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STUDY ON DURABILITY PROPERTIES OF SELF COMPACTING CONCRETE MADE WITH M-SAND AND FLYASH

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ABSTRACT

In this project, Self-compacting concrete (SCC) has been developed by using cement, fly ash and manufactured sand and coarse aggregate as main ingredients. Basic fresh properties tests on SCC with various proportions of cement and fly ash have been performed and found that the values of slump flow, V-funnel, and L-box are within the limits prescribed by EFNARC, Manufactured sand is fully replaced as common river sand and fly ash is replaced partially as binder. Common river sand is expensive due to demand and excessive cost of transportation from natural sources. Also large scale depletion of these sources creates environmental problems. Due to the demand of river sand, M-sand can be used and also it is economic alternative to the river sand. M-sand is the residue, failing or their non-valuable waste material after the extraction and processing of rocks to form fine particles less than 4.75mm. Fly ash is replaced as a binder with 10%, 20% and 30%. The effect of presence of fly ash with Super plasticizer was studied. Mix design has been developed for M_{25} grades using the mix design as proposed by EFNARC guidelines. Durability tests are conducted for this concrete and it is done by the tests of acid and chloride attack and water absorption test. The mix with Manufactured sand and fly ash were compared for strength characteristics. The test results confirm that the mixes developed in the present investigations satisfy the requirements for self-compacting concrete.

Keywords: Fine Aggregate, Coarse Aggregate, Cement, Fly Ash,W/C Ratio, Admixture.

I. INTRODUCTION

Cement concrete is the most extensively used construction material in many countries including India. Maintenance and repair of concrete structures is a growing problem involving significant expenditure. Many public agencies already spending 1/3 of the annual infrastructure fund for maintenance and repair of existing structures. Since the beginning of the use of the concrete, strength has been regarded as the most significant and important property of concrete. But it is now well reorganized that the strength of concrete may deteriorate with time, as a result of a combination of various factors that may include moisture ingress, coronation of concrete, reinforcement corrosion, chemical attack, poor quality of material and workmanship. Structure exposed to aggressive environment reveal that the high strength of concrete alone cannot guarantee its long term performance hence there is an urgent need to ensure durability types of structures for achieving economy in the life cycle cost.

II. MATERIALS

2.1. CEMENT

Ordinary Portland Cement (OPC 43 grade) confirming to IS 8112-1989 was used for the entire investigation. The required quantity was procured as single batch, stored in airtight bags and used for experimental program. The physical properties of this cement tested according to standard procedure confirm to the requirements of IS 12269 (1989).

2.1.1 Physical properties of Cement

Table 1: Physical properties of Cement

S.No	Properties	Value
1	Consistency	34 %
2	Initial setting time	35 min
3	Final setting time	300 min
4	Specific Gravity	3.15
5	Fineness	4 %
6	Compressive strength	
	(i) at 3 days	23 Mpa
	(ii) at 7 days	34 Mpa
	(iii)at 28 days	44 pa

2.2 FINE AGGREGATE

Manufactured sand confirming to zone II of IS 383 (1970) is used. The sieve analysis results are given table 2

Table 2: Sieve analysis result for M-sand

Sieve size	% weight retained	Cumulative % weight retained
4.75 mm	0.4	0.4
2.36 mm	15.1	15.5
1.18 mm	25.8	41.3
600 µ	19.8	61.1
300 µ	25.1	86.2
150 µ	10.7	96.9
75 µ	3.1	100
Pan	0	100
Fineness modulus of fine aggregate		3.01

2.2.1 Physical properties of M-sand

The physical properties of M-sand are given in below table 3

Table 3: Physical properties of M-sand

S.No	Properties	Value
1	Colour	Grey
2	Particle shape	More cubical than rounded
3	Specific gravity	2.63
4	Bulk density	1693 kg/m^3
5	Free moisture content in %	Nil
6	Sieve analysis	Zone II
7	Fineness modulus	3.01
8	Product	Manufactured as per IS, BS, ASTM Standards.

The use of M-sand as a replacement of fine aggregate in concrete receiving increased attention. The proper shape, surface texture, desirable grading to minimize void content, a highly workable mix with given parameter of mix design was achieved in the M-sand concrete. So, we get the proper strength mix by the use of crusher sand, fully replaced the river sand.

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2.2.2 Chemical composition of M-sand

The chemical composition contained in the M-sand are given in table 4.

Table 4: Chemical composition of M-sand

Constituent	Value in %
SiO_2	62.48
Al_2O_3	18.72
Fe_2O_3	6.54
CaO	4.83
MgO	2.56
K_2O	3.18
TiO_3	1.21

2.3 COARSE AGGREGATE

The coarse aggregate of size 12.5 mm crushed granite stone supplied from local quarry is used. The coarse aggregate should pass the 12.5 mm size sieve. In this project work, nearly rounded shape gravels are used as coarse aggregate for self compacting concrete, in single size or narrow gradation size.

2.3.1 Properties of Coarse aggregate

The properties of coarse aggregate are given in table 5.

Table 5: Properties of Coarse Aggregate

S.No	Properties	Value
1	Impact value	21 %
2	Crushing value	19.5 %
3	Specific gravity	2.75

2.4 WATER

Water is the important ingredient of concrete, as it actively participates in the chemical reaction with cement. The strength of cement concrete comes from the bonding action of the hydrated cement gel. The requirements of water should be reduced to that required for chemical reaction of hydrated cement, as any excess water would end up in formation of undesirable voids in the hardened cement paste of concrete. The water should be free from acids, organic and deleterious. materials. Hence good quality of potable water was used for mixing purpose.

2.5 FLY ASH

Fly ash also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash that does not rise is called bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Pulverized fly ash in form of extremely small particles and whose chemical constituents are clay minerals in the coal is obtained by the residue from modern thermal power stations. The two main reasons for the use of fly ash concrete which are prone to segregation and that the use of fly ash result in a lowered cost of materials in the finished concrete.

Fly ash is used as a replacement of binder. Specifications for the use of fly ash in concrete are given in CSA A3001, which classifies fly ash as F, CI and CH based on its Calcium oxide content.

Class F fly ash - < 8 % CaO content

Class CI fly ash - 8 % to 20 % CaO content

Class CH fly ash - > 20 % CaO content

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Fly ash is procured from Mettur Thermal Power Plant has been used as replacement of binder. The chemical composition of fly ash are given in table 4.6. In this investigation, class F fly ash is used. The Specific Gravity of Fly ash is 2.2

Table 6: Chemical composition of Fly ash

Chemical properties	Composition in %
SiO_2	45.98
Al_2O_3	23.55
Fe_2O_3	4.91
CaO	18.67
MgO	1.54
Na_2O	0.24
K_2O	1.80
SO_3	1.47
Loss of ignition	2.31
Cl	0.0053

2.6 ADMIXTURES

Admixtures are substances other than the cement, aggregates and water, which are added to concrete. Admixtures can enhance workability and make concrete easier to place under difficult conditions. Admixtures are of two types. They are

(i) Chemical admixtures

(ii)Mineral admixtures.

Chemical admixtures are essential ingredients in the concrete mix, as they increase the efficiency of cement paste by improving workability of the mix and they result in considerable decrease of water requirements. Plasticizers and super plasticizers are used mainly to increase workability in High Performance concrete.

Super plasticizers belongs to two main groups, they are

(i) Sulphonated Melamine formaldehyde condenses

(ii) Sulphonated Napthalene formaldehyde condenses.

Their action is explained by absorption of polyanions on the surface and by cement grains and by generation of negative potential, which eliminates attraction and co-agulation of grains. As a result, the decrease of internal friction is obtained and workability expressed by slump flow of 650 to 800 mm diameter is assured. india.

Usually, super plasticizer is added as 2 to 4 % of cement mass or 5 to 15 lit/m^3 of concrete. By considering the above facts, a **Melamine** based superplasticizer of SP840, Glenium B233 was used in % by weight of cement has been used in this investigation. As per the guidelines, the dosage range is 500 ml to 1500 ml per 100 kg of cementitious material is normally recommended.

The relative density of super plasticizer is 0.01 to 1.08 at 25°C

pH value is greater than 6

Chlorine ion content is less than 0.2%

2.7 MIX PROPORTIONS FOR SCC

Mix design is defined as the process of selecting the suitable ingredients of concreteand determining their relative proportions to produce the concrete for required strength as economically as possible. There is no specific method of mix design for self compacting concrete and high volume fly ash concrete. By trial and error process, the mix proportions are arrivedfor M_{25} grade concrete, by using the available materials and their corresponding properties are discussed below. The mix design is done by referring the code of IS 10262-2009 for conventional concrete and it is verified with the specifications and guidelines provided for Self Compacting Concrete in "EFNARC 2002 and 2005".

The mix proportions for SCC are given in table 7.

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Table 7: Mix proportions for SCC

Grade of concrete	Mix proportions	Water/powder ratio
M_{25}	1:1.51:1.64	0.40

Compressive strength by destructive and non-destructive test and durability tests such as chemical attack and water absorption tests have been conducted on various mixes to study the effect of presence of fly ash with admixtures.The mix proportions for various fly ash mixes are given in table 8.

The Characteristic compressive strength of concrete is 25 N/mm^2.

The target mean strength for this mix of concrete is 38.25 N/mm^2

The mix design is generally based on approach of evaluating the water demand and optimizing the flow and stability of the paste. It also have testing sensitivity for small variation in quantities of the concrete.

Table 8: Details of various Fly ash mixes

Mix Designation	Mix 1	Mix 2	Mix 3
Fly ash (%)	10	20	30
Cement (kg/m^3)	471.43	419.05	366.67
Fly ash (kg/m^3)	52.38	104.76	157.43
Coarse aggregate (kg/m^3)	859.44	859.44	859.44
Fine aggregate (kg/m^3)	792.35	792.35	792.35
Water (lit/m^3)	209	205	202.5
Superplasticizer (kg/m^3)	10.47	10.47	10.47
w/c ratio	0.42	0.42	0.42

2.8 TEST ON FRESH CONCRETE

2.8.1 SLUMP FLOW TEST

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete. This is a simple, rapid test procedure, though two people are needed if the T_{50} time is to be measured. It can be used on site, though the size of the base plate is somewhat unwieldy and level ground is essential. It is the most commonly used test, and gives a good assessment of filling ability. It gives no indication of the ability of the concrete to pass between reinforcement without blocking, but may give some indication of resistance to segregation. As per the guidelines from EFNARC, the diameter of flow of concrete should be in the range of 600 to 800mm within the time of 2 to 5 seconds.

Fig 2.1: Slump cone

Fig 2.2: Diameter of Slump flow

2.8.2 V-FUNNEL TEST

The equipment consists of a V-shaped funnel. The described V-funnel test is used to determine the filling ability (flowability) of the concrete with a Maximum aggregate size of 20mm. The funnel is filled with about 12 litre of concrete and the time taken for it to flow through the apparatus measured. After this the funnel can be refilled concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increase significantly.

This test measures the ease of flow of the concrete; shorter flow times indicate greater flowability. For SCC, a flow time of 10 seconds is considered appropriate. The inverted cone shape restricts flow and prolonged flow times may give some indication of the susceptibility of the mix to blocking. After 5 minutes of settling, segregation of concrete will show a less continuous flow with an increase inflow time. As per EFNARC specifications, the flow time range is 6 to 12 seconds. This test is used to evaluate the ability of the aggregate particles and mortar to flow through a continuously reducing without segregation and blocking of concrete. The V-funnel apparatus with filled concrete is shown in figure 2.3

Fig 2.3: V-funnel apparatus

2.8.3 L-BOX TEST

This test is based on a Japanese design for underwater concrete. The test assesses the flow of the concrete and also the extent to which it is subject to blocking by reinforcement. The apparatus is shown in figure 2.4.

Fig 2.4: L-Box test

The apparatus consists of a rectangular-section box in the shape of an 'L', with a vertical and horizontal section, separated by a moveable gate, in front of which vertical lengths of reinforcement bar are fitted. The vertical section is filled with concrete, then the gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (H_2/H_1). It indicates the slope of the concrete when at rest. This is an

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indication passing ability, or the degree to which the passage of concrete through the bars is restricted. This is a widely used test, suitable for laboratory and perhaps site use. It assesses filling and passing ability of Self Compacting Concrete and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section.

2.9 Interpretation of result

If the concrete flows as freely as water at rest it will be horizontal, So $H_2/H_1 = 1$. Therefore the nearer this test value, the 'blocking ratio', is to unity, the better the flow of the concrete. The EU research team suggested a minimum acceptable value of 0.8. T_{20} and T_{40} times can give some indication of ease of flow, but no suitable values have been generally agreed. Obvious blocking of coarse aggregate behind the reinforcing bars can be detected visually.

Table 9: Workability of self compacting concrete

S.No	Test	Unit	Value			Recommended values
			FA 10 %	FA 20 %	FA 30 %	
1	Slump flow diameter	mm	680	695	710	650-800
	$T_{500\ mm}$	sec	4	4	5	2-5
2	V-funnel	sec	8	8.5	10	6-12
	Time increase ($T_{5\ minutes}$)	sec	2	3	3	0-3
3	L-Box	H_2/H_1	0.86	0.9	0.9	0.8-1.0

2.9.1 TEST ON HARDENED CONCRETE

In hardened concrete, the compressive strength and durability tests are conducted for controlling and confirming the quality of concrete are inseparable part of any quality control program for concrete, which helps to achieve higher efficiency of material used and great assurance of the performance of the concrete with regard to both strength and durability.

2.9.2 COMPRESSIVE STRENGTH TEST

Compressive strength is one of the important properties of concrete. The aim of the experiment is to be the maximum load carrying capacity of concrete. Concrete cubes are casted in the mould size of 150mm x 150mm x150mm, with various mixes of fly ash. After 24 hours from casting, it should be demoulded and cured by soaked into the water. The curing period for the determination of compressive strength is 7 days and 28 days.

Fig 2.5: Compression test

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The bearing surface of the testing machine was wiped clean and the surface of the specimen was cleaned from sand and other materials which may come in contact with the compression plates while placing the cubes in the machine. The axis of the specimen was carefully aligned with the centre of thrust of the spherically seated plate.

The load was applied gradually without shock, increased continuously until the specimen fails to take the load. The maximum load applied to the concrete is recorded. The compressive strength of the specimen was calculated by the following expression:

$$\text{Compressive strength } (N/mm^2) = \frac{\text{Ultimate load}}{\text{Cross sectional area of the specimen}}$$

2.9.3 DURABILITY TEST METHODS

Durability studies were conducted at 3, 7, 14 and 28 days for various mixes of fly ash, to find out the resistance to chemical attack such as acid attack and chloride attack, water absorption test and water permeability test.

2.9.3.1 Chemical attack

The study of chemical action such as sulphuric acid, Hydrochloric acid and sea water effects was studied on the various mixes of fly ash on cube specimen size of 100x100x100 mm at the ages of 28 days. Casting and curing of concrete were made in the respective chemicals for the period of 28 days.

(i) Acid attack

This acid attack test is conducted for determining the durability of concrete, because the soil contain some sulphate in the form of calcium, sodium, potassium, gypsum and magnesium. They occur in soil or ground water. Ammonium sulphate is frequently present in agricultural soil and water from then use fertilizers or from sewage and industrial effluent. Water used in concrete cooling towers can also be a potential source of acid attack on concrete.

The term acid attacks denotes and increase in the volume of cement paste in concreteor mortar due to the chemical action between the products of hydration of cement and solution containing sulphates. Acid attack was tested on 100 mm size cube specimens at the age of 28 days of curing. The cube specimens were weighed and immersed in water diluted with 5% by weight of sulphuric acid for3,7,14 and 28days.

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.

Figure 2.6: Specimen soaked in Acid solution

(ii) Chloride attack

Chloride attack is one of the most important aspects for consideration when durability of concrete was concerned. Chloride attack is particularly important, because its permeability cause corrosion of reinforcement. Statistics have indicated that over 4% of structures are failed due to the corrosion of reinforcement. Chloride enters into the concrete from cement, water, aggregate and sometimes from admixtures. Present day, admixtures are generally containing negligible quantity of chloride. BIS specifies the maximum chloride content in the cement is 0.05%. Chloride can enter the concrete by diffusion from environment.

For each mix of concrete, three specimens were weighed and continuously soaked in water diluted with 5% by weight of hydrochloric acid for 3,7,14 and 28 days of exposure. Chloride attack on concrete may induced expansion and mass loss depending on the chemistry of cement material, permeability of concrete, chloride exposure conditions. Therefore, the chloride exposure specimens were monitored for change in both dimension and mass.

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.

Figure 2.7: Specimen soaked in Chloride solution

2.9.3.2 Water Absorption Test

When excess water in concrete evaporates, it leaves voids inside the concrete element creating capillaries which are directly related to the concrete porosity and permeability. By proper selection of ingredients and mix proportioning and following the good construction practices almost impervious concrete can be obtained. The flow of water through concrete is similar to flow through any porous body. The pores in cement paste consist of gel pores and capillary pores. The pores in concrete as a result of incomplete compaction are voids of larger size which give a honeycomb structure leading to concrete of low strength.

Due to problems associated with the absorption test and permeability tests, measures the response of concrete to pressure, which is rarely the driving force of fluids entering concrete, there is a need for another type of test. This test should measure the rate of absorption of water by capillary suction, “sorptivity” of unsaturated concrete.

The 150mm x 150mm x 150mm size concrete cubes were used for this test. After casting, the cubes were immersed in water for 28 days curing. These specimens were surface dried for few hours only. Then it is weighed. This weight was noted as the surface dry weight (W_1) of the cube. Then the specimen is oven dried for 24 hours at the temperature110°C until the mass became constant and again weighed. This weight was noted as the dry weight (W_2) of the cube. After that the specimen was kept in water for 24 hours and take it out and again weight it. Then this weight was noted as the wet weight (W_3) of the cube.

The water absorption for the concrete cube specimen was observed in percentage. The figure 2.8 and 2.9 are the cubes dried in oven and the cubes were soaked in ordinary water for determining the amount of water absorbed into the concrete.

Figure 2.8: Oven drying of specimen

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Figure 2.9: Specimen immersed in water for absorption

The water absorption of the concrete specimen has been determined by the following expression.

$$\text{Percentage water absorption} = \frac{(W3-W2)}{W2} x\ 100$$

Where, W_1 = Surface dry weight of cube in grams

W_2 = Oven dry weight of cube in grams

W_3 = Wet weight of cube after 24 hours in grams.

2.10 NON-DESTRUCTIVE TEST

There are several in-situ Non-Destructive test method are available to access the condition of building structures. Ultrasonic pulse velocity and Rebound Hammer tests are most frequently used, to determine the physical properties of concrete without crushing the concrete.

(i) Ultrasonic Pulse Velocity Test

This test helps to access the integrity and homogenity of concrete flow detection, de-lamination, depth of crack and presence of honey combs etc. Ultrasonic scanning is a recognized non-destructive test method and it confirms to BS:4408 to ASTM:597 and also IS 13311 (part I)-1992. This test is basicallya wave propagation test and consist of transmitting ultrasonic pulse of 50-60 Hz frequency through concrete medium and measuring the travel time of ultrasonic pulses for known measured length.

The main object of this test is to determine the compressive strength of concrete without destruct the concrete. Also to measure the velocity of the pulses of longitudinal vibrations passing through concrete. There is a reduction in the pulse velocity, if the concrete under test has low compaction, voids or damaged material.

Table 10: Quality of concrete

Pulse Velocity (km/s)	Quality of concrete
4.0 and greater	Excellent
4.0 – 3.5	Good
3.5 – 3.0	Satisfactory
Less than 3	Poor integrity

The pulse velocity increases or decreases as the concrete matures or deteriorates or change with time. In this Ultrasonic Pulse velocity experimental, PUNDIT (Portable Ultrasonic Non destructive Digital - Indicating Tester) unit is used. The ultrasonic pulse velocity is found out by direct transmission on concrete cubes.

In this test, two methods are used to find the pulse velocity. They are

- ✓ Direct method
- ✓ Semidirect method.

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(a) Direct method


(b) Semi-direct method

Figure 2.10: Ultrasonic Pulse Velocity Test

III. RESULTS AND DISCUSSION

3.1 GENERAL

In this chapter, the results of the experimental investigations are carried out are presented. The compressive strength for destructive and non-destructive test and the durability test on the concrete specimens are discussed.

3.2 RESULT OF COMPRESSIVE STRENGTH TEST

The test conducted on the cubical concrete specimen of size 150 x 150 x 150mm and the age of testing of the specimens are 7 days and 28 days.

Table 3.1: Compressive strength test result for various Fly ash mixes at 7 days

Fly ash Mix (%)	Sample No	Ultimate load (tonnes)	Compressive strength (N/mm²)	Mean Compressive strength (N/mm²)
10	1	68	29.65	30.52
	2	72	31.39	
	3	70	30.52	
20	1	58	25.29	26.16
	2	62	27.03	
	3	60	26.16	
30	1	51	22.24	23.11
	2	55	23.98	
	3	53	23.12	

Table 3.2: Compressive strength test result for various Fly ash mixes at 28 days

Fly ash Mix (%)	Sample No	Ultimate load (tonnes)	Compressive strength (N/mm²)	Mean Compressive strength (N/mm²)
10	1	73	31.83	33.14
	2	76	33.14	
	3	79	34.44	
20	1	76	33.14	32.26

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	2	72	31.39	
	3	74	32.26	
30	1	70	30.52	30.52
	2	69	30.08	
	3	71	30.96	

3.3 RESULT OF CHEMICAL ATTACK

3.3.1 ACID ATTACK

The compressive strength test can be carried out by the help of Compression Testing Machine for destructive test and Ultrasonic Pulse velocity testing instrument for non-destructive test of concrete.

(a) Observation of Result

The acid attack on the self compacting concrete cube specimen of various fly ash mixes are given in the table 3.3. The loss of weight of the cubes is increases with increases of fly ash content in the concrete. The compressive strength of acid exposed concrete cubes is gradually decreasing with the increases of fly ash content.

(b) Physical observation

Golden yellow coloured patches were formed on the surface of concrete of all the fly ash mixes. All the grade of mix is eroded slightly. The fine aggregate was visually seen on all the concrete specimen.

Figure 3.1: Acid attacked concrete cubes

Table 3.3: Compressive Strength of Cube Immersed in Sulphuric acid Solution

Fly ash Mix (%)	Weight (Kg)		Loss of weight		Compressive strength (N/mm²)	Mean Compressive strength (N/mm²)
	Initial	Final	in Kg	in %		
10	2.510	2.505	0.005	0.19	23.54	23.21
	2.575	2.570	0.005	0.19	23.54	
	2.590	2.580	0.010	0.38	22.56	
20	2.565	2.550	0.015	0.58	21.58	20.93
	2.630	2.620	0.010	0.38	19.62	
	2.620	2.605	0.015	0.57	21.58	
30	2.350	2.325	0.025	1.06	21.58	19.62
	2.545	2.520	0.025	0.98	17.66	
	2.600	2.570	0.030	1.15	19.62	

3.3.2 CHLORIDE EFFECT

The compressive strength values of specimen immersed in hydrochloride solution were tabulated in table 3.4. The compressive strength test can be carried out by the help of Compression Testing Machine for destructive test on concrete.

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Table 3.4: Compressive Strength of Cube Immersed in Chloride Solution

Fly ash Mix (%)	Weight (Kg)		Loss of weight		Compressive strength (N/mm²)	Mean Compressive strength (N/mm²)
	Initial	Final	in Kg	in %		
10	2.625	2.620	0.005	0.19	32.37	31.06
	2.590	2.585	0.005	0.19	29.43	
	2.595	2.590	0.005	0.19	31.39	
20	2.590	2.580	0.010	0.38	23.54	23.54
	2.565	2.555	0.010	0.38	24.52	
	2.590	2.570	0.020	0.77	22.56	
30	2.490	2.475	0.015	0.60	19.62	19.95
	2.495	2.475	0.020	0.80	20.60	
	2.495	2.475	0.020	0.80	19.62	

(a) Observation of Result

The chloride attack on the self-compacting concrete cube specimen of various fly ash mixes are given in the table 3.4. The loss of weight of the cubes is increases with increases of fly ash content in the concrete.

The compressive strength of chloride exposed concrete cubes is gradually decreasing with the increases of fly ash content.

The percentage loss of strength is higher in fly ash content compared to other chemicals.

(b) Physical observation

Brownish yellow colored patches were formed on the surfaces of the concrete on all the fly ash content mixes. The aggregates are visually seen in the exposed surfaces of concrete specimens. All the grade of mix is eroded slightly.

Figure 3.2: Chloride attacked concrete cubes

3.4 LOSS OF WEIGHT FOR DIFFERENT EFFECTS

The percentage loss of weight increases with the fly ash content. The loss of weight is severe in H_2SO_4 exposure condition. The percentage loss of weight for different types of exposure conditions was given in table 3.5.

Table 3.5: Percentage loss of weight for different types of exposure conditions

Fly ash mix (%)	Loss of weight (%)	
	HCL	H_2SO_4
10	0.19	0.25
20	0.51	0.51
30	0.67	1.06

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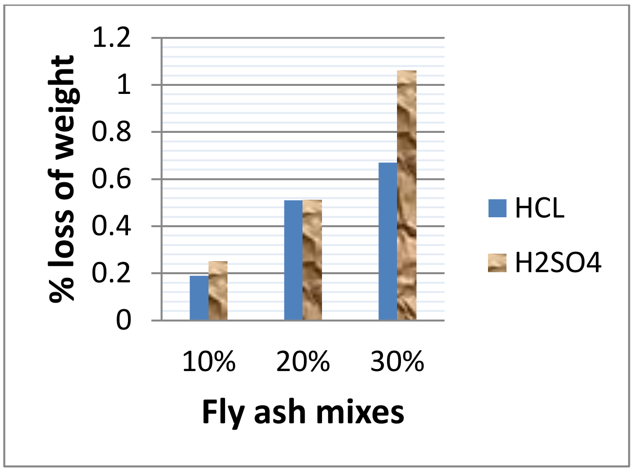

Figure 3.3: Percentage loss of weight in different exposure conditions

3.5 LOSS OF STRENGTH FOR DIFFERENT EFFECTS

The percentage loss of strength increases with the fly ash content replacement for all the types of exposure conditions. The loss of strength was severe in hydrochloric acid for all the mixes of concrete. The loss of strength was minimum in sea water exposure condition. The percentage loss of strength for different types of exposure conditions were given in the table 3.6.

Table 3.6: Percentage loss of strength for different types of exposure conditions

Fly ash mix (%)	Compressive strength (N/mm^2)			Loss of strength (%)	
	Water	HCL	H_2SO_4	HCL	H_2SO_4
10	33.14	31.06	23.21	6.27	29.96
20	32.26	23.54	20.93	27.03	35.12
30	30.52	19.95	19.62	34.63	35.71

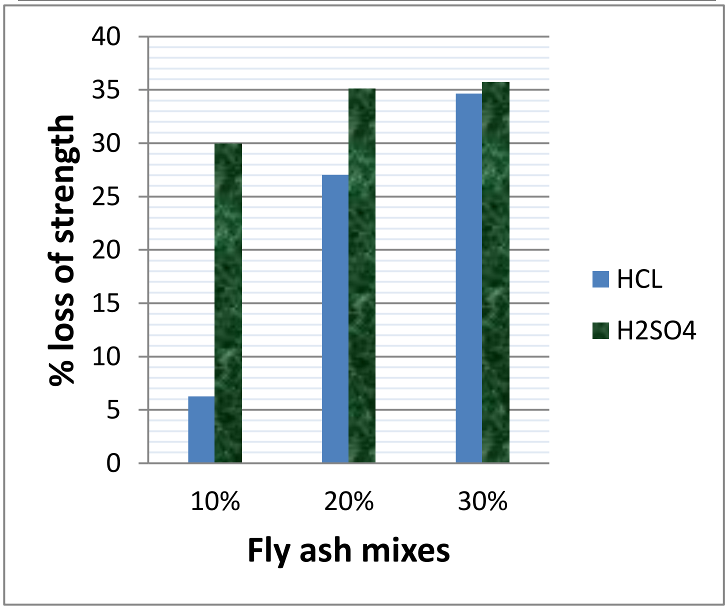

Figure 3.4: Loss of strength in different exposure conditions

3.6 RESULT OF WATER ABSORPTION TEST

The table 3.7 gives the water absorption test results of percentage replacement of fly ash in concrete for 28 days curing. The percentage replacement versus percentage water absorption results are graphically shown in figure 3.5

Table 3.7: Average % water absorption at 28 days for different Fly ash mixes

Fly ash mix (%)	Dry weight in gm (W_2)	Wet weight in gm (W_3)	% water absorption	Average % water absorption
10	8.390 8.290 8.500	8.490 8.395 8.575	1.19 1.26 0.88	1.11
20	8.215 8.265 8.540	8.310 8.355 8.620	1.16 1.08 0.93	1.06
30	8.865 8.220 8.645	8.950 8.295 8.725	0.95 0.91 0.92	0.92

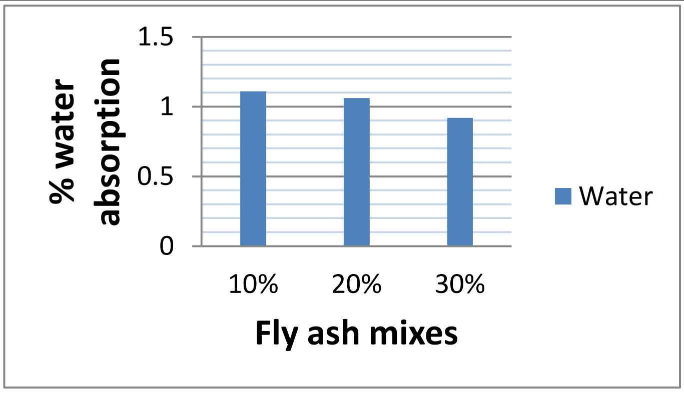

Figure 3.5: Percentage water absorption of concrete

3.7 RESULTS OF NON–DESTRUCTIVE TEST

The results of non-destructive test are given in table 3.8. The non-destructive test gives the result 20% less than the results given by the compressive strength by destructive test in all the types of exposure conditions of concrete.

Table 3.8: Compressive strength test results for Non-destructive test

Fly ash mix (%)	Compressive strength (N/mm^2)			Mean Compressive Strength (N/mm^2)		
	Water	HCL	H_2SO_4	Water	HCL	H_2SO_4
10	38.5 36.5 35.6	35.8 34.6 33.3	32.3 31.8 31.4	36.87	34.57	31.83
20	34.2 32.0 31.3	33.6 31.8 32.3	30.9 30.1 29.6	32.5	32.57	30.2
30	31.8 30.9 29.0	32.0 30.1 28.6	26.2 25.2 24.3	30.57	30.23	25.23

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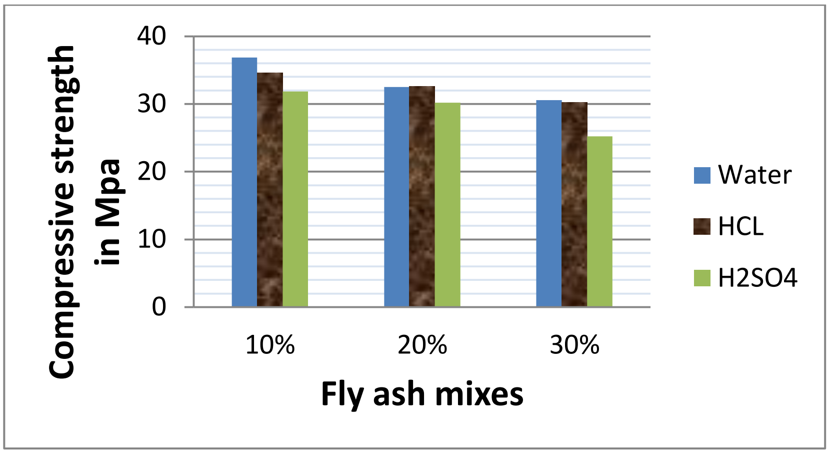

Figure 3.6: Non-Destructive Compressive strength

IV. SUMMARY

In this investigation, 18 cubes are casted for the determination of compressive strength, 27 cubes for durability studies such as chemical exposure, effect of marine environment and 9 cubes for the water permeability test. All the test, fly ash content is replaced by 10%, 20% and 30% by the weight of cement. For each fly ash mixes, three number of samples were casted for taking the average value of test. This study is conducted with the use of super plasticizer in various proportions of fly ash in concrete. The presence of super plasticizer in this concrete gives the better durability characteristics in various mixes of fly ash in concrete.

V. CONCLUSION

The following conclusions are drawn based on the present investigations discussed:

- In the case of acid attack, the loss of weight is predominant in addition to the reduction of strength.
- In chloride attack, the strength of concrete is reduced in severe condition when compared to the other chemical effect of the concrete.
- For all the mixes of concrete, under aggressive environment only slight variation was found in the weight loss of cube specimens.
- The compressive strength of concrete is decreased with increases of fly ash content in the concrete.
- The non-destructive test gives the result 20% less than the results given by the compressive strength by destructive test in all the types of exposure conditions of concrete.
- Water absorption in concrete is decreased with the increases of fly ash content in the concrete.

VI. SCOPEOF FURTHER WORK

In this project work, the compressive strength for destructive and non-destructive test and the durability tests are studied for self compacting concrete.

In future, the following works may be carried out on the self-compacting concrete.

- Experimental study on self compacting concrete with different combination of sizes of coarse aggregate.
- Experimental study on self compacting concrete by using various types of admixtures.
- Experimental study on self-compacting concrete with replacing of cement by Pozzolanic materials.
- Other materials are replaced as the fine aggregate, other than M-sand and river sand.
- Other durability properties such as Corrosion resistance test, sea water effect, impact, abrasion resistance, creep, shrinkage, water permeability testetc. can be studied.
- Fly ash content can also be changed for further investigations.

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