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PERFORMANCE OF SCC BY PARTIAL REPLACEMENT OF CEMENT BY MINERAL ADDITIVES

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Abstract: An experimental study was executed to review the effectiveness of mineral additives over the strength and flexural performance of SCC mix trials subjected to monotonic loads. RCC beam specimens of desired grade were casted in the present study. To assess the fresh properties of concrete slump flow, U-Box, V-Funnel and L-Box test were done and for hardened characteristics compressive as well as tensile strength tests were performed for 7 days and 28 days. Monotonic loading was displacement-controlled for this test. Test results indicate that the stress-strain relationship was linear at the initial stage while non-linearity gradually developed with the increasing load as the stiffness reduces. The faster rate of loading retards the propagation of internal micro-cracks and develops the external cracks.

Key words: ***Self-Compacting Concrete, Monotonic Loading, Stress–Strain Curve, Fracture Mechanism.***

1. INTRODUCTION

Self-Compacting Concrete (**SCC**), that possesses the capacity to flow subjected to its own weight excluding any external method for compaction, has radically transformed concrete placement process in modern construction aspects. Such concrete should possess a comparatively small yield value conforming high flow ability, considerable passing ability without any bleeding and adequate viscosity to withstand segregation and must conserve its homogeneity during the processes of conveyance, placement and curing to confirm adequate structural performance and durability for long term.

The first model of SCC mix was published by ***Kazumasa Ozawa & Hajime Okamura*** [1] using conveniently obtainable materials. In addition, it was experienced that by using various types of admixtures, a highly workable concrete can be produced. Hence, SCC minimizes payment for laborers, reduces noise and promotes advanced construction methods. Later on, ***Nan***

Su et al [2], suggested that a simple design mix approach can be incorporated in which primarily required quantities of aggregates are evaluated first with respect to total aggregate volume and then paste volume is calculated such that the concrete possesses the key parameters for SCC.

In the year of 2003, ***Hajime Okamura and Masahiro Ouchi*** [3] suggested a rational design approach, in which some test methods and investigations had been carried out for producing SCC. Now considering the potency of mineral admixtures over concrete certain investigations were executed afterwards. ***Mustafa Şahmaran et al*** [4] has contributed research on the effect of fresh properties for SCC from which it has been concluded that parameters governing the SCC properties can be evaluated by testing on mortars whereas assessment were done to check the efficiency of different mineral additives and chemical admixtures in making SCC mortars. ***Mehmet Gesoglu et al*** (2008) [5] also proposed the investigational study to analyze properties of SCCs while using mineral admixtures. This study indicated that the GGBS and silica fume exhibit the best functioning when the durability of the concrete is to be considered into account.

Recently also in India, research and developments for SCC has been emphasized by different researchers. ***P. Dinakar et al*** (2013) [6] investigated the effect of using fly ash (10%-70%) by replacing cement on the attributes of SCC). The results stated that fly ash along with pozzolanic cement can be wielded to produce high performance concrete.

2. PROCEDURE

EFNARC (***European Federation of National Associations Representing for Concrete***), representing producers and application agencies has set some guidelines for design of SCC mix, which include: (i) bringing down the ratio of coarse aggregates to the total volume of aggregates; (ii) increasing the paste volume by increment of fine aggregate volume and by achieving optimum volumetric water-cement ratio (w/c) for the proper paste composition; (iii) carefully controlling the maximum size of coarse aggregate and total paste volume equivalent to the powder content of cement or cementitious materials; and (iv) using superplasticizers to get stability to control the rheology of the paste volume.

The present study was executed on beam specimens for different mix proportions by combining mineral additives to the mix. The main aim of this paper is to evaluate the workability behavior and also structural performance under the action of flexure and to compare the results to that for the conventional concrete.

3. MATERIALS FOR TESTING

2.1 Cement

Cement is a powdered substance that converts into a paste form usually by adding water and after filling and moulding into a definite formwork transforms into hardened state.

2.2 Fine Aggregates

Fine aggregate or sand is an acquisition of grains of inorganic substances derived from the disintegration of rock. In this study, sand passing through 4.75 mm sieve having a specific gravity of 2.62 was used. The grading zone was found to be Zone - II as per IS: 383-1970.

2.3 Coarse Aggregates

Coarse aggregates are acquired in either rounded or crushed shape made of rock. Basically, having greater specific surface area rounded coarse aggregates are preferred rather than crushed aggregates. In this investigation crushed stones with maximum 20 mm size were taken with IS specifications.

2.4 Fly Ash

Fly ash is a finely divided remainder, made from the combustion of pulverized coal and transferred by the flue gases and accumulated by mechanical separators, from thermal plants. In accordance with Indian standard fly ash of specific gravity 2.2 was used in this study.

2.5 Silica Fume

Silica fume or micro silica when added to the concrete mix leads to the improvement of concrete by contributing to strength property.

2.6 Alccofine

Alccofine 1203 lowers down water requirement for a given workability of high strength concrete. It can also be utilized either to ameliorate strength or as a workability aid to improve flow.

2.7 Chemical Admixtures

Super plasticizers are essential key ingredient for SCC to impart fluidity to the mix and enhance necessary workability. Usually, poly-carboxylate ether based (PCE) are proved to be convenient as they produce a homogeneous, cohesive concrete without any chance for segregation.

4. TESTING OF SELF COMPACTING CONCRETE

4.1 Slump flow test on self-compacting concrete

This test is for assessing workability for fresh concrete for which a frustum of cone shaped mould is used for checking flow. Here the slump flow test specifies the flow of the concrete in the horizontal direction. Generally, slump flow of approximately 650 mm to 800 mm are within the acceptable range.

4.2 L-box test on self-compacting concrete

This test gives an idea whether the concrete flows to that extent up to which it is subjected to obstruction due to reinforcement. The value of L-box ratio or "Blockage Ratio" is computed as H_2/H_1. As per research, blocking ratio value within 0.8 to 1.0 is considered acceptable.

4.3 V-funnel test on self-compacting concrete

This test is aimed to assess the ease of concrete flow by which it can be easily assessed whether the mix is susceptible to blocking. This test gives the easiness of concrete flow where lesser flow time indicates higher flow ability. A time of 10 seconds is to be considered appropriate.

4.4 U-box test method on self-compacting concrete

This test gives the easiness where it assures better capability of mix to flow and passing.

Table 1: Acceptance Criteria for Self-Compacting Concrete

Test Method	**Unit**	**Typical Range of Values**	
		Minimum	**Maximum**
Slump Flow	**mm**	650	800
V-Funnel	**sec**	8	12
L-Box	**(H_2/H_1)**	0.8	1.0
U-Box	**(H_2-H_1) mm**	0	30

5. TESTING OF BEAM SPECIMEN

For mix type 1 (normal mix) beams were casted by nominal mix. For mix type 2, fly ash was added by partial replacement of cement. Concrete mixes were made by 10% fly ash combining with 5% of silica fume for SCC Mix 1, and with 10% of silica fume for SCC Mix 2 by replacing cement. For SCC Mix 3 and SCC Mix 4, partial replacement of cement is done by alccofine (10%) combining with silica fume as 5% and 10% respectively.

Table 2: Mix Proportions of Self Compacting Concrete

Mix Type		Normal Mix	Concrete with Fly Ash	SCC Mix 1	SCC Mix 2	SCC Mix 3	SCC Mix 4
Cement (kg/m^3)		370	285	460.95	433.84	460.95	433.84
Fly Ash (kg/m^3)		-	122	54.23	54.23	-	-
S.Fume (kg/m^3)		-	-	27.11	54.23	27.11	54.23
Alccofine (kg/m^3)		-	-	-	-	54.23	54.23
Fine Agg. (kg/m^3)		686.44	799.1	855.95	855.95	855.95	855.95
Coarse Agg. (kg/m^3)	20 mm	456.4	531.2	259.15	254.59	265.25	260.69
	12.5 mm	848.4	986.44	481.27	472.81	492.62	484.15
Water (kg/m^3)		148	197.2	197.2	197.2	197.2	197.2
S.P (kg/m^3)		7.4	8.14	5.42	5.42	5.42	5.42
W/P Ratio		1.26	1.35	1.07	1.04	1.10	1.08

Fig. 1: (a) Curing Process where beams are kept in water bath; (b) Finished beam specimens after curing

For each trial, along with beam specimen also cubes and cylinders have been casted to evaluate compressive strength and tensile strength respectively.

Fig. 2: (a) Cubes and cylinders after casting; (b) Cubes and cylinders after curing

6. RESULTS AND DISCUSSION

5.1 Fresh Characteristics of Self Compacting Concrete

Fresh properties of SCC were assessed based on its main criterion: ability to fill, ability for passage without blockage and segregation resistance.

Table 3: Fresh Properties of Different SCC Mixes

SCC Mix Type	SCC Mix 1	SCC Mix 2	SCC Mix 3	SCC Mix 4
Fly Ash (%)	10	10	-	-
Silica Fume (%)	5	10	5	10
SP Dosage (%)	1	1	1	1
Slump Flow (mm)	700	675	690	665
V-Funnel (Sec)	9	10	7	11
L-Box (H_2/H_1)	0.86	0.8	0.92	0.9
U-Box (H_2-H_1) (mm)	17	27	25	29

5.2 Hardened Characteristics of Self Compacting Concrete

Hardened properties of SCC were evaluated based on paste strength, interfacial bonding and strength contributed by aggregates. Hardened concrete should possess superior strength, adequate durability, optimum density, fire resistance, impact resistance etc.

Table 4: Hardened Properties of Different SCC Mixes

Mix Type		Normal Mix	Concrete with Fly Ash	SCC Mix 1	SCC Mix 2	SCC Mix 3	SCC Mix 4
Fly Ash (%)		-	30	10	10	-	-
S.Fume (%)		-	-	5	10	5	10
Alccofine (%)		-	-	-	-	10	10
Average Compressive Strength (N/mm^2)	7 Days	23.11	31.5	24.89	27.11	20.89	29.78
	28 Days	48.44	48.89	49.13	48.31	48.62	49.11
Tensile Strength (N/mm^2)	28 Days	3.39	3.61	3.78	3.24	3.59	3.72

5.3 Determination of Flexural Strength

In this investigation, the effect of loading rate on the displacement of simply supported beams contingent on pure bending was studied mainly. The failure mechanism patterns were same at applied loading rates for these beams of different mix proportions.

When the tension reinforcement got yielded, the stiffness of the RC beam reduced quickly and evidently the loading-displacement curve turned flatter. By further load increment, the concrete at compressive zone got crushed and the beam should reach the ultimate state, and then the strain value increases rapidly but without any further increment of loading.

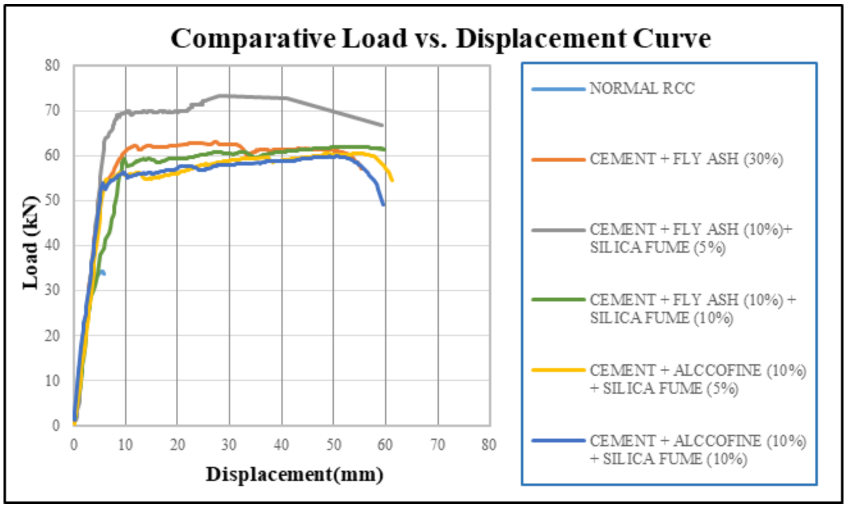

Fig. 3: Comparative Loading-Displacement Curve for Normal Concrete & SCC Mixes

7. CONCLUSION

1. In case of workability parameters, all the SCC mixes show satisfactory values as per the acceptance criterion. For slump flow, SCC mix type 1 gives better flow result rather than the other three types of SCC mix trials. For V-funnel mix type 1 takes lesser time to flow out from the funnel whereas, the other mixes take more time than SCC mix type 1. Also, for L-Box and U-Box test SCC mix type 1 is giving better results rather than other mixes.
2. Stiffness and ductility – these two terms are to be considered for analysis of the comparative load versus displacement graph for different mixes. Stiffness indicates the unit deformability in the elastic stage while ductility gives significant value of plastic deformability beyond the specimen getting yielded. It was seen that for SCC mix type 1 (with 5% silica fume and 10% fly ash) the beam specimens show more load carrying capacity than the other beam specimens. For nominal mix, peak load is very less than the other mixes offering more stiffness to the beam at the verge of failure whereas beam specimens for SCC mixes show more ductility indicating much more deformation at the plastic stage.

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