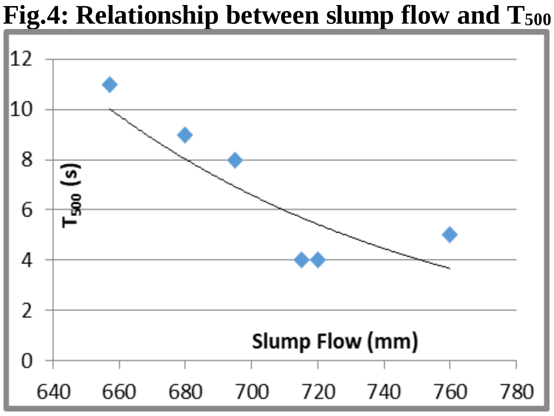

Fig.5 the V-funnel time shows that with an increase in paste volume and with optimum quantity of viscosity modifying agent, the overall viscosity and filling ability of SCC has been improved. The SCC mix thus took lesser time to fall through the V-funnel. During the trials variation in V-funnel value was ranging between 25 sec and 11 sec. The value of 11 seconds indicates viscosity class VS2 as per EFNARC classification. However, in few of the trials the v funnel got chocked and test could not be completed. The mix which are having higher powder content and lower water-powder ratio are observed having more tendency of chocking through the funnel bottom.

In Fig.6 the resulting value of L box test, which is conducted to analyse the passing ability of the mix was varied from 0.68 to 0.85 with the variation of paste volume from349.6 litre/m^3 to 416.52 litre/m^3. The passing ability value of 0.85 shows passing ability class PA2, which is suitable for structures with a gap of 60mm to 80mm as per the European Guidelines for Self-Compacting Concrete.

Fig. 5: Relationship between v-funnel and paste volume

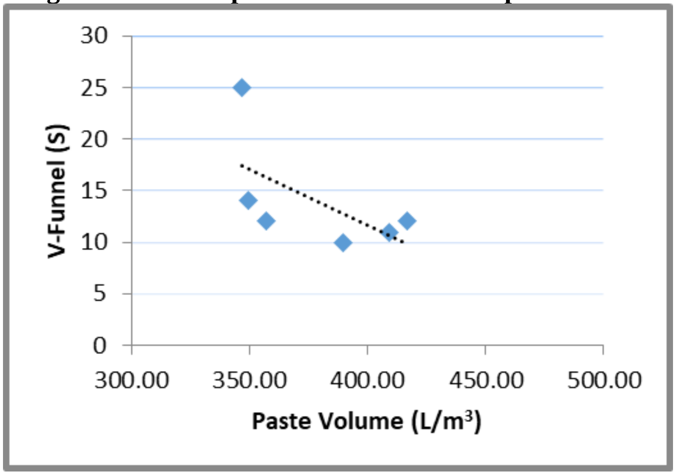

Fig. 6: Relationship between L box and paste volume

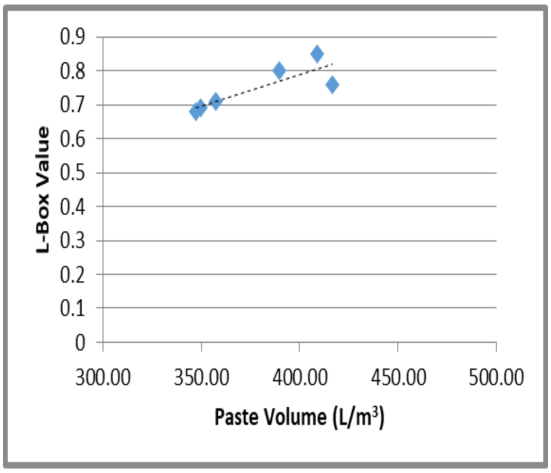

Fig.7 (clockwise from top left): Laboratory Investigation for Slump flow, U box, V funnel and L box during trials

5.2Mechanical Properties

Compressive Strength

Similar to the conventional concrete compressive strength of SCC also depends upon the water-powder ratio. The relationship between water to powder ratio and 28 days compressive strength is shown in Fig. 5. The graph shows a good corelation, with highest compressive strength at water-powder ratio of 0.95 and lowest compressive strength at water to powder ratio of 1.39. The variation of compressive strength with paste volume is shown as Fig.6.

Cube specimens were tested for 7 days and 28 days compressive strength. The 28 days target strength for M35 grade of SCC was required to be achieved in conjunction with the conformity to fresh engineering properties. The cement content used in trials, varies from 415kg to 515kg, however the 28 days compressive strength varies from 35.13 MPa to 51.75MPa. In case of controlled trial mixes, the desired fresh properties and compressive strength were achieved with a powder content of 450 kg and water powder ratio of 1.27.

For desired target strength and to achieve fresh properties of SCC, the optimum quantity of OPC cement used was 455 kg, which was used with 155 kg of external mineral admixture fly ash. It was also observed that the trial mixes having external fly ash addition, achieved the fresh properties of SCC due to enhanced paste volume and improved powder content.

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Fig.8: Relationship between compressive strength and water powder ratio

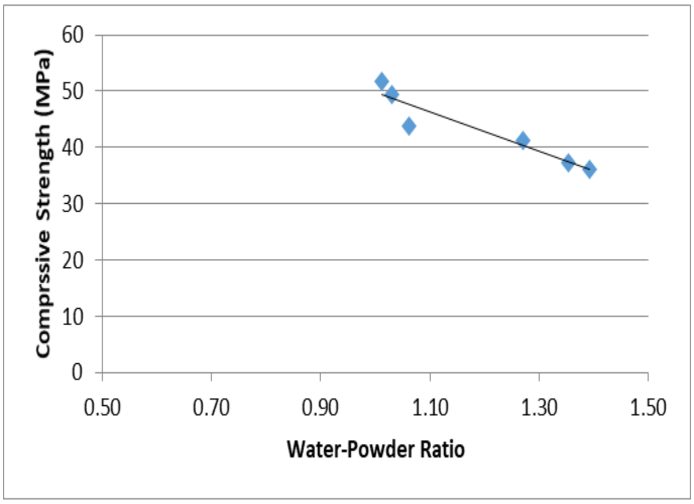
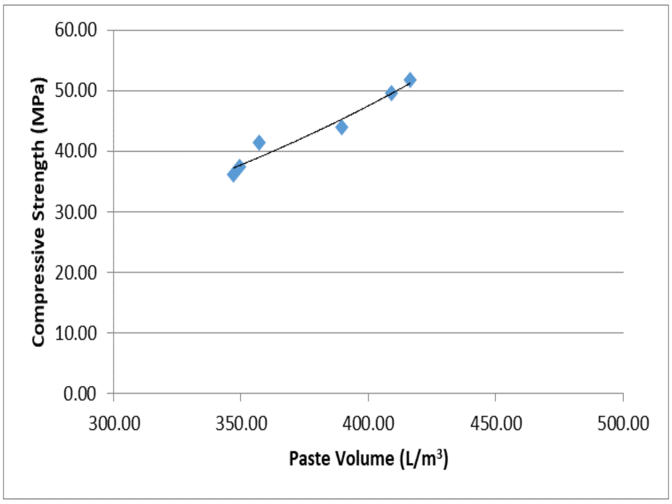


Fig.9: Relationship between compressive strength and paste volume



VI. CONCLUSION

The conventional SCC mixes are considered as OPC with mineral admixtures such as fly ash, GGBS, Micro Silica etc. A number of research programs have been conducted globally to optimise the conventional mixes but these mixes are less environment friendly due to higher CO_2 emissions from cement production units as well economy is also questionable due to higher OPC content.

In this study, efforts were made to establish a design mix of SCC which not only fulfils the mechanical properties but also conforms to requirements of fresh properties. To summarize the test results, it can be said that powder content was increased by increasing the cement content and with external addition of fly ash. In both cases the fresh properties of SCC were achieved however higher cement content was required to conform the fresh properties in binary mix of OPC and fly ash and thus mechanical properties such as 28 days compressive strength of controlled mix were on higher side compared to binary mixes.

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