A PAPER ON SELF- COMPACTING CONCRETE WITH HIGH LEVELS OFFLY ASH

1Eisirigayala Gnaneswar, 2K.Shammad basha,3M.mallikarjuna
1M.Tech Student, 23Assistant Professor
DEPT OF CIVIL ENGINEERING
SVR Engineering College, Nandyal

ABSTRACT
Self- compacting concrete (SCC) was developed in 1980s in Japan[1] This investigation focuses on the workability characteristics of SCC and also the strength parameters. The cement used for the study is 43 Grade Ordinary Portland cement and is partially replaced by 50% and 75% of flyash. Based on the guidelines of European FederatioN of producers And contractors of specialist pRoducts for struCtures (EFNARC)[2], the mix proportions have been chosen and in this study the cement content alone is varied without varying the aggregate content and the water- powder ratio is kept as 0.4 throughout the study. Water reducing admixture (WRA) and viscosity modifying admixture (VMA) are used in this study in order to achieve the workability characteristics.

Keywords: Self-compacting concrete; Super plasticizer; Flyash; Workability.

1. INTRODUCTION

To achieve a high flow rate and to avoid obstruction by closely spaced reinforcement, Self Compacting Concrete is designed with limits on the nominal maximum size of the aggregate, the amount of aggregate and aggregate grading. However when the flow rate is high, the potential for segregation and loss of entrained air voids increases. These problems can be alleviated by designing a concrete with a high fine to coarse aggregate, low water-cementitous material ratio, good aggregate grading and high range water reducing admixture, viscosity modifying admixture [3].

Self Compacting Concrete which flows under its own weight and fills into every corner of form work and passes through even restricted spacing of reinforcement, without the need for vibration. The transition zone in SCC is free of micro cracks, in contrast to the normal concrete.[4] In order to get a homogeneous and stable mix in SCC a large amount of powder element plus pozzolanic additions is required so that neither water nor slurry separates out.

2. MATERIALS AND METHODS

The ingredients used for the study were the same as that used for conventionally vibrated concrete except the usage of mineral and chemical admixtures. In order to achieve SCC, optimum proportions are selected considering the characteristics of cementitious materials, aggregate quality, paste proportions, aggregate - paste interaction, type of admixtures, dosage and mixing. Selection of type of cement mainly depends on the specific requirements of concrete. It determines strength and properties of fresh and hardened concrete. For this study Ordinary Portland cement of 43Grade with specific gravity 3.15 was used. River sand passing through 4.75mm sieve with fineness modulus of 3.416 and specific gravity 2.57 which falls under grading zone II has been used as fine aggregate for the entire investigation. The coarse aggregate is the strongest and the least porous component of concrete. Crushed granite aggregate with a maximum nominal size of less than 20mm and bulk density 1680 Kg/m^3 and specific gravity of 2.83 were used throughout the investigation.

2.1 Mineral Admixture

Fly ash has been shown to be an effective addition for SCC providing increased cohesion and reduced sensitivity to changes in water content. However, high levels of fly ash may produce a paste fraction which is so cohesive that it can be resistant to flow.Flyash (class F) obtained from Mettur Thermal Station is used as a partial replacement of cement up to 75%. The properties of flyash are as follows. Specific Gravity of Fly Ash (Class F) = 0.8. Main Chemical composition of fly ash is (i)Silica-54.5% (ii) Alumina-33.54% (iii) Iron Oxide- 2.69%

2.2. Chemical admixtures

A high performance concrete super plasticizer (SP) based on modified polycarboxylic ether to reduce water-powder ratio for the required workability is considered to be apt for the present investigation. The physical properties of Glenium B233 obtained from BASF construction chemicals are (i)Relative Density is 1.09 (ii)p^H= 7 (iii) Yellowish liquid.

Glenium B233 is a ready to use admixture that is added to the concrete. The maximum effect is achieved when it is added after the addition of 50 to 70 % of the water. For the same workability SP may be used as water reducer which, in turn, will increase the early strength as well as the 28 day value.[5] VMA is added along with SP since it is considered as a combined type of SCC which is more robust than mix without VMA [6]. Glenium Stream 2 is a VMA which is used in combination with the Glenium B233 in order to guarantee maximum efficacy. Glenium Stream 2 consists of a mixture of water-soluble polymers which is adsorbed onto the surface of the cement granules, thereby changing the viscosity of the water and influencing the rheological properties of the mix. Glenium Stream 2 has a dual action. It decreases viscosity and maintains internal cohesion of the concrete during casting and the polymer chains of the admixture arrange themselves in the direction of flow of the mix. It resists segregation due to aggregation of the polymer chains when the concrete is not moving. Glenium Stream 2 is Colorless liquid, its Relative Density is 1.01, and pH is 8.

3. EXPERIMENTAL PROGRAM

An SCC optimized from preliminary investigations was chosen as the starting concrete. The investigation covered the effects of fluctuations of the strength of SCC related to the variations in the dosage of chemical admixtures on the time-dependent behavior of the slump flow, the funnel speed and the height of rise in the box test. The changes in workability characteristics caused due to this variation of plasticizer dosage were also investigated and given in the table 3. The composition of the concrete is shown in Table1. The concrete components were mixed in the sequence – aggregate, cement and fly ash, 2/3 mixing water and 1/3 mixing water with plasticizer.

Table 1 Typical range of SCC mix composition

Constituent	Typical range by mass (kg/m^3)	Investigation 1	Investigation 2
Powder	380 – 600	500	400
Water	150 – 210	200	200
Coarse aggregate	750 – 1000	900	900
Fine aggregate	48 – 55 % of total aggregate weight	50 %	50 %

Self-compactibility test method stipulations are not universally accepted rules. Degree of tolerance depends on the engineering judgment, material type and variety.[7] The following tests were then carried out at fresh state to study the workability characteristics of SCC: - Slump flow test, Associated time T_{500} that the SCC requires to flow to a diameter of 500 mm, V – funnel test, L - box test, Slump flow with J-ring combination test, U – box test [8].The tests were repeated for each and every mixes with different chemical admixture dosage by keeping the water-powder ratio constant through out the investigation. . Immediately after that the fresh concrete tests on the SCC, the concrete cubes, cylinders and prisms are cast for studying the hardened concrete properties. Compressive strength test, Split tensile strength test, Flexural strength test and Modulus of elasticity test were carried out at hardened state of SCC

The mix proportions taken for the investigation is based on the EFNARC [2] guidelines. The investigation is carried out by varying the powder content and the chemical admixtures dosage. In the first investigation the powder content has been kept as 500 kg/m^3 and 21 mixes (CF1- CF21) have been tested in order to achieve the SCC characteristics. Then, the powder content is reduced to 400 kg/m^3 and again its fresh state characteristics are studied by various mixes (S1 – S7). Table 2.gives the details of the mix compositions with different chemical admixture dosage taken for the investigation.

Table 2 Mix composition taken for the investigation

Mix no.	Cement (kg)	Fly ash (%)	Fly Ash (kg)	Sand (kg)	Coarse Aggregate (kg)	Water (kg)	Glenium B233 (%)	Glenium Stream2 (%)
CF3	6.25	50	6.25	22.5	22.5	5	0	0
CF4	3.125	75	9.375	22.5	22.5	5	0	0
CF7	6.25	50	6.25	22.5	22.5	5	0.50	0
CF8	3.125	75	9.375	22.5	22.5	5	0.50	0
CF20	6.875	50	6.875	24.75	24.75	5.5	5	0.30
CF21	3.4375	75	10.3125	24.75	24.75	5.5	5	0.30
S5	5.5	50	5.5	24.75	24.75	5.5	5.5	0.4
S6	2.75	75	8.25	24.75	24.75	5.5	5.5	0.4

Various workability tests as discussed earlier are carried out for the mix compositions obtained and workability results are shown in Table 3.The classes for the SCC mix obtained from the workability test results are shown in Table 4 as per EFNARC [2].

The hardened concrete test results for the SCC mixes obtained are given in the Table 5. The typical stress – strain curve has been in given in Fig 1 and the various hardened concrete test results obtained are compared for different mixes in Table 5. The different values of Modulus of Elasticity are compared in Table 5 and they are almost directly proportional to Hardened concrete results. Comparison of Slump Spread values has been shown in Fig.2.

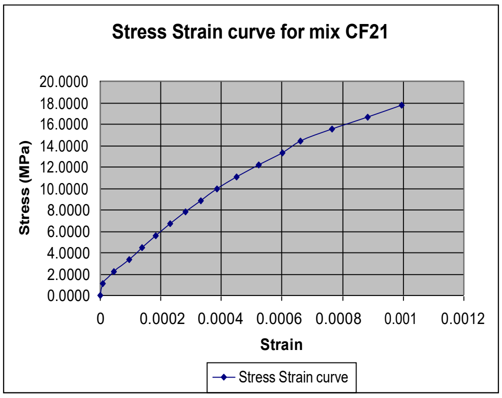

Fig 1 Typical Stress Strain Curve

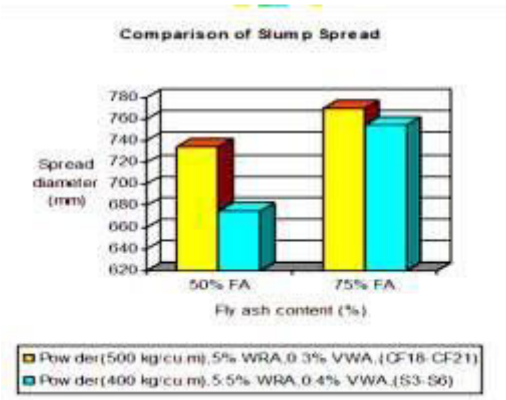

Fig 2. Comparison of Slump Spread

The SCC mix proportions that were obtained using EFNARC [2] are capable of achieving the SCC characteristics with the replacement of cement by fly ash. More than 25 mixes were carried out to examine the SCC characteristics for developing High Volume Fly ash Self Compacting Concrete (HVFSCC) mixes for Indian conditions. These mixes were proportioned with total powder (cement plus fly ash) contents of 500 kg/m^3 and 400 kg/m^3.

Cement replacement level ranging from 0 to 75 % of fly ash and the water/powder ratio as 0.4 for 500 kg/m^3 and 0.5 for 400 kg/m^3 were considered in the study. Coarse and fine aggregate contents are kept as 900 kg/m^3 throughout the investigation and the chemical admixture dosage is varied in order to obtain the SCC characteristics.

The optimum dosage of the Glenium B233 is found to be 5% for mixes CF18 to CF21 and 5.5% for mixes S3 to S6 when combined with Glenium stream 2 of 0.3% for mixes CF18-CF21 and 0.4% for mixes S3-S6. The test results of the workability investigations are summarized in Table 3. Based on the test results, various classes of SCC as per EFNARC [2] are shown in Table 4. It is observed that mixes CF19, CF20, CF21, S5 and S6 satisfy all the classes of SCC. Also the results clearly explain that the high volume of fly ash replacement in cement improves the workability characteristics of SCC.

Table 3 Workability test results

Mix no.	Slump Spread (mm)	T500 (sec)	J ring height (mm)	Time for V funnel(sec)	Filling Height U box (mm)	L box h2/h1
CF3	-	-	-	-	-	-
CF4	-	-	-	-	-	-
CF7	280	-	-	-	-	-
CF8	270	-	-	-	-	-
CF20	735	2.03	83	6	330	0.8
CF21	770	1.7	59	5.25	331	0.81
S5	675	4.1	78	8.5	312	0.81
S6	755	2	42	5	340	0.85

Table 4 Various classes for the SCC mixes

Mix No.	Slump flow class	Viscosity class	Passing ability class
CF20	SF2	VS1/VF1	PA2
CF21	SF3	VS1/VF1	PA2
S5	SF2	VS2/VF1	PA2
S6	SF3	VS1/VF1	PA2

The hardened concrete results are summarized in Table 5. It is observed that the replacement of cement with fly ash as carried out has decreased the strength parameters at 28 days. The average 28 days compressive strength is varied in the range of 15 to 30 MPa. .

Table 5. Hardened concrete test results

Mix. No	Compressive strength(MPa)	Split tensile strength(MPa)	Flexural strength(MPa)	Young's modulus(MPa)
CF20	25	2.5	4.3	19703
CF21	20	1.9	3.06	17794
S5	21	2.6	2.9	23342
S6	17.3	1.8	2.85	20229

From the above discussion, it was found that it is difficult to achieve the self compacting properties without the fly ash content and chemical admixtures. Table 6 gives the details of the Mix proportions for the required strength.

Table 6. Mix proportions for required strength

Mix Ratio	W/P ratio	WRA (%)	VMA (%)	Replacement of cement by fly ash (%)	Proposed Compressive Strength (MPa)	Obtained compressive strength (MPa)
1 : 1.8 : 1.8	0.4	5	0.3	25	30	27.9
1 : 1.8 : 1.8	0.4	5	0.3	50	25	25
1 : 1.8 : 1.8	0.4	5	0.3	75	20	20
1 : 2.25 : 2.25	0.5	5.5	0.4	50	20	21

4. CONCLUSIONS

Based on the investigation conducted following conclusions are drawn.

To achieve the self compacting properties the mix should contain more fly ash, that is, 25 to 75 % replacement of cement by flyash and the WRA should be used along with VMA.

Cement can be replaced by fly ash up to 75% in order to obtain the SCC characteristics with 28 days compressive strength of 20 Mpa (S6 Mix for which the ingredients are given in Table 2)

It is also possible to obtain the SCC characteristics by reducing the powder content as low as 400 kg/m^3 with a little increase in VMA dosage (0.3% to 0.4% S3 to S6 mixes) or no increase in VMA dosage(0.3% only S1 to S2 mixes)

The visual assessment of various mixes showed that VMA is necessary for achieving SCC characteristics without segregation for both the powder contents 400kg/m^2(CF 16 to CF 21)as well as 500kg/m^3(S1 to S6)

In this investigation, the best self compacting properties were obtained for a fly ash replacement of 75 percent and a fine aggregate content of 50 % of the total aggregate, using a 43 grade ordinary Portland cement. The water-powder ratio was 0.4.

As the percentage of fly ash increases, the workability properties of SCC are increased with reduction in strength (CF18 to CF21 as well as S3 to S6 mixes)

SCC mix requires high powder content (500 kg/m^3), lesser quantity of coarse aggregate (900 kg/m^3), high range SP (5 to 5.5% of cementitious material) and VMA (0.3% to 0.4% of cementitious material) to give stability and fluidity to the concrete mix.

It is possible to achieve strengths varying from 15 – 30 Mpa when the cement is replaced by high volume of fly ash.

The optimum dosage of the Glenium B233 is found to be 5% for mixes CF18-CF21 and 5.5% for mixes S3-S6 when combined with Glenium stream 2 of 0.3% for mixes CF18-CF21 and 0.4% for mixes S3-S6.

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