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A STUDY ON DURABILITYOF SELF COMPACTING CONCRETE IMMERSED IN ACIDIC SOLUTIONS -A REVIEW

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Abstract-The basic philosophy in the construction of every structure is it should perform its intended functions successfully through the expected and anticipated life time, irrespective of external exposure conditions. The ability of the concrete is to resist and withstand any environmental conditions that may result in early failure or severe damages and it is a major concern to the engineering professional. Out of all the deteriorating agents acid attack is one of the phenomena that plays a vital role in disintegrating concrete structures depending on the type and concentration of the acid. Certain acids are harmless. The present investigation focused on durability of concrete and the effect of $H2So_4$ and HCL on High Strength Self Compacting Concrete. This paper investigates the study of workability and durability characteristics of Self-Compacting Concrete (SCC) with Viscosity Modifying Admixture (VMA), and containing Class F fly ash. For 10%,20%30%, The mix design M35,M40,M80 for SCC was arrived as per the Guidelines of European Federation of National Associations Representing for Concrete (EFNARC). The super plasticizer used was Glenium B233 and the viscosity modifying agent used was Glenium Stream 2. The experiments are carried out by adopting a water-powder ratio of 0.45. Workability of the fresh concrete is determined by using tests such as: slump flow, T50, V-funnel, L-Box and U-box tests. The durability of concrete is tested by acid resistance, sulphate attack and saturated water absorption at the age of 7 days and 28 ,56 days

Keywords: Self Compacting Concrete, Durability, deterioration, Compressive strength, viscosity modifying agents,Acids,,sulphates,chlorides

I. Introduction

If we go through the annals of concrete history it reveals that for a long time concrete was believed to be very durable material requiring a little or no maintenance to the large extent the assumption may be true except when it is exposed to highly aggressive environment. The impression that concrete is very durable material is being threatened because the structures constructed in highly polluted urban and industrial areas, aggressive marine environments, harmful sub soil water in coastal areas and many other hostile conditions are being deteriorated, hence the longevity of these structures is reduced. In the past, earlier to 1930 the strength of the concrete was only considered in the concrete mix design procedure, since it was believed that strength of the concrete is an all pervading factor for all other desirable properties of concrete.

This paper throws light on durability of high strength self compacting concrete. It is believed that it is very much appropriate to discuss the strength and durabilityrelationship, impact of water/cement ratio, permeability and effects of acids, chlorides and sulphates on durability of concrete.

II. Self Compacting Concrete (SCC)

The exponential growth of population, rapid industrialization and increasing urbnization has tremendously enhanced the demand for infrastructure. In the process of creation of infrastructure the role of concrete has become very significant. Concrete was found to be one of the essential and indispensable materials to fulfill the need of construction industry. The flexibility, suitability and adoptability of the concrete have increased its utility at every stage of construction of structures. The strength and the durability of concrete depend up on the degree of compaction. The desirable workability may be achieved through vibration, but it is not possible to ensure full compaction. Hence inadequate compaction leads to the formation of large number of voids. The voids left in the concrete may reduce the strength and durability of concrete. The self compacting concrete has emerged as the panacea for this problem. Making concrete structures without vibration is not a new concept it has been existed in the past but the strength of those concretes were very low. The modern application of self compacting concrete (SCC) is focused on high strength, high performance and more reliable uniform quality. The contribution of researchers at the University of Tokyo, Japan led to the development of SCC that doesn’t require vibration to achieve full compaction. Soon after its development it has become popular in Japan for prefabricated products and ready mix concrete. The successful use of SCC in Japan has drawn the attention of several European countries. They too have worked and formed a European federation (EFNARC) and gave design specifications, guidelines to produce and use high quality SCC.

III. Literature Review

Ganesan Net. al studied the effect to f steel fibres on the durability parameters of self-compacting concrete (SCC) such a spermeability, water absorption, abrasion resistance, resistance to marine as well as sulphate attack and concluded that addition of steel fibres improved the durability aspects of self compacting concrete.

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S.Venkateshwara Rao et.al aims at developing standard and high strength Self Compacting Concrete with different sizes of aggregate based on Nansu's mix design procedure. Also, fly ash optimization is done in study with the graded course aggregate.

SeshadriSekhar.Tet.alstudiedon theeffectofglassfibers onthedurabilitypropertiesof glassfibreselfcompacting concretefordifferentgradesofconcretesM30toM65and also discussed about durability factors also. **Seshadri Sekhar.T[(8)]** et.aldevelopedthehighstrengthselfcompacting concreteusingmineraladmixtures.

Dhiyaneshwaran.S, Ramanathan.P, Baskar.I and Venkatasubramani.R (2013) In their experimental investigations they studied the workability and durability characteristics of self-compacting concrete (SCC) with viscosity modifying admixture (VMA) and containing class F Fly ash. The mix design for SCC was arrived as per the guidelines of EFNARC. In this investigation, SCC was made by usual ingredients such as cement; fine aggregate, coarse aggregate, water and mineral admixture fly ash at various replacement levels (10%, 20%, 30%, 40% and 50%). The super plasticizer used was glenium B233 and the viscosity modifying agent used was glenium stream 2. The experiments are carried out by adopting a water-powder ratio of 0.45. Workability of the fresh concrete is determined by using tests such as slump flow, T_{50} , V-funnel, L-Box and U-Box tests. The durability of concrete is tested by acid resistance, Sulphate attack and saturated water absorption at the age of 28, 56 and 90days.

IV. Present Study:

The present study, shows the behavior and strength changes of M40 grade SCC with partial replacement of cement with In mineral admixture Fly Ash after curing the cubes with acids (HCl & H_2So_4) for 14,28,and 56 days by comparing with normal curing. Rational method of mix design was adopted for mix design of M40 grade SCC for the trial mixes in the absence of BIS code for SCC mix design. Based on these studies, inference was drawn for durability of structures exposed to such aggressive environment.

The aim of the present study is also to identify and estimate the effect of $H_2 S0_4$, HCL and Na_2So_4 on concrete made up of micro silica, and super plasticizer. The work ability studies are also conducted and the durability of the concrete is studied against the attack of $H_2 So_4$, HCL

IV.I Durability Study

Its ability to resist weathering action, chemical attack, abrasion or any other process of deterioration.

In order to study the durability characteristics, that is, the sulphate attack and chloride attack the SCC cubes were immersed in sodium chloride and Magnesium sulphate solutions. The cubes were demoulded and dipped in the respective solutions. Then the cubes were taken from the solutions after 7, 14, 28, 56, 90 days and their corresponding compressive strengths were noted. Sodium chloride solution of three different strengths was used. Salt content of soil is 0.5M so 0.25,

0.5 and 0.75M was used. Similarly Magnesium sulphate solution was also of three different strengths. They are4% MgSO4, 5% MgSO4, 6% MgSO4 were used

Fly ashType-II flyash confirming to I.S. 3812 –1981of IndianStandardSpecificationwasusedasPozzolanaAdmixture

V. Acids

Sulphuric acid: Sulphuric acid attack cause extensive formation of gypsum in the region close to the surfaces and tends to cause disintegration, mechanical stress which ultimately lead to spaling and exposure of the fresh surface. Owing to the poor penetration of sulphuric acid, the chemical changes of the cement matrix are restricted to the regions close to the surface. However, in some cases it is observed that deterioration process occurs accompanied by the scaling and softening of the matrix due to early decomposition of calcium hydroxide and the subsequent formation of large amount of gypsum.

The chemical reaction involved in sulphuric acid attack on cement based materials can be given as follows

$Ca(OH)_2+H_2SO_4 \rightarrow CaSO_4.2H_2O$

$3CaO.2SiO_2.3H_2O+H_2SO_4 \rightarrow CaSO_4.2H_2O+Si(OH)_4$

Hydrochloric acid: The chemical formed as the products of reaction between hydrochloric acid and hydrated cement phases are some soluble salt and some insoluble salts. Soluble salts mostly with calcium, are subsequently leached out, whereas insoluble salts along with amorphous hydrogels remain in the corroded layer. Besides dissolution, the interaction between hydrogels may also result in th formation of some Fe-Si, Al-Si, Ca-Al-Si complexes which appear to be stable in Ph range above 3.5

$Ca(OH)_2+2HCl \rightarrow CaCl_2 +2H_2O$

The reaction essentially causes leaching of $ca(OH)_2$from the set cement. After leaching out of $Ca(OH)_2$, C-S-H and ettringite start to decompose, with release of ca^{2+} to counteract the loss in $Ca(OH)_2$ and the set cement starts to disintegrate accelerating the dissolution

$Ca_6Al_2(SO_4)_3(OH)_{12}.\ 26H_2O \rightarrow 3Ca_2^{+} +2[Al(OH)_4]^{-} +4OH^{-}+26H_2o$

$3Ca^{2+}+2[Al(OH)_4]^{-}+4oh^{-} +12HCl \rightarrow 3CaCl_2+2AlCl3+12H_2o$

There are few indications through experiments about the formation of friedel's Salt $C_3A.CaCl_2.10H_2O$ by the action of $CaCl_2$, formed due to reaction of HCl with CH and C_3A. Hydrochloric acid attack is a typical acid corrosion which can be characterized by the formation of layer structure

Exposure Of Concrete To Acid:

Concrete is an important versatile construction material, used in wide variety of situations. So it is very important to consider its durability as it has indirect effect on economy, serviceability and maintenance. Concrete is not fully resistance to acids. Most acid solutions will slowly or rapidly disintegrate Portland cement concrete depending upon the type and concentration of acid. Certain acids, such as oxalic acid and phosphoric acids are harmless. The most vulnerable part of the cement hydrate is Ca(OH)2, but C-S-H gel can also be attacked. Siliceous aggregates are more resistance than calcareous aggregates. Concrete can be attacked by liquids with PH value below 6.5, but the attacks are severe only at a PH below 5.5, below 4.5 the attack is very severe. As the attack proceeds, all the cement compounds are evenly broken down and leached away, together with any carbonate aggregate material. With the sulphuric acid attack, calcium sulphate formed can be proceed to react with calcium aluminate phase in cement to form calcium sulphoaluminate, which on crystallization can cause expansion and disruption of concrete. If acids or salt solutions are able to reach the reinforcing steel through cracks or porosity of concrete, corrosion can occur which will cause cracking.

Acid Attack – Mechanism:

Concrete being very alkaline in nature, is extremely susceptible to acid attack. The mechanism for this process is very simple. The products of cement hydration are shown below.

CS + H $\rightarrow$C-S-H + CH

Calcium Silicate + Water $\rightarrow$ Calcium Silicate Hydrate + Calcium Hydroxide

Acid attack is caused by the reaction of an acid and the calcium hydroxide portion of the cement paste which produces a highly soluble calcium salt by product. These soluble calcium salts are easily removed from the cement paste thus weakening the paste's structure as a whole. This basic reaction is shown below.

Acid X + CH $\rightarrow$ CX + H

Acid + Calcium Hydroxide$\rightarrow$ Calcium Salt + Water

More aggressive acids such as hydrochloric, acetic, nitric, and sulphuric acids produce calcium salts that are very soluble. Less aggressive acids such as phosphoric and humic acids produce calcium salts with a lower solubility. These low soluble salts can act as a partial inhibitor to the overall process by blocking tiny passage in the cement paste through which water flows. This reduces the amount of calcium salts that enter into solution and retard the overall process.

A more aggressive and destructive case of acid attack occurs when concrete is exposed to sulphuric acid. The calcium salt produced by the reaction of the sulphuric acid and calcium hydroxide is calcium sulphate which in turn causes an increased degradation due to sulphate attack. This process is illustrated below.

$H_2SO_4 + Ca(OH)_2 \rightarrow Ca(SO)_4 + 2H_2O$

Acid + Calcium Hydroxide $\rightarrow$Calcium Sulphate+ Water (calcium sulphate product contributes to sulphate attack)

The dissolution of calcium hydroxide caused by acid attack proceeds in two phases. The first phase being the acid reaction with calcium hydroxide in the cement paste. The second phase being the acid reaction with the calcium silicate hydrate. As one would expect the second phase will not begin until all calcium hydroxide is consumed. The dissolution of the calcium silicate hydrate, in the most advanced cases of acid attack, can cause severe structural damage to concrete.

VI. Influence of Sulphate Attack On Concrete

Most of Soils contain sulphate residues in the form of Calcium, Sodium, Potassium and magnesium. Most of them are present either in soil or ground water. As the solubility of Calcium sulphate is low, ground water contains more quantities of other sulphates rather than calcium sulphates, the presence of Ammonium sulphate is predominant in agriculture soils and industrial effluents. Industrial structures exclusively concrete cooling towers are subjected to sulphate attack. Therefore the affect of sulphate on concrete structures is unavoidable. The intensity of sulphate attack is more severe when it attacks in solution form by entering the porous concrete and reacts with hydrated ccement products, rather than its affect in solid form. Magnesium sulphate causes more damage to concrete than other sulphates, sulphate attack may be evidenced in the form of whitish appearance.The sulphate attack may be evidenced when an increase in the volume of cement paste in concrete takes place during the chemical action between the product of hydration of cement and solution containing sulphates. In the hardened state of concrete C-A-H reacts with sulphate salt from outside calcium sulpho alluminate, as this product of the reaction responsible for increase of volume up to 27 percent, causes disintegration of concrete

The following equations represent the reactions of various sulphates with hardened cement paste; equation (1) shows how sodium sulphate is attacking

Ca (OH)2, Ca (OH)2 + Na2 So4.10 H2→CaSo4.2H2O + 2NaOH + 8H2O

Equation (2) shows the reaction of sodium sulphate with Calcium Aluminate Hydrate,

2(3CaO Al2O3.12 H2O) + 3(Na2So4.10 H2O) → 3CaO.Al2O3.3CaSo4.31H2O+2Al(OH)3+6NaOH+17H 20

In this reaction calcium Sulphate attacks only calcium aluminate and produce calcium Sulpho aluminate (3CaO.Al2O3.3CaSo4.32H2O) known as attringite, the molecules of water may be 32 or 31.

In fact the strength of the solution increases the rate of sulphate attack on concrete High water/cement ratio causes serious damage to concrete with in short duration of time. The concrete with low water/cement ratio reduces the intensity of damage by resisting the impact of magnesium sulphate.

VII. Test on acid attack of high strength self-compacting concrete using mineral admixtures

The chemical resistance of the concrete was studied through chemical attack by immersing test specimens of size 150 X150 X 150 mm cubes in 5% sulphuric acid (H2So4) solution and 5% hydrochloric acid(Hcl) solution and in normal water(H2o) to compare the strength and weight loss between water and acid curing respectively. The deterioration of specimens are presented in the form of percentage reduction in weight and percentage reduction in compressive strength concrete of specimens at 14, 28 and56 days. After period of curing the specimens were removed from the curing setup and their surfaces were cleaned with soft nylon brush to remove weak reaction products and loose material from the specimen. The initial weights were measured and the specimens were identified with number

The following test methods have been used to produce the concrete with above said workable conditions.

Characteristic	Test method	Measured value
Flowability/ filling ability	Slump-flow	total spread
	Kajima box	visual filling
Viscosity/ flowability	T_{500}	flow time
	V-funnel	flow time
	O-funnel	flow time
	Orimet	flow time
Passing ability	L-box	passing ratio
	U-box	height difference
	J-ring	step height, total flow
	Kajima box	visual passing ability
Segregation resistance	penetration	Depth
	sieve segregation	percent laitance
	settlement column	segregation ratio

Table - I

Test Results For Fresh SCC M40

S.NO	METHOD	UNITS	VALUE
1	Slump flow test	Mm	721
2	V-Funnel Test	Sec	10
3	L Box test	h_2/h_1	0.87

Table - II

Test Results For Fresh SCC M80

Grade	M80
Slumpflowmm)	661.41
T50(sec)	5.00
V-funnel(sec)	12.00
L-Box(h2/h1)	0.9

Table - III

VIII. Impact of water/cement ratio on durability of concrete

The impact of water/cement ratio is very much significant on concrete. The increase in water quantity leads to the presence of more water this will become a contributory factor for volume change therefore higher water/cement ratio leads to higher permeability. The use of higher water /cement ratio leads to consecutive and cyclical disruptive actions. Higher water/cement ratio increases permeability, higher permeability causes volume change, volume change result in cracks, cracks causes disintegration of the structure eventually structure will be failed. Hence lower water/cement ratio is always needed to produce more durable, dense and impermeable concrete. The impact of water/cement ratio is greatly visible and identifiable in the micro-structures of the concrete. The effect of chloride ions on the concrete made of low water/cement ratio is very much slower than in the concrete with higher water/cement ratio. The reaction is 10-50 times slower than that of higher water/cement ratio concrete. It has already been proved that low water/cement ratio concretes are less sensitive to carbonation affect, rather than higher water/cement ratio on concrete.

In actual practice maintaining low water/cement ratio i.e. lower than 0.4 had been very difficult. The advent of modern super plasticizers had made it easy to produce the concrete even at 0.25 to 0.20 water/cement ratios. We could able to make a high strength and high performance self compacting concrete at 0.24 water/cement ratio.

Out of all the factors influence the durability of concrete chemical attack is a chief factor which is responsible for deterioration of structures by causing volume change and cracking. When we study the chemical action on concrete we shall have to study sulphate attack, alkali – aggregate reaction, carbonation, acid attack and effect of sea water.

Mix Proportion for 1m3 SCC

Cement Fine Aggregate Coarse Aggregate Fly Ash Water Admixture 376 Kg 514.14 Kg 649.9 Kg 505.7 Kg 203 l 6 Kg

IX.Mixture Proportions

Mix proportion of SCC (M40)

Mix (M40)	Cement	Fly ash	SAND	C.A	WATER	SP	VMA
CM	1	0.4703	2.3142	1.7885	0.6105	0.015	0.0049
SCC 1	0.90	0.5703	2.3142	1.7885	0.6105	0.015	0.0049
SCC 2	0.80	0.6703	2.3142	1.7885	0.6105	0.015	0.0049
SCC 3	0.70	0.7703	2.3142	1.7885	0.6105	0.015	0.0049

Table - IV

SCC (M40) mix design ratios

Cement	CA	FA	Fly ash	Water	SP	VMA
391.638	700.434	906.337	184.187	239.094	5.875	1.958
1	1.7885	2.3142	0.4703	0.6105	0.015	0.0049

Table - V

X. Test results:

The following tables gives the test results of compressive strength of self-compacting concrete with the addition of fly ash admixture at different percentages after the effect of normal(water) and acid curing (HCL & H_2SO_4).

Fig .I

Compressive Strength Test of Cube

The following results are the compressive strengths of self-compacting concrete of M40 grade with different percentages of fly ash mix after curing the cubes in normal water at 14, 28, 56 days.

showing Strengths of cubes immersed in normal water

Mix type	Strength in Mpa		
	14 days	28 days	56 days
SCC Normal	38.01	56.17	62.02
FA 10%	35.43	54.57	61.85
FA 20%	32.21	50.63	58.34
FA 30%	31.68	46.53	54.89

Table - VI

Fig .II

SCC cube on effect of sulphuric acid curing.

The following results are compressive strengths of self-compacting concrete of M40 grade with different percentages of fly ash mix after curing the cubes with 5% concentration of sulphuric acids at 14, 28, 56days

Table 4.2 Strength of cubes immersed in sulphuric acid of 5 % concentration

Mix type	Strength in Mpa		
	14 days	28 days	56 days
SCC Normal	35.21	54.34	59.37
FA 10%	34.23	51.03	59.63
FA 20%	32.53	49.52	57.26
FA 30%	30.95	44.93	52.68

Table - VII

SCC cube with the effect on hydrochloric acid curing The following results are compressive strengths of self-compacting concrete of M40 grade with different percentages of fly ash mix after curing the cubes with 5% concentration of hydrochloric acids at 14, 28, 56 days

Strength of cubes immersed in hydrochloric acid of 5 % concentration

Mix type	Strength in Mpa		
	14 days	28 days	60 days
SCC Normal	35.23	54.93	62.53
FA 10%	35.07	52.85	12.09
FA 20%	33.62	51.83	58.34
FA 30%	30.43	44.34	53.32

Table - VIII

Grade	Average weight without chemical Immersion(Kg)	Name of the Chemical used(5%)	Decrease weight after 28 day chemical immersion(Kg)	percentage decrease in weight after 28 days
M40	2.16	Hydrochloric Acid	2.11	9.26
M40	2.19	Sulphuric Acid	2.49	11.62

Table - IX

Grade	Compressive strength without chemical immersion	Chemical used (5%)	Decrease in Compressive strength after 28 day chemical immersion	percentage decrease in compressive strength after 28 days
M80	82 N/mm^2	HCL	68.62 N/mm^2	16.31
M80	82 N/mm^2	H_2SO_4	43.40 N/mm^3	47.07

Table - X

Solution	Average Compressive Strength (MPa)			
	7^{th} Day	14^{th} Day	28^{th} Day	56^{th} Day
Control Concrete(water curing)	46.65	54.51	67.70	69.18
NaCl 0.25M	43.55	50.51	60.40	61.23
NaCl 0.5M	40.42	46.82	56.21	57.30
NaCl 0.75M	37.32	43.21	52.32	53.02

Table – XI :Cubes of M35 immersed in chloride solution

Solution	Average Compressive Strength (MPa)			
	7^{th} Day	14^{th} Day	28^{th} Day	56^{th} Da
Control Concrete (water curing)	46.65	54.51	67.70	69.18
4% $MgSO_4$	45.46	51.56	60.00	60.89
5% $MgSO_4$	43.56	49.16	58.20	57.24
6% $MgSO_4$	42.52	47.26	56.80	55.45

Table - XIICubesM35immersed in sulphate solution

XI. Graphs:

The following graphs shows the strength variations with respective to time with normal and acid curing.

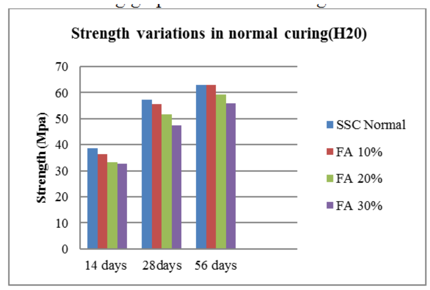

Fig .III

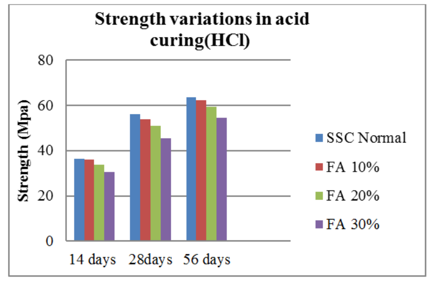

Fig .IV

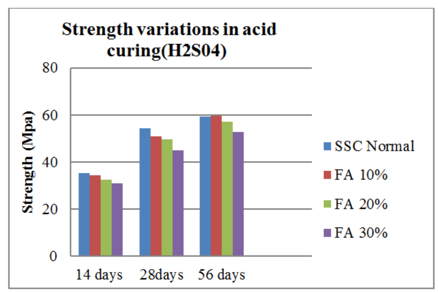

Fig .V

Percentage Loss of weight of specimens after immersing in 10% HCL Solution

The percentage loss of weight is observed to be 1.68% for 28 days, 3.74% for 56 days, 4.25% for 90 days and respectively. The percentage weight loss is observed to be increasing in correspondence with time. .

Percentage Loss of weight of specimens after immersing 10% H2So4 Solution

The percentage loss of weight is observed to be 8.12% for 28 days, 14.78% for 56 days, 23.38% for 90 days and. The percentage weight loss is observed to be increasing in correspondence with time.

Percentage Loss of compressive strength of specimens after immersing in10 % HCL solution

its observed to be 4.74% for 28 days, 6.28% for 56 days, 9.38% for 90days and respectively. The percentage loss is observed to be increasing in correspondence with time. As the attack proceeds, all the cement compounds are evenly broken down and leached away, together with carbonate aggregate material.

Gradeof Concrete		10%HClsolution	10%H_2So_4solution
		Relative strength	Relative strength
M80	28	75.29	77.79
	56	73.62	70.60
	90	70.87	61.60

Table - XIII

Percentage Loss of compressive strength of specimens after immersing in 10 % H2So4 solution

thepercentagelossofcompressive strengthisobservedtobe22.21%for28days,29.42%for56days, 38.40%for90daysrespectively. Withthesulphuricacidattack,calciumsulphateformedcan beproceedtoreactwithcalciumalumininate phaseincement toformcalciumsulphoaluminate,whichoncrystallizationcan causeexpansionanddisruptionofconcrete.

Durabilityfactorsofspecimensafterimmersingin10 %HCLsolution

thedurabilityfactorsareobservedtobe14.81%for28days,29.15 %for56days,45.31%for90daysandrespectively.

Durabilityfactorsofspecimensafterimmersingin10 %Na2So4solution

thedurabilityfactorsareobservedtobe15.11%for28days,31.11 %for56days,50.00%for90daysandrespectively.

XII.Conclusion

The following conclusions are drawn from the test results and analysis present in this paper

- Percentage decrease in weights of the specimens without and with immersion in HCL and H2So4 solutions of 5 % concentration at 28 days was found to be 11.26, 14.62 and 10.32 % on average of each 10, 20, and 30 % of fly ash respectively.
- From these results it has been identified that the intensity of attack by H_2S0_4 is comparatively more than the attack of HCL on the specimens.
- The percentage decrease in compressive strength of the specimens without and with immersion in HCL and H2S04 solution of 5 % concentration after 28 days was found to be 3.09, 1.54 and 4.60 % and 8.16, 4.08, 5.47% average of each 10, 20, and 30 % respectively.
- For 30% fly ash replacement the fresh properties observed were good as compared to 10%, 20% fly ash replacement. Hence if we increase the fly ash replacement we can have better workable concrete.
- The acid resistance of SCC with fly ash was higher when compared with concrete mixes without fly ash at the age of 14, 28, 56 days.
- Compressive strength loss decrease with the increase in fly ash in concrete.and Water absorption percentage decreases with the increase in fly ash. For 30% replacement of fly ash, the low water absorption level is good indicator of limited open porosity that can inhibit high flow of water into the concrete.
- When the specimen is immersed in acid solutions for 14, 28, 56 days respectively the average reduction in weight increases, and the weight is decreased when fly ash content is increased in the concrete. Compressive strength loss decreases with the increase in fly ash in concrete.
- Percentage decrease in weights of the specimens without and with immersion in HCL, H2So4and Na2 So4 solutions of 5 % concentration at 28 days was found to be 11.26, 14.62 and 10.32 % respectively. From these results it has been identified that the intensity of attack by H2S04 is comparatively more than the attack of HCL and Na2SO4 on the specimens. The percentage decrease in compressive strength of the specimens without and with immersion in HCL, H2S04 and Na2S04 solution of 5 % concentration after 28 days was found to be 16.31, 47.07 and 19.86 %
- Thepercentageweightlossof highstrengthself compactingconcretemixesafterimmersingin 10 % HCLsolutionincreasescorrespondingtothetime.
- The percentage weight loss of high strength self compactingconcretemixesafterimmersingin10% H_2So_4 solutionincreasescorrespondingtothetime. Thepercentagelossofcompressivestrengthofhigh strength self compacting concrete mixes after immersing in 10% HCL solution increases correspondingtothetime.
- Thepercentagelossof compressivestrengthofhigh strengthself compactingconcretemixesafter immersingin10%H_2So_4 solutionincreases correspondingtothetime.Higherthe Durabilityfactorhigherwill bethe resistancetotheacidandsulphateattacks
- The compressive strength of cubes immersed in magnesium sulphate solution decreases as the strength of the solution increases
- The weight loss of the specimen immersed in sulphate and chloride solution increases as exposure day increases. This is due to deterioration of concrete

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