AN EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF FLY ASH AND SILICA FUME ON SELF COMPACTING CONCRETE

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ABSTRACT - In this study presents an exploratory investigation Self Compacting Concrete (SCC) with the partial replacements of fly ash and silica fume. The work done made with various partial replacement of cement by silica fumes with fly ash percentage as 25%. After these replacements, cube specimens are cast and cured. The specimens are cured in water for 7, 14 & 28 days. The slump, V-funnel and L-Box tests are carried out on the fresh Self Compacting Concrete and in harden concrete compressive strength and split tensile strength values are concluded. Trials have been made to examine the different properties of the Self Compacting Concrete and to determine the possibility of various replacements of fly ash, silica fume that can to be used in Self Compacting Concrete.

Keywords: Self Compaction concrete, Silica Fume, Fly Ash.

CHAPTER-1

INTRODUCTION

Concrete mixture, characterized by high resistance to segregation and which can be cast without compaction or vibration are termed as Self-Compacting Concrete (SCC). Better quality concrete and substantial improvement in working conditions are observed due to the exclusion of compaction or vibration. SCC mixes contains a very high content of fine fillers, including cement, which further leads to high compressive strength concrete. The pozzolanic action of marble dust can be explained in terms of hydration of cement producing calcium hydroxide and its voids can be filled by micro silica or other powder material particles. The Indian standard IS: 456-2000 permits the use of mineral admixtures for modifying the properties of concrete. The use of industrial waste products such as fly ash and silica fume, which has both pozzolanic and cementitious properties, lead to cost and energy saving.. In this study an influence of marble dust on fresh and hardened properties of fly ash induced SCC have been studied.

CHAPTER-2

LITERATURE REVIEW

Er. Raj P. Singh Kushwah, Prof. (Dr.), Ishwar Chand Sharma, Prof (Dr.) PBL Chaurasia(2015) presented in his paper that the marble can be utilized in concrete mix by replacement of fine aggregates. Different mechanical properties of marble slurry are determined like specific gravity, fineness modulus was founded and it also showed that utilization of marble slurry by replacing it with sand upto 30% which shows equal strength as of conventional concrete i.e. 1:2:4 cement concrete ratio with 0% marble slurry. It concludes that marble slurry can easily be utilized in cement concrete mix.

Bahar Demirel (2010) presented the use of fly ash as in place of fine aggregate in concrete ix and check the mechanical properties of mix. In this experimental study, the effects of using waste fly ash have been studied as a fine material on the mechanical properties of the concrete. Four different series of concrete-mixtures were prepared by replacing the fine sand (passing 0.25 mm sieve) with waste marble powder at different proportions like 0, 25, 50 and 100% by weight. For determining the effect of the waste fly ash on the compressive strength with respect to the curing age, compressive strengths of the samples were recorded at the curing ages of 7, 14, 28 and 90 days. Different properties like the porosity values, ultrasonic pulse velocity (UPV), and dynamic modulus of elasticity and the unit weights of the series were determined and compared with each other. It had been observed that the addition of WMD such that would replace the fine material passing through a 0.25 mm sieve at particular proportions enhances the effect on compressive strength. Marble powder is a by-product of marble production facilities and it creates large amount of environmental pollution. To prevent this problem marble powder can be utilized by mixing in the concrete mix.

Baboo Rai, Khan Naushad (2011) studied the influence of fly ash in cement concrete mix. In this paper the effect of use of fly ash and granules has been studied by partially replacing with mortar and concrete constituents. And check the different properties like relative workability and compressive and flexure strengths. By partial replacing the constitution it reveals that increased waste powder or waste marble granules ratio result in increased workability and compressive strengths of the mortar and concrete.

Hassan A. Mohamadien(2012) investigate the effect of fly ash on different percentages as partial replacement for cement on mortar. It represents the different types of mortar mixtures with same workability, cement to sand ratio of 1:3 and water cementitious material ratio of 0.4, prepared with marble powder and silica fumes used in the mixes separately. By replacement of fly ash with cement content separately at 0%, 5%, 10%, 15%, 20%, 30% and 50 % by weight were investigated. Different mechanical properties of mortar were measured in terms of compressive strength at 7 and 28 days and it revealed that the strength developments at 7, and 28 days and maximum development rate of compressive strength was observed at 15% replacement ratio for each the marble powder and marble dustseparately. It showed that compressive strength was increased by 31.4%, 48.3% at 7, and 28 days respectively at 15% replacement ratio of marble dustwith cement content and also in replacement of marble powder with cement content the compressive strength increased by 22.7%, 27.8% at 7, and 28 days at 15% replacement ratio of marble powder with cement content respectively.

Noha M. Soliman (2013) presented the effect of using Marble Powder in Concrete Mixes and also its effect on the strength of R.C. Slabs. This research aims to study the effect of using marble powder as partially replace of cement on the properties of concrete. The behavior of reinforced concrete slabs by using marble powder is also investigated. The main consideration in this investigation is the percentage of marble powder as partial replacement of cement constituent in concrete mixes. The experimental results showed that, the use of definite amount of marble powder as a replacement of cement content increases the workability, compressive strength and tensile strength. Use of marble powder enhances the structural performance of the tested slabs as it increased the stiffness and the ultimate strength compared to the control slabs.

V. M. Sounthararajan and A. Sivakumar (2013) adds lime content in marble powder and check its effects on concrete mix. In this research work, the waste marble powder upto 10% by weight of cement was investigated for hardened concrete properties. The effect of different percentage replacement of marble powder on the compressive strength, splitting tensile strength and flexural strength was calculated. It can be noted that the influence of fine to coarse aggregate ratio (F/C) and cement-to-total aggregate ratio (C/TA) had a higher influence on the improvement in strength properties. The immense increase in the compressive strength of 46.80 MPa at 7 days for 10% replacement of marble powder in cement content was calculated and also showed an improvement in mechanical properties as compared to the conventional concrete.

CHAPTER-3

MATERIALS AND EXPERIMENTATION

MATERIAL PROPERTIES

The materials used for this experimental programme are cement, river sand, coarse aggregate, silica fume, fly ash, super plasticizer and water were locally available at the institute vide the construction agencies working in the institute. The succeeding subsections describes in detail about the materials used.

CEMENT

OPC grade 43 conforming to IS: 8112-1989 was used in the present experimental work. The various laboratory tests confirming to IS: 4031-1996 (PART 1 to 15) specification was carried out and the physical properties were found as such:

Fineness - 0.225m^2/g

Consistency - 30%

Initial setting time - 30 min

Final setting time - 600 min

Specific gravity - 3.15

FLY ASH AS CEMENTESIOUS MATERIAL

Fly ash samples (fig 3.1) taken from NTPC were used in this study. Fly ash was not processed and, used as received. The sample satisfied the requirements of IS 3812(Part I).

Figure 3.1 Fly Ash Sample

The physical properties as supplied by the NTPC is presented in table 3.1.

PHYSICAL PROPERTIES OF FLY ASH

Sl. no.	Physical Properties	Observed values
1	Specific Gravity	2.2
2	Initial Setting	45 min
3	Final Setting	280 min
4	Consistency	35
5	Soundness (autoclave	0.06

	expansion %)	
6	Fineness (M2/Kg)	368

The chemical properties as supplied by the NTPC is presented in table 3.2.

CHEMICAL PROPERTIES OF FLY ASH

Sl. No.	Test Conducted	Observed Values (%)	Requirement as per IS:3812(part-I):2003 Reff.: 2013
1	Loss of Ignition	2.53	5.0(max)
2	Silica as SiO_2	59.51	35 (min)
3	$SiO_2+Al_2O_3+Fe_2O_3$	86.85	70(min)
4	Available alkalis as Na_2O	0.43	1.5 (max)
5	Reactive silica	29.32	20(min)
6	Magnesium as MgO	1.97	5.0 (max)
7	Sulphate as SO_3	2.07	3.0 (max)
8	Total Chloride	0.032	0.05 (max)
9	Lime Reactivity	4.9 N/mm^2	4.5(min)

PHYSICAL PROPERTIES OF MINERAL ADDITIVES.

PROPERTY	MARBLE POWDER
COLOUR	2.72
SPECIFIC GRAVITY	2.78
SPECIFIC SURFACE AREA	2.42
FORM	POWDER
ODOUR	ODOURLESS

FINE AGGRIGATES

Ordinary sand from local river bed having the following characteristics has been used

Specific gravity - 2.66

Fineness modulus - 2.60

Water absorption - 1.35

Sand after sieve analysis (table 3.5) confirm to zone III as per IS 383-1970.

SIEVE ANALYSIS OF FINE AGGREGATE

IS Sieve	Wt. Retained(Kg)	Cum. Wt.(Kg)	%cum Retained	% Passing	Remarks
4.75mm	0.0	0.0	0	100	**Sand Zone III As per IS: 383-1970**
2.36mm	0.0	0.0	0	100	**Sand Zone III As per IS: 383-1970**
1.18mm	0.087	0.087	8.7	91.3	
600µ	0.289	0.376	37.6	62.4	
300µ	0.333	0.709	70.9	29.1	
150µ	0.243	0.952	95.2	4.80	

COARSE AGGREGATE

Locally available crushed stone from local market with maximum graded size of 16 mm has been used as coarse aggregate. The physical properties for the coarse aggregate as found through laboratory test resulted in

Aggregate crushing value = 24%

Aggregate impact value = 29%

Specific gravity = 2.74

Water absorption = 0.755

SIEVE ANALYSIS OF COARSE AGGREGATE

Sieve size(mm)	Weight retained(Kg)	Cum.wt(Kg)	%cum retained	Percentage passing	Remarks
20	0.00	0.00	0	100	16mm graded
16	0.00	0.00	0	100	
12.5	----	----	----	----	
10	2	2	40	60	
4.75	2.75	4.75	95	5	

CHEMICAL ADMIXTURES

Polycarboxylic ether based super plasticizer with viscosity modified admixture supplied by BASF India limited with a brand name of Master Glenium SKY 8630/8632 (fig: 3.3) was used in the present research work. Master Glenium SKY 8630/8632 is an admixture of a new generation based on modified polycarboxylic ether which produces Smart Dynamic Concrete/ Self Compacting Concrete with inbuilt Viscosity Modifying admixture. The properties as obtained from the manufacturer are shown below.

PROPERTIES OF CHEMICAL ADMIXTURE

Aspect	Light brown liquid
Relative density	1.08 ± 0.01 at 25°C
Ph	≥ 6 at 25°C
Chloride ion content	< 0.2%

CHAPTER-4

EXPERIMENTAL INVESTIGATION

SLUMP FLOW TEST

The slump flow test (EFNARC 2002 which is pictured below is the simplest and most commonly used test method for SCC.

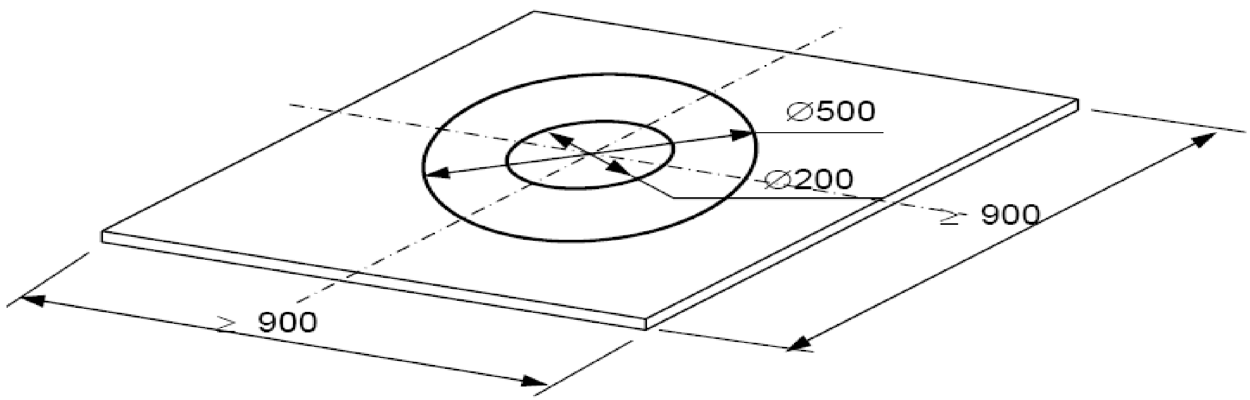


Fig. 3.4. Experimental setup of slump flow

The flowability and the flow rate of SCC without obstructions is assured by Slump flow and T500. The result indicates the filling ability of SCC, and the T500 time measures the speed of flow. Finally, the viscosity of the paste can be visualized.

A good estimation of filling ability can be determined by Slump flow and T500 test. A slump flow value of 650mm at least is required for SCC.

Further, the T50 time is one of the indications of flowability for SCCs mixes. If the flow time is between 2-5 seconds then it is useful or acceptable for housing application and if the flow time is within 3-7 sec then it is acceptable for civil engineering purposes

J- RING TEST

The J-Ring test (EFNARC 2002) extends common filling ability test methods in order to characterize passing ability of self consolidating concrete mixtures. The J-Ring test device can be used with the slump flow test or v-funnel test.

The test apparatus as developed is shown in figure below and is used to determine the passing ability of the concrete. The spacing of the bars is in accordance with normal reinforcement provided at the construction sites. However, three times the size of maximum aggregate is considered to be suitable.

The J-Ring is used in combination with the Slump flow or eventually even the V funnel test assesses the flowing ability and the passing ability of the concrete.

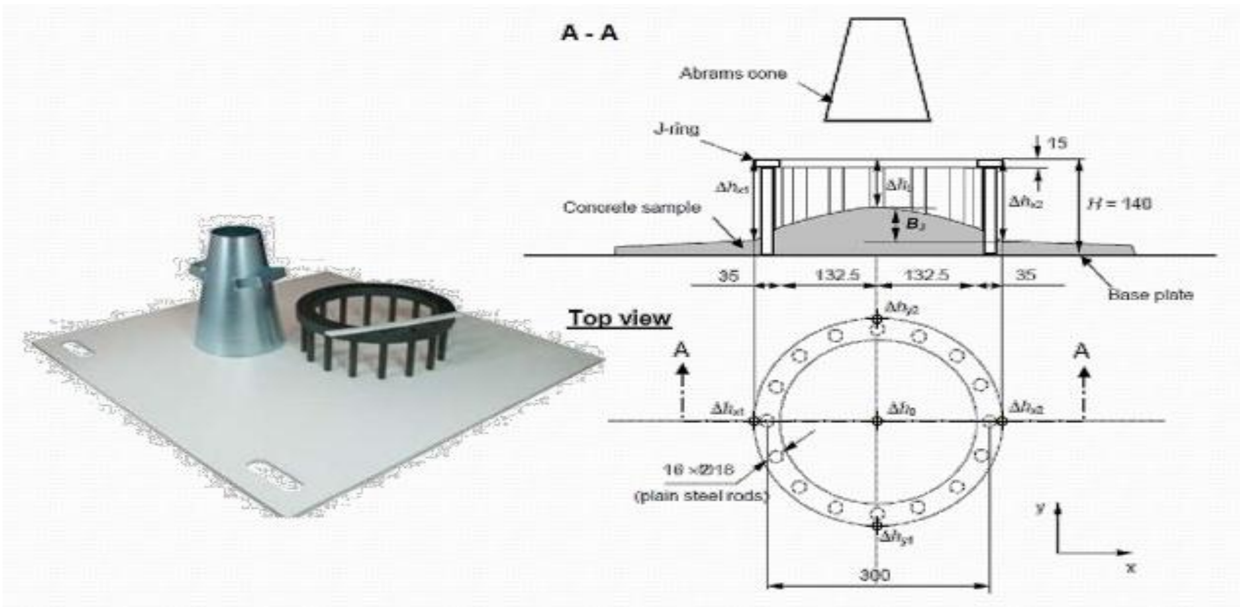


Fig. 3.5. J-Ring

L-BOX TEST

This test method provides a procedure to determine the passing ability of SCCs mixes. The SCC is allowed to pass through the specified gaps of reinforcing bars; the maximum height reached by the SCC is measured. This measured height indicates the blocking characteristics of SCC.

L-box has arrangement and the dimensions as shown in Figure. The H_2/H_1 ratio is known as blocking ratio. Blocking ratio in the range of 0.8 to 1 has been recommended by the EU research team and by EFNARC (2002).

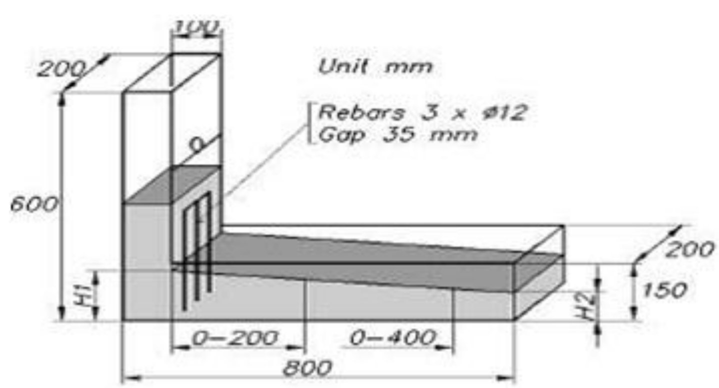


Fig. 3.6. L-Box

The diameters and spacing of the bars is in accordance with normal reinforcement provided at the construction sites. However, three times the maximum size of aggregate is considered appropriate.

Further, the combination of L-box and slump flow tests was found to be preferable to a combination of J-Ring and slump flow tests.

V-FUNNEL TEST

The V-Funnel Test equipment developed in Japan consists of a V-shaped funnel. Arrangement and the dimensions are shown in Figure.

It determines the ability to fill (flowability) of SCC with a maximum aggregate size of 20mm. This test measures the ease with which the concrete flows. If the flow time of concrete through the V funnel is less than 10 seconds then the concrete can be classified as SCC. The inverted cone shape of the funnel is assumed to restrict the flow, and extended flow times gives indication of the vulnerability of the mix to blocking.

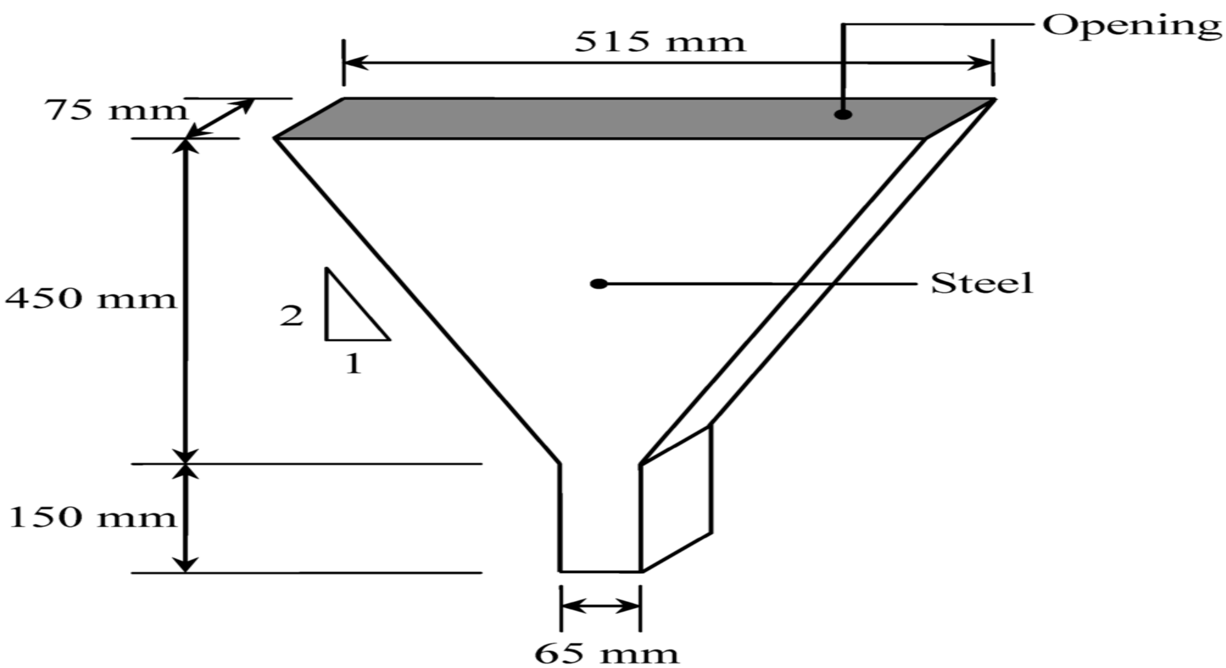


Fig. 3.7. V-Funnel

TESTS FOR STRENGTH IN COMPRESSION

Two types of compression test specimens are used: cubes and cylinder. In the present work cube specimens were preferred. 150mm size Cube Moulds conforming to IS code IS: 10086-1982. The concrete cubes were caste in the mould. After 24 hours the sample were removed from the mould and then cured in clean water at normal room temperature for 28 days. After 28 days the cubes were left to dry for 2 or 3 hours.

The specimens were tested for compressive strength on compression testing machine. The load were applied and increased continuously at a constant rate of 140/cm^2/min (approx) until the specimen breaks.

Fig. 3.8. Compressive strength apparatus

SPLIT TENSILE STRENGTH TEST

This is also sometimes referred as "Brazilian Test" as this test was developed in Brazil in 1943. This comes under indirect tension test methods. Cylindrical specimen was placed horizontally between the loading faces of a compression testing machine the load was applied along the vertical diameter of the cylindrical sample. A concrete cylinder of size 150mm diameter and 300mm height was subjected to the action of a compressive force along two opposite edges.

Horizontal tensile stress = 2P/Π D L

Where P = Compressive load on the cylinder.

L = Length of cylinder.

D = Diameter of cylinder

In the present investigation, the split tensile strength test has been conducted on desired grade of SCC at 28 days.

The acceptance criteria of self compacting concrete are given in table 3.8 and fault finding in results are given in table 3.9 and table 3.10 as per EFNARC 2002.

Workability Properties for SCC

Table –: Testing methods for workability properties Of SCC

Sl.	Method	Property
1	Slump-Flow	Filling ability
2	T_{50cm} Slump Flow	Filling ability
3	V-Funnel	Filling ability
4	V-Funnel At $T_{5minutes}$	Segregation resistance
5	L-Box Passing	Passing ability
6	U-Box Passing	Passing ability

The initial mix design of SCC all three workability parameters need to be assessed to ensure that all aspects are fulfilled. A full-scale test was verified the SCHSC of the chosen design.

For site quality control, two test methods are generally sufficient to monitor production quality. Typical combinations are Slump-flow and V-funnel or Slump-flow and J-ring.

Workability requirement

The requirements as per European code, at the time of placing, likely changes in workability during transport should be taken into account in production and the typical acceptance criteria, for SCC with a maximum aggregate size up to 20 mm are shown in table.

Table 3.8 Acceptable Criteria for Self Compacting Concrete

Sl.	Method	Unites	Typical Range of values	
			Minimum	Maximum
1	Slump-flow by Abrams cone	mm	650	800
2	T_{50cm} slump flow	sec	2	5
3	V-funnel	sec	6	12
4	V-funnel at $T_{5minutes}$	sec	0	+3
5	L-box Passing	(h_2/h_1)	0.8	1.0
6	U-box Passing	(h_2-h_1)mm	0	30
7	J-ring Passing	mm	0	10

These typical requirements shown each test method are based on European code SSC specification and practice. Special care should always be taken to ensure no segregation of the mix is likely as, at present.

Workability Properties of SCC and Alternative Test Methods

Table: Workability properties of SCC & Alternative test methods

Property	Test methods		Modification of test according to max. aggregate size
	Lab (mix design)	Field (QC)	
Filling ability	Slump flow T_{50cm} slump flow V-funnel Orimet	Slump flow T_{50cm} slump flow V-funnel Orimet	None max 20 mm
Passing ability	L-box U-box Fill-box	J-ring	Different opening in L-box, U-box and J-ring.
Segregation resistance	GTM test V-funnel at $T_{5minutes}$	GTM test V-funnel at $T_{5minutes}$	None

CHAPTER -5

EXPERIMENTAL RESULTS

TEST RESULTS

Fifty four cube samples and thirty six cylindrical specimens for M60 grade of fly ash induced SCC have been tested in laboratory. All the specimens were cast with fly ash percentage replacement to cement at 30% by weight of cement. Further, the water to powder ratio for all mixes were maintained at 0.36. Super plasticizer dosage for all the mixes were 2.2% by weight of cement.

A comparative study is carried out to study the effect of partial replacement of marble dustby weight of cement on properties of SCC. Four properties of concrete namely flowability, compressive strength, and split tensile strength has been selected for study.

FLOWABILITY TEST RESULTS

Workability is the primary requirement of SCC. The various aspects of workability characteristic are

- Flowability
- Viscosity
- Passing ability and
- Segregation resistance

The various flowability tests conducted in lab where as per EFNARC (2002) and the test conducted were Slump Flow Test, J-Ring Test, L-Box Test and V-Funnel Test.

The results of the slump flow tests of fly ash induced SCC with different percentage of silica fumes are presented in table 4.1.

The spread diameter of slump flow varied between the ranges of 655-725 mm. A minimum slump flow of 650 mm is generally recommended for SCC. From figure 4.1 it can be observed that the flow improves at 2% replacement of marble dust by weight of cement after that there was gradual decrease in spread diameter. However, the spread for all mixes were within the specified range recommended by EFNARC (2002).

SLUMP FLOW TEST RESULTS

Mix No.	% of Fly ash by Weight of Cement	SLUMP FLOW TEST (time in sec)			Spread Diameter in mm
		300mm	500mm	700mm	
1	0	1	3	4	705
2	4	0.4	1.3	3.6	725
3	8	0.5	1.5	3.8	680
4	12	0.65	1.8	4.2	672
5	16	0.8	2.1	5.02	655
6	20	0.72	1.86	4.4	670

Further, no segregation was observed during the J- Ring test. The V-Funnel time and the L-Box blocking ratio were also within the specified range laid down by EFNARC (2002).

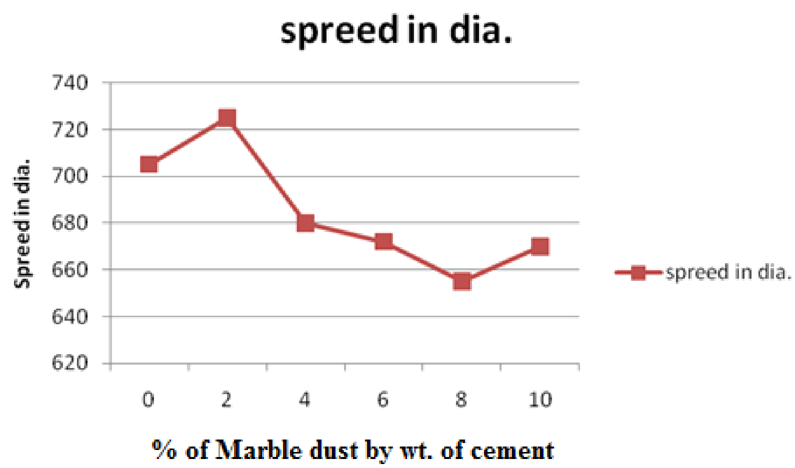
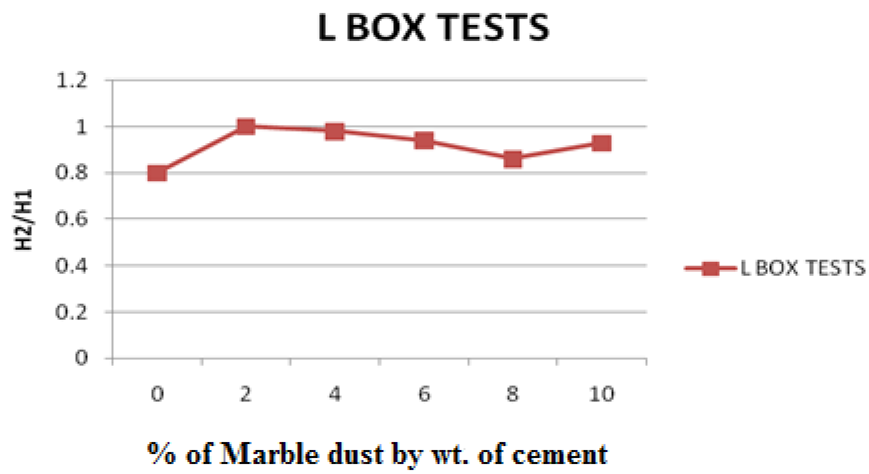


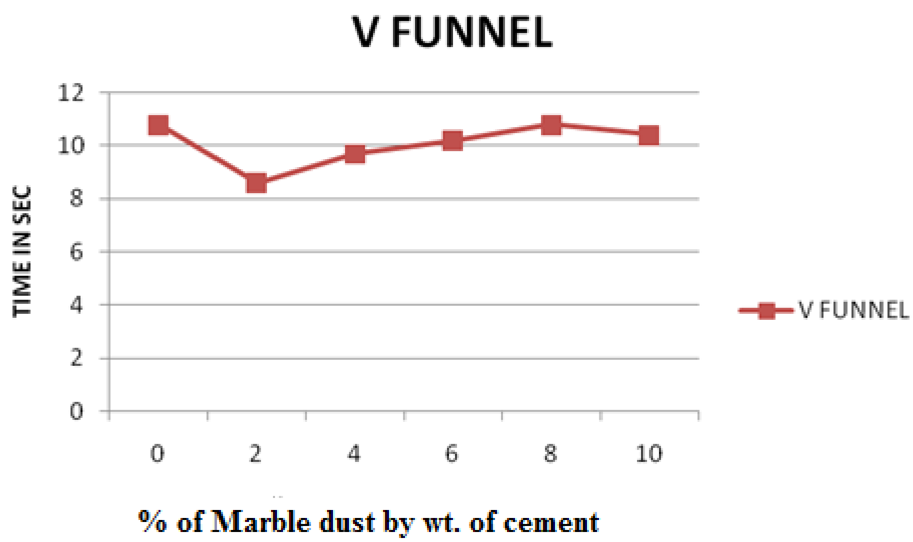
Fig. 4.1. Slump Flow Test Results

L-BOX AND V-FUNNEL TEST RESULTS

Mix No.	% of Fly Ash by Wt of Cement	L Box Test	V-Funnel Test
		H_2/H_1	Time in sec
1.	0	0.8	10.8
2.	4	1	8.6
3.	8	0.98	9.7

4.	12	0.94	10.2
5.	16	0.86	10.8
6.	20	0.93	10.4





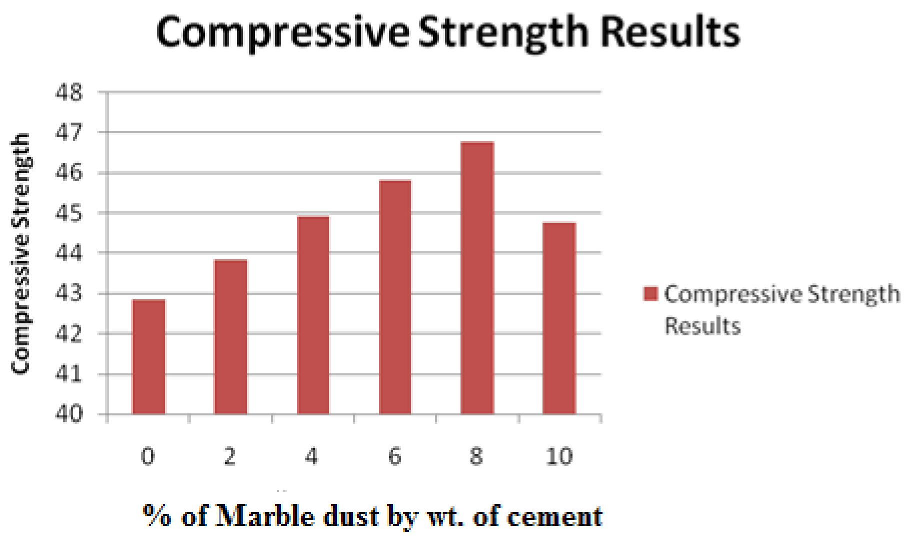
From visual inspection during mixing process and during the flowability test it was observed that the addition of marble dust nullified the stickiness observed in mixes without marble dust and further, the mixes were highly cohesive.

COMPRESSIVE STRENGTH TEST RESULTS

Cube specimens prepared for compressive strength were tested in laboratory and different crushing strengths were found which are substantiated in table 4.3.

COMPRESSIVE STRENGTH TEST RESULTS OF CUBE

Mix No.	% of Fly ash by Weight of Cement	Compressive Strength Test Results of Cube (28 Days)
1	0	42.86
2	4	43.85
3	8	44.94
4	12	45.82
5	16	46.77
6	20	44.77



It can be seen that the compressive strength increased gradually with addition of silica fume. An increase in strength is expected due to the pozzolanic action of silica fume.

It is clear that at 6% replacement of fly ash dust by weight of cement the increase in compressive strength was 7% while the increase was about 9% when percentage replacement was 8% as compared with reference mix.

Decrease in compressive strength was observed when fly ash replacement was 10% as compared to 6% and 8% replacement of marble dust by weight of cement.

Fig. 4.3. Compressive Strength Test Results

CHAPTER-6

CONCLUSIONS AND SUGGESTIONS FOR FUTURE STUDY

1. The slump flow varied between the ranges of 655-725 mm

2. Addition of fly ash nullified the stickiness observed in mixes without silica fumes and further, the mixes were highly cohesive.

3. Increase in percentage of fly ash content from 0% to 8 %, an increase in compressive strength was recorded.

4. At 6% replacement of fly ash by weight of cement the increase in compressive strength was 7% while the increase was about 9% when percentage replacement was 8% as compared with reference mix.

5. At 10% replacement of fly ash with cement there was slight decrease in compressive strength as compared to 4, 6 and 8% replacement of silica fumes by weight of cement

6. The values of splitting tensile-strength range between 3 and 4 MPa,

7. The increase in split tensile strength is almost 10% at 2% replacement and 13% at 4% replacement of marble dust by weight of cement.

8. The increase in split tensile strength is almost 20% at 6% and 8% replacement of marble dust by weight of cement.

9. However at 10% replacement the increase in split tensile strength is only about 9%.

CHAPTER-7

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