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RESEARCH ARTICLE OPEN ACCESS

Self Compacting Concrete And Its Properties

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ABSTRACT
Self-compacting concrete (SCC), which flows under its own weight and doesn't require any external vibration for compaction, has revolutionized concrete placement. Such concrete should have relatively low yield value to ensure high flow ability, a moderate viscosity to resists segregation and bleeding and must maintain its homogeneity during transportation, placing and curing to ensure adequate structural performance and long term durability.
Self-compacting concrete (SCC) can be defined as a fresh concrete which possesses superior flow ability under maintained stability (i.e. no segregation) thus allowing self-compaction that is, material consolidation without addition of energy. Self-compacting concrete is a fluid mixture suitable for placing in structures with Congested reinforcement without vibration and it helps in achieving higher quality of surface finishes. However utilization of high reactive Metakaolin and Flyash asan admixtures as an effective pozzolan which causes great improvement in the porestructure. The relative proportions of key components are considered by volumerather than by mass. self compacting concrete (SCC) mix design with 29% of coarse aggregate, replacement of cement with Metakaolin and class F flyash, combinations of both and controlled SCC mix with 0.36 water/cementitious ratio(by weight) and388 litre/m3 of cement paste volume. Crushed granite stones of size 16mm and12.5mm are used with a blending 60:40 by percentage weight of total coarse aggregate. Self-compacting concrete compactibility is affected by the characteristics of materials and the mix proportions; it becomes necessary to evolve a procedure formix design of SCC. The properties of different constituent materials used in this investigation and its standard tests procedures for acceptance characteristics of self compacting concrete such as slump flow, V-funnel and L-Box are presented.
KEYWORDS: Self Compacting Concrete, Flyash , Properties.

I. INTRODUCTION

As per EFNARC Guidelines for SCC mix design, one of the most important differences between SCC and conventional concrete is the incorporation of a mineral admixture. Thus, many studies on the effects of mineral admixtures on the properties of SCC have been conducted. These studies show the advantage of mineral admixture usage in SCC, such as improved workability with reduced cement content..Since cement is the most expensive component of concrete, reducing cement content is an economical solution. Additionally, the mineral admixtures can improve particle packing and decrease the permeability of concrete. Therefore, the durability of concrete is also increased (Assie et al., 2007). Industrial byproducts or waste materials such as limestone powder, fly ash and granulated blast furnace slag are generally used as mineral admixtures in SCC (Felekoglu et al., 2006; Unal et al., 2006). Thereby, the workability of SCC is improved and the used amount of by-products or waste materials can be increased. Besides the economical benefits, such uses of byproducts or waste materials in concrete reduce environmental pollution (Bosiljkov, 2003).

The three properties that characterise a concrete as self-compacting Concrete are
Flowing ability—the ability to completely fill all areas and corners of the
formwork into which it is placed
Passing ability—the ability to pass through congested reinforcement without
separation of the constituents or blocking
Resistance to segregation— the ability to retain the coarse components of the mix
in suspension in order to maintain a homogeneous material.

Fly ash is an industrial by-product, generated from the combustion of coal in the thermal power plants.The increasing scarcity of raw materials and the urgent need to protect the environment against pollution has accentuated the significance of developing new building materials based on industrial waste generated from coal fired thermal power stations creating unmanageable disposal problems due to their potential to pollute the environment. Fly ash, when used as a mineral admixture in concrete, improves its strength and durability characteristics. Fly ash can be used either as an admixture or as a partial replacement of cement. It can also be used as a partial replacement of fine aggregates, as a total replacement of fine aggregates and as supplementary addition to achieve different properties of concrete Viscosity Modifying Admixtures (VMA) make the concrete more tolerant to variations in the water content of the mix, so that plastic viscosity is maintained and segregation is prevented (EFNARC, Materials Self-compacting concrete was made of cement,sand, water, fly ash and mineral admixture.

1) Cement: Ordinary Portland cement, 43 Grade conforming to IS: 12269 – 1987.
2) Fine aggregate: Locally available river sand confined Grading zone II of IS: 383-1970.
3) Coarse aggregate: Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per IS: 383 – 1970.
4) Mineral admixture: Dry Class F-Fly ash confined as per IS 3812-2000.

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Table 1. Chemical Properties of Fly Ash
Chemical properties (%)

SiO2	45.98
Al2O3	23.55
Fe2O3	4.91
CaO	18.67
Na2O	0.24
K2O	1.8
SO3	1.47
Cl	0.0053

5) Chemical admixture: Super plasticizer Glenium-B233 as per EN 934-2 T3.1/3.2.and viscosity modifying agent Glenium stream -2 as per ENC 180VMA

Aspect	Light brown liquid
Relative density	1.09 ± 0.01 at 25°C
pH	>6
Chloride ion content	< 0.2%

Table 3. Typical Properties of VMA

Aspect	Colourless free flowing liquid
Relative density	1.01 ± 0.01 at 25°C
Ph	>6
Chloride ion content	< 0.2%

6) Water: Water used was fresh, colorless, odorless and tasteless potable water free from organic matter of any type

II. MIX PROPORTIONS

One control and five SCC mixes with different replacements of mineral admixture were prepared and examined to quantify the properties of SCC. Table 4 presents the composition of SCC mixtures. The replacement was carried out at levels of 10%, 20%, 30%, 40% and 50% of cement content. After iterative trial mixes the water/powder mass ratio (w/p) was selected as 0.45. The total powder content was varied as 450kg/m3, 500 kg/m3, 530 kg/m3 as iterative values and finally fixed as 530 kg/m3. Some design guidelines have been prepared from the acceptable test methods. Many different test methods have been developed in attempts to characterize the properties of self-compacting concrete. So far, no single method or combination of methods has achieved universal approval and most of them have their adherents. Similarly, no single method has been found which characterizes all the relevant workability aspects. So, each mix design should be tested by more than one test method in order to obtain different workability parameters.

Table 4. Mixture Proportions for Fly Ash Self-Compacting Concrete (kg/m3)

Materials	**Control**	**Fly Ash 10%**	**Fly Ash 20%**	**Fly Ash 30%**	**Fly Ash 40%**	**Fly Ash 50%**
Cement	530	477	424	371	318	265
Fly ash	-	53	106	159	212	265
Water/Powder	0.45	0.45	0.45	0.45	0.45	0.45
Sand	768	768	768	768	768	768
Coarse aggregate	668	668	668	668	668	668

Super plasticizer	0.86	0.86	0.86	0.86	0.86	0.86
VMA	0.082	0.082	0.082	0.082	0.082	0.082

III. WORKABILITY TEST METHODS

For determining the self-compactability properties; slump flow, T50 time, V-funnel flow time, L-box blocking ratio, U-box difference in height tests were performed. In order to reduce the effect of workability loss on variability of test results, fresh state properties of mixes were determined within a period of 30 minutes after mixing. The order of testing was as below, respectively.

1. Slump flow test and measurement of T50cm time;
2. V-funnel flow test;
3. L-box test;
4. U-box test.

IV. DURABILITY TEST METHODS

Durability studies were conducted at 28, 56 and 90 days for various mixes to find out the resistance to acid attack, sulphate attack and saturated water absorption.

V. Acid Resistance

Acid resistance was tested on 150 mm size cube specimens at the age of 28 days of curing. The cube specimens were weighed and immersed in water diluted with one percent by weight of sulphuric acid for 28, 56 and 90 days. Then, the specimens were taken out from the acid water and the surfaces of the cubes were cleaned. Then, the weight and the compressive strength of the specimens were found out and the average percentage of loss of weight and compressive strength were calculated.

Sulphate Attack

The sulphate attack testing procedure was conducted by immersing concrete specimens of the size 100x100x100 mm over the specified initial curing in a water tank. Then, they were cured in 5% Sodium sulphate solution for 28, 56 and 90 days, respectively. This type of testing represents an accelerated testing procedure, which indicates the performance of particular concrete mixes to sulphate attack on concrete. The degree of sulphate attack was evaluated by measuring the weight losses of the specimens at 28, 56 and 90 days, respectively.

Saturated Water Absorption

Saturated water absorption test was conducted on 100mmx100mmx100mm cubes at the age of 28 and 90 days. The specimens were weighed before drying in a hot air oven at 1050ºC. The drying process was continued, until the difference in mass between two successive measurements at a 24 hour interval closely agreed. The dried specimens were cooled at room temperature and then immersed in water. The specimens were taken out at regular intervals of time, surface dried and weighed. The difference between the saturated mass and the oven dried mass expressed as a percentage of the oven dried mass gives the saturated water absorption.

Table 5. Slump Flow and T50 Time of SCC with Fly Ash

Mix proportions (%)	Slump (mm)	T50 (Sec)
MFA-0	660	5
MFA-10	675	4
MFA-20	685	3.6
MFA-30	690	3.1
MFA-40	685	3.4
MFA-50	678	3.7

From slump flow and T50 tests, 30% replacement of fly ash behaves better compared with other ratios.

L-Box Test and U-Box Test

Using L-box test, the passing ability of SCC beyond the reinforcing bars can be found. The mix having high powder content and lesser coarse aggregate passes easily through the reinforcing bars.

VI. RESULTS AND DISCUSSION

In this study, fresh, hardened properties and durability of self-compacting concrete were investigated by using waste materials (class F fly ash) at five replacement rates for cement. The investigations were carried out according to appropriate criteria given by European standards. In the present study, such properties of self-compacting concrete produced with fly ash were investigated based on fresh concrete tests, specifically workability, strength and durability tests.

Fresh Properties

Slump Flow Test and T50 Test

The slump value plays a major role in SCC. By the value of slump, it is possible to know the effectiveness of flow in SCC; i.e., flowability of SCC under congested reinforcements can be studied at site through this test. The slump values also determine the durability of the mix, segregation and bleeding in the mix. The minimum value of slump is to be 650mm and the maximum value 800 mm for a fresh SCC. The slump values and T50 values for different mixes are shown in Fig.1. This helps us know the filling ability of SCC.

The ratio of is used to indicate the value of the result of L-box. The minimum value of can be 0.8 and the maximum value 1.0.

U-box test is used to find the passing ability of SCC through the reinforcing bars, similar to that of the L-box test. The limitation of U-box test as specified by EFNARC guidelines is the difference in height H to be within the limit of 0-30 mm. The passing ability of L- ox and U-bo x test is shown in Fig.2. From this U-Box and L- Box Test the passing ability of the concrete is tested and concludes that with increase in fly ash the passi ng ability inc reases. In this mix, 30% repl acement by fly ash behaves better in p ssing ability of concrete.

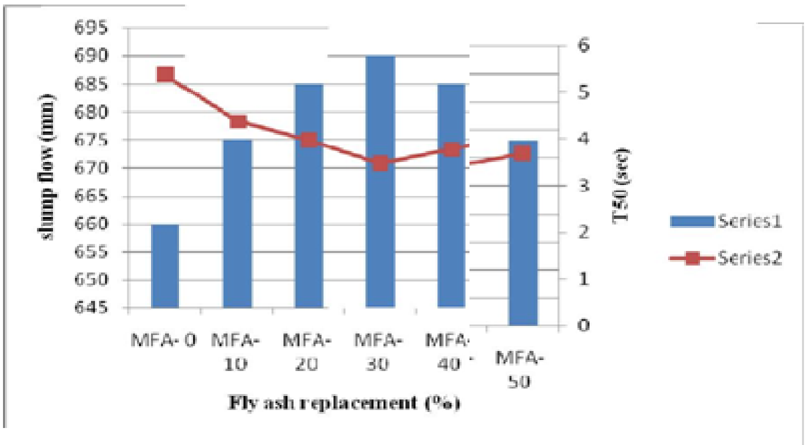


Figure 1: Slump Flow and T50 Tim e of SCC with Fly Ash

Tab le 6. U- Box and L- Box ests of SCC with Fly Ash

Mix proportions (%)	U-Box (h_2-h_1) Mm	L-Box (h_2/h_1)
MFA-0	28	0.920
MFA-1 0	24	0.933
MFA-2 0	22	0.946
MFA-3 0	19	0.953
MFA-4 0	19.5	0.950
MFA-5 0	20	0.946

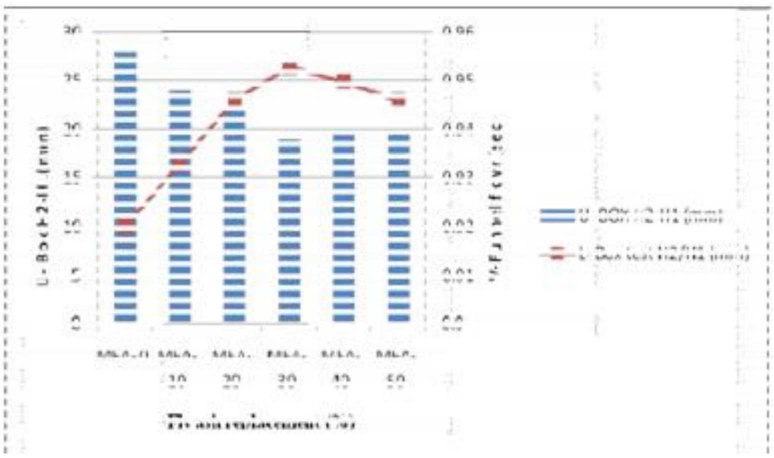


Figure 2 : U- Box and L- Box Test of SCC With Fly Ash

V-Funnel Test

V-funnel test is used to find out th flowing ability of the SCC. The test res lts show that the time tak en for a higher replacement is much less due to fineness in the mix. Th influence of time is show n in Fig.3. T he minimum time for the flow of the entire concrete dumped in th e V-funnel is 6 sec and the maximum time to fall completely is 12 se c.

Using V- Funnel test , the flowin g ability of the concrete is investigated, and it is con luded that with the increase in fly ash the flowability increases. In this mix, 30% repl acement by fly ash behaves better in respect to flow ability of con crete.

Mechanical Properties

Compressive, split and flexure study results at different ages a re shown in Figures (4, 5 and 6). When c mpared to the control mixture, increasi g amounts of mineral admixtures generally decrease the strength. In this mix, 30% replacement b y fly ash behaves better in respect to mech anical properties of concrete.

Table 7. V- Funnel Test of SCC with Fly Ash

Mix proportions (%)	V-funnel (Sec)
MFA-0	12
MFA-10	10.6
MFA-20	9.8
MFA-30	8.5
MFA-40	7.9
MFA-50	7.6

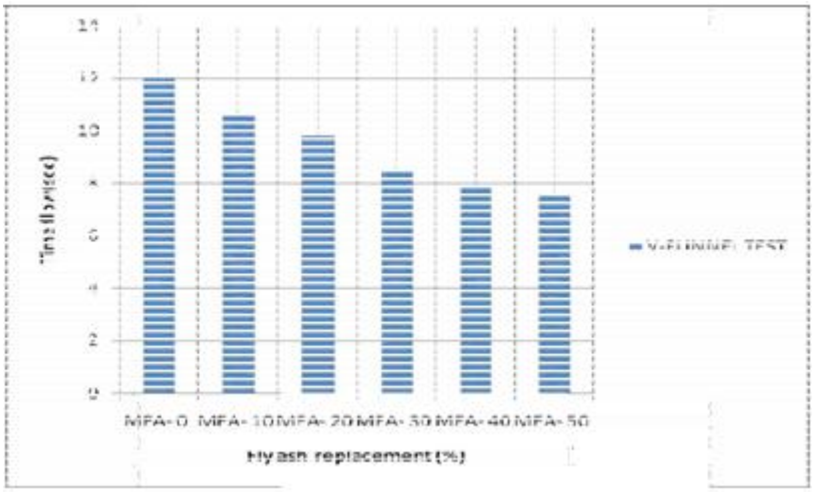


Figure 3: V- Funnel Test of SCC with Fly Ash

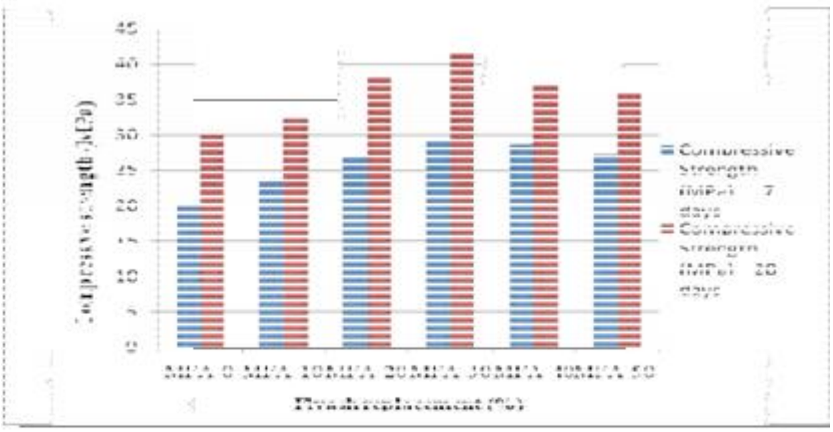


Figure 4: Compressiv Strength Results

Table 9. Split Tensile Strength

M ix prop rtions (%)	S lit Tensile Strength (MPa)	
	7 da ys	28 days
MF A-0	1.0	1.74
MFA-10	1.2	1.88
MFA-20	1.3	2.01
MFA-30	1.4	2.06
MFA-40	1.3	1.96
MFA-50	1.2	1.84

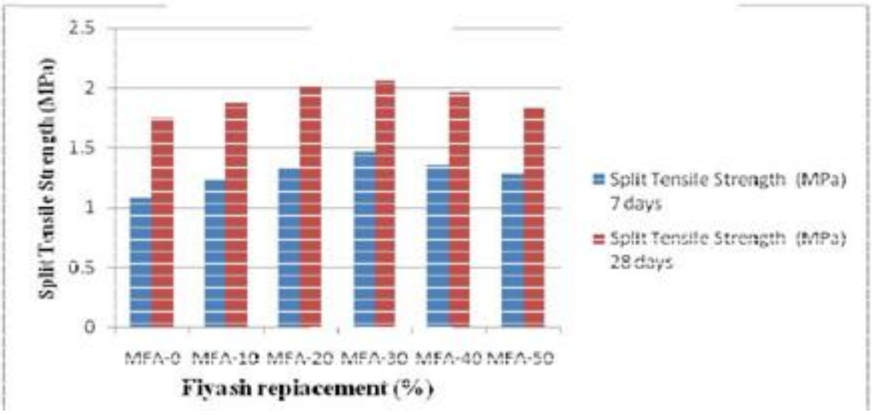


Table 10. Flexural Strength

Mix proportions (%)	Flexural Strength (MPa)	
	7 days	28 days
MFA-0	2.14	3
MFA-10	2.87	4.20
MFA-20	3.59	5.01
MFA-30	4.58	5.80
MFA-40	4.20	5.20
MFA-50	3.20	4.70

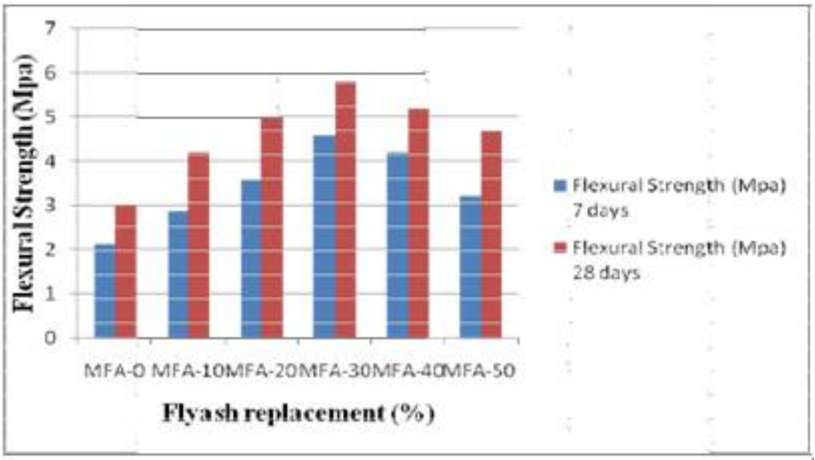


Figure 6: Flexural Strength Results

Durability Study

Acid resistance

Weight and compressive strength values of the specimens w ere found ou t for the age f 28, 56 and 90 days. The average percentage of w eight loss a nd compressive strength wer e calculated for acid test as shown in Table 11, and F ig.7 shows t he graph for the acid resistance.

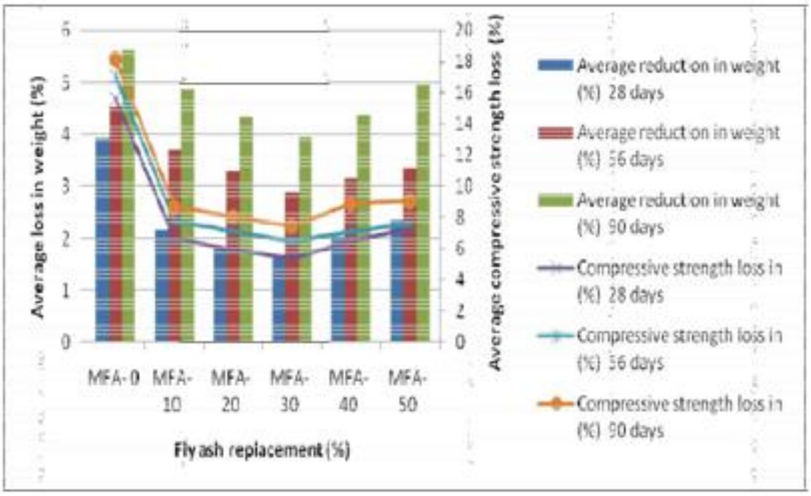
It is obs erved that w ith the incr ease in flysh cntent the w eight reducti on of the specimens gets reduced and the compressive strength loss is alo reduced.

S ulphate Atta ck Test

The sulphate attack was evaluated by measuring the weight losses o f the specimens at 28, 56 and 90 days, respectively. T he results fo r sulphate attack test are sh own in Table 12 and in Fi .8.

Table 11. Acid Resistanc e Test Results

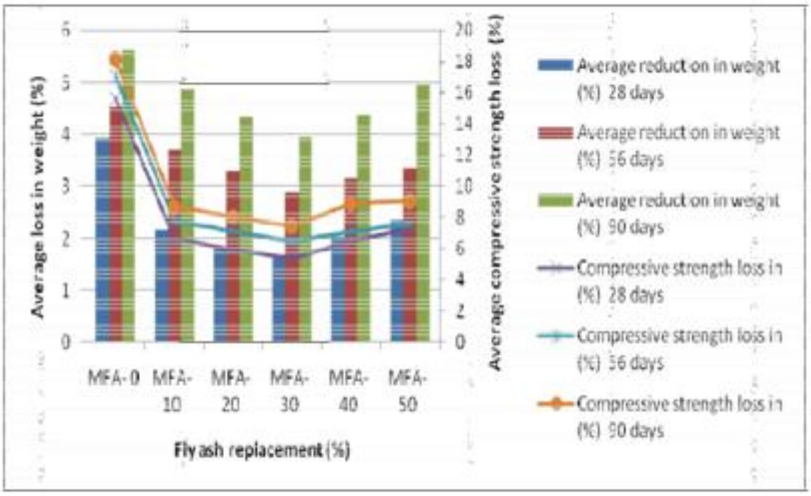
Mix proportions ( )	Average reduction in weight (%)			Average loss of Co mpressive strength (%)		
	28 days	56 days	9 0 days	28 days	56 days	90 days
MFA-0	3.94	4.54	5. 2	10.6	12.1	13.2
MF -10	2.16	3.71	4. 8	6.7	7.8	8.66
MF -20	1.83	3.28	4. 2	5.9	7.12	8.02
MF -30	1.61	2.89	3. 6	5.35	6.51	7.43
MF -40	2.02	3.14	4. 8	6.45	7.16	8.87
MF -50	2.35	3.36	4. 6	7.3	7.62	9.05



Figur e 7: Acid Resistance

Table 11. Acid Resistanc e Test Results

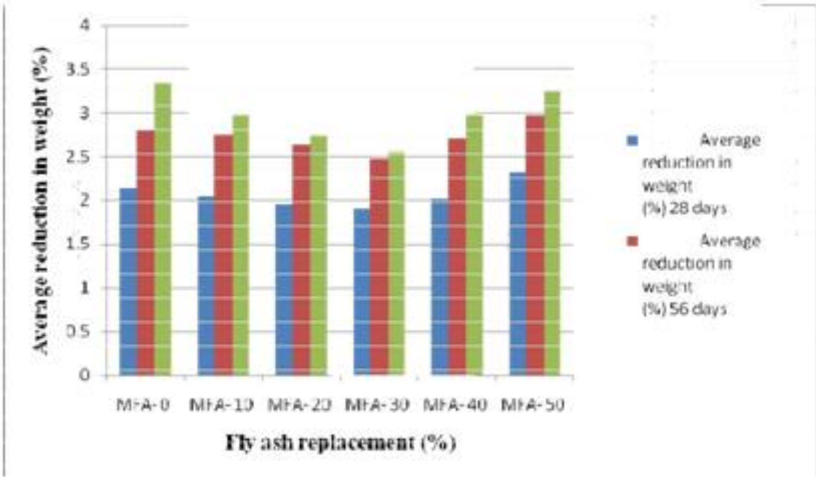
Mix proportions ( )	Average reduction in weight (%)			Average loss of Co mpressive strength (%)		
	28 days	56 days	9 0 days	28 days	56 days	90 days
MFA-0	3.94	4.54	5. 2	10.6	12.1	13.2
MF -10	2.16	3.71	4. 8	6.7	7.8	8.66
MF -20	1.83	3.28	4. 2	5.9	7.12	8.02
MF -30	1.61	2.89	3. 6	5.35	6.51	7.43
MF -40	2.02	3.14	4. 8	6.45	7.16	8.87
MF -50	2.35	3.36	4. 6	7.3	7.62	9.05



Figur e 7: Acid Resistance

Table 12. Sulphate Attac k Test Results

Mix proportions (%)	Ave rage reductio n in weight (%)		
	28 days	56 days	90 days
MFA- 0	2.14	2.8	3.35
MFA- 10	2.05	2.75	2.98
MFA- 20	1.96	2.64	2.74
MFA- 30	1.9	2.48	2.56
MFA- 40	2.02	2.71	2.98
MFA- 50	2.32	2.98	3.24



VII. CONC LUSION

In this study, it ha been foun that with the increase in super plasticizer dosage the workability is increased. So, the r equired slum value fulfilli ng the crite ria of EFNAR C can be obt ained.

For 30% fly ash replacement, the fresh properties observe were good as compared to 10%, 20%, 40% an d 50% fly ash replacemen t. Hence, if we increase the FA replacement we c an have a better workable concrete.

The dos ge of VMA should be prop erly designed as it may change the ba sic criterion o f SCC. In ot her words, he flowability may fall below 500m slump if the dosage of VMA is mor than desired.

The locally avail able Viscosity Modifyi ng Admixtu re (VMA) has a substantial influence on the fres h properties of SCC. A s mall change in VMA dose makes a substantial change in S CC properti s; i.e., flowing ability, passing ability, stability and segregation resistance.

The results of the mechanical properties (compressive, split and flexure strengt) have shown significant performance differences, and the higher compressive strength has been obtained for fly ash replacemen t. Also, the in crease in replacement level has resulte in a decrease in strength f r the increase in fly ash. So, 30% replacement leve l could be of optimum consideration for flowabilit y, mechanical properties a nd durability study.

The acid re sistance of S CC with fly ash was higher when compared with concrete mixes without fly ash at the age of 28, 56 a nd 90 days. Compressi ve strength loss decreas es with the increase in fly ash in con crete.

When the specimen is immersed in sodiumsulphate olution for 28, 56 and 90 days, respectively, the average reduction in weight increases and the weigh t is decreased when fly ash is increase d in the concr ete.

Saturated water absorption percenta ge decreases with the increase in fly ash. For 30% replacement of fly ash, the low water absorption l evel is a good indicator of limited open porosity that can inhibit high flow o f water into the concrete.

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