Strength And Durability Study Of High Strength Self Compacting Concrete

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ABSTRACT

Sound and reliable structural design demands high quality experimental data and rational analysis of the mechanical properties of the constituent materials of which the structural elements are made. Although several theoretical models and much experimental data on the behaviour of Self compacting concrete are available in published literature, there is a lot of scope for research and investigations area of the Self compacting Concrete. In present investigation an attempt is made to report study Mechanical properties of High Strength Self Compacting concrete with different materials other than those used commonly like Crushed basalt, Quartz sand, Quartz powder etc., Investigation is also carried on Permeability and Durability characteristics of Concrete. It is well known that the properties of concrete are affected by cementitioius matrix, aggregate, and the transition zone between these two phases. Reducing the water-cement ratio and the addition of pozzolanic admixtures like silica fume are often used to modify the microstructure of the matrix and to optimize the transition zone. The Reduction of the water-cement ratio results in a decrease in porosity and refinement of capillary pores in matrix. One way to increase concrete flowing ability is minimizing the voids among particles of the powder mixture composed with cement, silica fume and other fine components

Key words: Chloride Ion Penetrability, Crushed basalt, Compressive strength, Durability , Flexural Strength, High Strength concrete, Quartz powder , Quartz sand ,Self compacting Concrete, Split tensile strength

I – INTRODUCTION

Concrete is considered a brittle material, primarily because of its low tensile strain capacity and poor fracture toughness. For a long time concrete was considered to be very durable material requiring a little or no maintenance. The assumption is largely true, except when it is subjected to highly aggressive environments. The build concrete structures in highly polluted urban and industrial areas, aggressive marine environments, harmful sub-soil water in coastal area and many other hostile conditions where other materials of construction are found to be non-durable. One of the main reasons for deterioration of concrete in the past is that too much emphasis is placed on concrete compressive strength. As a matter of fact, advancement in concrete technology has been generally on the strength of concrete. It is now recognized that strength of concrete alone is not sufficient, the degree of harshness of the environmental condition to which concrete is exposed over its entire life is equally important.

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Therefore, both strength and durability have to be considered explicitly at the design stage.

High-strength and High-performance concrete are being widely used throughout the world and to produce them it is necessary to reduce the water/binder ratio and increase the binder content. High-strength concrete means good abrasion, impact and cavitations resistance. Using High-strength concrete in structures today would result in economical advantages. Most applications of high strength concrete to date have been in high-rise buildings, long span bridges and some special structures. Major application of high strength concrete in tall structures have been in columns and shear walls, which resulted in decreased dead weight of the structures and increase in the amount of the rental floor space in the lower stories.

Self Compacting Concrete is defined as a category of high performance concrete that has excellent deformability in the fresh state and high resistance to segregation, and can be placed and compacted under its self weight without applying vibration. The elimination of vibration for the compaction of fresh concrete makes the use of the self –compacting concrete beneficial in terms of cost reduction and improvement of the work environment. Due to intrinsic low porosity, SCC usually has high performance properties in terms of mechanical behaviour and durability.

II – LITERATURE REVIEW

Okamuraet.al, [1] proposed a mix design method for SCC based on paste and mortar studies for superplasticizer compatibility followed by trail mixes. However, it is emphasized that the need to test the final product for passing ability, filling ability, and flow and segregation resistance is more relevant. **Vengala et.a1, [2]** found that use of fine fly ash for obtaining Self Compacting Concrete resulted in an increase of the 28 day Compressive Strength Concrete by about 38%. Self Compacting Concrete was achieved when volume of paste was between 0.43 and 0.45.**Subramanian and Chattopadhyay et.al, [3]** described the results of trails carried out to arrive at an approximate mix proportioning of Self Compacting Concrete. Self Compatibility was achieved for Water to Powder ratio ranging from 0.9 to 1.1 when Coarse Aggregate and Sand content were restricted to 46 % and 40% of the mortar volume respectively. **Dr.Srinivasa Rao. P et.al., [4]** had proposed the relationship between Splitting Tensile Strength and Compressive Strength by the test results and found that Split Tensile Strength is proportional to 0.78 power of Compressive Strength for normal concrete. **Dr.Malathy et.al, [5]** had developed the mix design for different grades of concretes and studied the flow properties and strength properties for Self compacting Concrete. **Kosmatka, S. H., B. Kerkhoff, et al. [6]** reported that concrete made with higher w/cm shows a higher permeability index for the same duration of curing and the same curing temperature. A wetter sample will have lower air permeability due to the water blocking the pores of the concrete and increases the time for the passage of air. A permeable concrete is more susceptible to ion penetration (which can lead to corrosion of Metals usually steel reinforcement) to stresses that are induced by the expansion of water as it freezes, and to chemical attack (leaching, efflorescence, sulphate attack). If properly cured, most concretes become significantly less permeable with time. Therefore, it is important to specify the age at which the permeability is measured. There is no universally accepted standard test method for measuring the permeation properties of concrete. Permeation procedures may be categorized by their respective transport mechanisms as given below. Water absorption, Water permeability (flow), Ionic flow (Rapid Chloride Permeability Test). **Bilodeau et al. [7]** measured water and chloride permeability of concretes having 55 to 60 % cement replacement with various sources of fly ash. They reported coefficient of water permeability of fly ash concretes in the range of 1.6 x 10-14 to 5.7 x 10-13 m/s. The values of chloride permeability (less than 650 coulombs at 91 days) observed in this investigation for fly ash concretes were comparable to that for silica fume concrete. **Hooton et.al, [8]** investigated on influence of silica fume replacement of cement on physical properties and resistance to sulphate attack, freezing and thawing, and alkali-silica reactivity. He reported that the maximum 28-day compressive strength was obtained at 15% silica fume replacement level at a w/b ratio of 0.35 with variable dosages of HRWRA. **Prasad et al. [9]** has undertaken an investigation to study the effect of cement replacement with micro silica in the production of High-strength concrete. **Yogendran et.al [10]** investigated on silica fume in High-strength concrete at a constant water-binder ratio (w/b) of 0.34 and replacement percentages of 0 to 25, with varying dosages of HRWRA. The maximum 28-day compressive strength was obtained at 15% replacement level. **Lewis [11]** presented a broad overview on the production of micro silica, effects of standardization of micro silica concrete-both in the fresh and hardened state. **Bhanja and Gupta et.al, [12]** reported and directed towards developing a better understanding of the isolated contributions of silica fume concrete and determining its optimum content. Their study intended to determine the contribution of silica fume on concrete over a wide range of w/c ratio ranging from 0.26 to 0.42 and cement replacement percentages from 0 to 30. **Tiwari and Momin et.al, [13]** presented a research study carried out to improve the early age compressive strength of Portland slag cement (PSC) with the help of silica fume. Silica fume from three sources- one imported and two indigenous were used in various proportions to study their effect on various properties of PSC. **Venkatesh Babu and Natesan et.al, [14]** Investigated on physico-mechanical properties of High-performance concrete (HPC) mixes, with different replacement levels of cement with condensed silica fume (CSF) of grade 960-D

III – EXPERIMENTAL PROGRAMME

The objectives of the experimental study are given below.

To study the Compressive, Flexural Strength and Split Tensile Strength behavior at 28,56, 90 and 180 days for M80 Grade High Strength Self Compacting Concrete Mix.

To study Durability and Permebility Characteristics (RCPT) of High Strength Self Compacting Concrete immersed in 5 % HCl, Na_2So_4, Na_2So_4 solutions.

Materials Used

A. Cement

Ordinary Portland cement of 53 grades available in local market is used in the investigation. The cement used has been tested for various proportions as per IS 4031 – 1988 and found to be confirming to various specifications of IS 12269-1987. The specific gravity was 3.15 and fineness was 2800 cm2/gm

B. Coarse Aggregate

Basalt originates from "hot spot" volcanoes, massive basalt flows and mid oceanic ridges. Basalt is a dark-colored, fine-grained, igneous rock composed mainly of plagioclase and pyroxene minerals. In present investigation Crushed basalt metal of Size 2 to 5 mm is used as Coarse Aggregate with Specific gravity of 3.10 and is obtained from local source.

C. Quartz Powder and Quartz Sand

Quartz has a hardness of 7 on Mohs scale and a density of 2.65 g/cm³. Quartz is a common constituent of granite, sandstone, limestone, and many other igneous, sedimentary, and metamorphic rocks. It has a hexagonal crystal structure and is made of trigonal crystallized silica. In present investigations the size of quartz sand is 0.3 to 0.8 mm and Quartz powder is in order of 0 -10 µm. Quartz sand is used a fine aggregate with Specific gravity of 2.65 and Quartz powder is used as a cementitioius material with Specific gravity of 2.63. These are obtained from local source.

D. Viscosity Modifying Agent

A Viscosity modified admixture for Rheodynamic Concrete which is colorless free flowing liquid and having Specific of gravity 1.01+0.01 @ 250C and pH value as 8+1 and Chloride Content nil was used as Viscosity Modifying Agent.

E. Admixture

The Modified Polycarboxylated Ether based Super Plasticizer which is Brown Color and free flowing liquid and having Relative density 1.08+0.01 and pH value greater than 6 and Chloride Content nil was used was Super Plasticizer. Flow tests were carried out on pastes containing different water to powder ratios or different superplasticizer dosages with a flow cone as in conventional self-compacting concrete. Superplasticizer dosage of about 1.8% was determined in powder mass as the optimum dosage to above Mix.

F. Micro Silica

Commercially available Micro silica from Elkem Metallurgy, India Ltd. Mumbai having Specific gravity of 2.1 is used. Micro Silica (very fine non-crystalline silicon dioxide) is a by-product of the manufacture of silicon, ferrosilicon or the like, from quartz and carbon in electric arc furnace. The Specific surface area was 20000 cm^2/gm

IV – EXPERIMENTAL INVESTIGATION

A. Mix proportion

As there is no standard procedure available for designing the mix proportions for Self Compacting Concrete proportion based on the Experimental trail was adopted. Water to cementitioius material by weight was kept at about 0.215 for M 80 grade of concrete. The Mix proportion for M80 grade SCC is reported in Table No. I

Table I: Quantities of Materials Required Per 1 cum Of High Strength Self Compacting Concrete

S.No:	Material	Weight Kg)
1	Crushed basalt-2 to 5mm (Z)	1022
2	Quartz Sand (0.3 to 0.8mm) (QS)	437
3	Quartz Powder (0 to 10 μm) (QP)	202
4	Micro Silica (M)	142
5	Cement (R)	472
6	Water (W)	175 lt
7	Super Plasticizer (1.8 % of (M+R+QP)	14688 ml
8	VMA (0.1 % of (M+R+QP)	816 ml
9	W /(M + R + QP)	0.215

B. Preparation of specimen & Testing Procedure

The program consists of casting and testing a total of 84 specimens. The specimens of standard cubes (150mmX150mmX150mm),(100mmX100mmX100mm), standard cylinders of (150mm Dia X 300mm height) and standard prisms of (100mmX100mmX500mm) were cast. Universal testing machine was used to test all the specimens.

C. Rapid Chloride Permeability Test (RCPT)

Corrosion is mainly caused by the ingress of chloride ions into concrete annulling the original passivity present. Rapid chloride permeability test (RCPT) has been developed as a quick test able to measure the rate of transport of chloride ions in concrete. This test was conducted as per ASTM C 1202-94. Concrete disc of size 100 mm diameter and 50 mm thickness of HSSCC were cast and allowed to cure. After curing the concrete specimens were subjected to RCPT by impressing 60V. Two halves of the specimens are sealed with PVC container of diameter 90mm. One side of the container is filled with 3% sodium chloride solution (that side of the cell will be connected to the cathode terminal of the power supply) and other side sodium hydroxide solution was poured and connected to anode terminal as shown in “Fig.1”. “Fig.3” shows the experimental set up for determining chloride using RCPT. Table II represents the rating of concrete as per ASTM-C 1209-94.

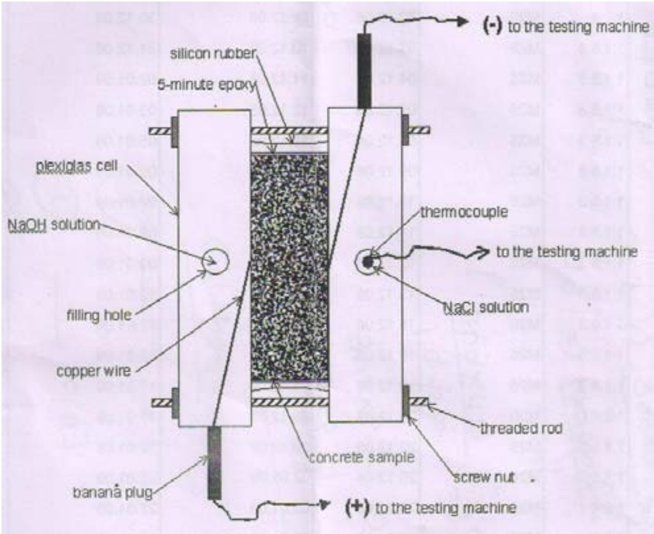

Fig .1 Schematic diagram of RCPT [ASTM C 1202- 94]

D.Testing of specimens

The specimens were fit in the chamber with the required brass as well as rubber oaring. The record time is set as 30 minutes and also the log time as 6 hours and 30 minutes and the current of 60V is passed continuously. The data logger records the readings of corresponding cells at the every record time with its initial readings. At the end of log time, the system halts after taking the final reading.

Average current flowing through one cell is calculated by,

I = 900 * 2 * I Cumulative coulombs.

$$I_{CUMMULATIVE} = I_0 + I_{30} + I_{60} + I_{90} + I_{120} + I_{150} + I_{180} + I_{210} + I_{240} + I_{270} + I_{300} + I_{330} + I_{360}$$

I_0 = Initial current reading in mA.
I_{30} = Current reading at 30 minutes in mA.
I_{60} = Current reading at 60 minutes in mA.
I_{90} = Current reading at 90 minutes in mA.
I_{120} = Current reading at 120 minutes in mA.
I_{150} = Current reading at 150 minutes in mA.
I_{180} = Current reading at 180 minutes in mA.
I_{210} = Current reading at 210 minutes in mA.
I_{240} = Current reading at 240 minutes in mA.
I_{270} = Current reading at 270 minutes in mA.
I_{300} = Current reading at 300 minutes in mA.
I_{330} = Current reading at 330 minutes in mA.
I_{360} = Current reading at 360 minutes in mA

Table No.II.RCPT ratings (per ASTM C1202-94)

Charge Passed (coulombs)	Chloride Ion penetrability
>4000	High
2000 - 4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

E. **Tests on Fresh Concrete**

Conventional workability tests devised for conventionally vibrated concrete mixes are not adequate of SCC as they are not sensitive to detect all the characteristics of SCC mix. Many different methods have been developed to characterize the properties of SCC. As no single method has been found till date that characterizes all the relevant workability aspects, the mix was tested by more than one test method for the different workability parameters. The following test methods were used to characterize the workability properties of SCC for the final acceptance of the SCC mix proportion. Deformability and Viscosity of fresh concrete is evaluated through the measurement of slump flow time and diameter, L-Box ratio test and V-funnel flow time are shown ("Fig.2")

Slump Flow Test

The slump flow test is used to assess the horizontal free flow and the filling ability of SCC in the absence of obstructions. It is recommended to maintain slump flow value as 650 to 800 mm.

T 50cm Slump Flow Test

This test is used along with slump flow test to assess the flowability of SCC.

V-Funnel

This test is used to determine the filling ability, flow-ability and segregation resistance of SCC

L-Box

This test assesses the flow of the concrete in presence of reinforcement obstructions.

Summary of test results of workability parameters of High Strength Self compacting Concrete are reported in Table III

Test method	Mix	Permissible limits as per EFNARC Guidelines	
		Max	Min
V-Funnel	8 sec	6 sec	12 sec
V-Funnel at T_5 min	12 sec	11 sec	15 sec
Abrams slump flow	720 mm	650 mm	800 mm
T 50cm slump flow	3 sec	2 sec	5 sec
L- Box	0.9	0.82	1
	1 sec	1 sec	2 sec
	2 sec	2 sec	3 sec

Fig .2 Workability Tests on High Strength Self Compacting Concrete

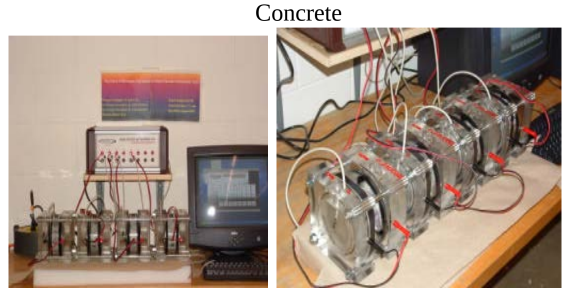

Fig .3 Experimental set up of RCPT and Specimens immersed in HCl, H_2So_4, and Na_2So_4 solution

Fig .4 Acid Pond Set up

V – RESULTS AND DISCUSSIONS

A. Workability

As it is observed from Table No.III, the basic requirements of high flowability and segregation resistance as specified by guidelines on Self Compacting Concrete by EFNARC (15) are satisfied.

B. Compressive strength, Split Tensile Strength, Flexural Strength Durability and Permeability Results of High Strength Self Compacting Concrete

The results are presented from Table IV to XIII and Fig 5.0 to 8.0

It is observed from Table No.IV, that, Compressive Strength of High Strength Self Compacting Concrete Specimens at 28, 56, 90 and 180 days are 90.60 MPa, 93.56 Mpa, 96.08 Mpa, 99.42 Mpa.

It is observed from Table No. V, that, Percentage Increase in Compressive Strength of High Strength Self Compacting Concrete Specimens 3.26 % at 56 days, 6.05 % at 90 days and 9.74 % with respect to 28 days.

It is observed from Table No .VI, that, Split Tensile Strength of High Strength Self Compacting Concrete Specimens at 28, 56, 90 and 180 days are 6.81 MPa, 7.07 Mpa, 7.46 Mpa, and 7.82 Mpa.

It is observed from Table No.VII, that, Percentage Increase in Split Tensile Strength of High Strength Self Compacting Concrete Specimens 3.81 % at 56 days, 9.54 % at 90 days and 14.83 % with respect to 28 days.

It is observed from Table No .VIII, that, Flexural Strength of High Strength Self Compacting Concrete Specimens at 28, 56, 90 and 180 days are 8.62 MPa, 8.93 Mpa, 9.35 Mpa, and 9.95 Mpa.

It is observed from Table No. IX that, Percentage Increase in Flexural Strength of High Strength Self Compacting Concrete Specimens 3.59 % at 56 days, 8.46 % at 90 days and 15.42 % with respect to 28 days

It is observed from Table No. X, that, Percentage Weight loss of High Strength Self Compacting Concrete Specimens immersed in 5 % HCl Solution at 28, 56, 90 and 180 days are 4.59 %, 6.45%, 10.12 %, and 13.37%

It is observed from Table No .XI, that, Percentage Weight loss of High Strength Self Compacting Concrete Specimens immersed in 5 % H_2So_4 Solution at 28, 56, 90 and 180 days are 1.27 %, 3.41%, 5.42 %, and 7.39%

It is observed from Table No .XII, that, Percentage Weight loss of High Strength Self Compacting Concrete Specimens immersed in 5 % Na_2So_4 Solution at 28, 56, 90 and 180 days are 0.77 %, 1.24%, 2.17 %, and 3.39%

It is observed from Table No .XIII, that, Chloride Ion Penetrability of High Strength Self Compacting Concrete Specimens at 28, 90 and 180 days are 431 & 379, 333 & 277 and 191 & 145

Table IV.Compressive Strength of HSSCC Specimen with (w/b= 0.215) at 28, 56, 90 and 180 days

S.No	W/C ratio	Compressive strength (Mpa)			
		28 Days	56 Days	90 Days	180 Days
1	0.215	90.60	93.56	96.08	99.42

Table V. Percentage Increase in Compressive Strength of HSSCC Specimen with (w/b= 0.215) with respect to 28 days

S.No	W/C ratio	% Increase in Compressive strength (Mpa)		
		56 Days	90 Days	180 Days
1	0.215	3.26	6.05	9.74

Table VI Split Tensile Strength of HSSCC Specimen with (w/b= 0.215) at 28, 56, 90 and 180 days

S.No	W/C ratio	Split Tensile strength (Mpa)			
		28 Days	56 Days	90 Days	180 Days
1	0.215	6.81	7.07	7.46	7.82

Table VIII Percentage Increase in Split Tensile Strength of HSSCC Specimen with (w/b= 0.215) with respect to 28 days

S.No	W/C ratio	% Increase in Split Tensile strength (Mpa)		
		56 Days	90 Days	180 Days
1	0.215	3.81	9.54	14.83

Table VIII. Flexural Strength of HSSCC Specimen with (w/b= 0.215) with at 28, 56, 90 and 180 days

S.No	W/C ratio	Flexural strength (Mpa)			
		28 Days	56 Days	90 Days	180 Days
1	0.215	8.62	8.93	9.35	9.95

Table IX Percentage Increase in Flexural Strength of HSSCC Specimen with (w/b= 0.215) with respect to 28 days

S.No	W/C ratio	% Increase in Flexural strength (Mpa)		
		56 Days	90 Days	180 Days
1	0.215	3.59	8.46	15.42

Table X. Percentage Weight loss of HSSCC Specimen with (w/b= 0.215) immersed in 5 % HCl solution at 28, 56, 90 and 180 days

S.No	W/C ratio	% Weight loss of Specimen			
		28 Days	56 Days	90 Days	180 Days
1	0.215	4.59	6.45	10.12	13.37

Table XI. Percentage Weight loss of HSSCC Specimen with (w/b= 0.215) immersed in 5 % H_2So_4 solution at 28, 56, 90 and 180 days

S.No	W/C ratio	% Weight loss of Specimen			
		28 Days	56 Days	90 Days	180 Days
1	0.215	1.27	3.41	5.42	7.39

Table XII Percentage Weight loss of HSSCC Specimen with (w/b= 0.215) immersed in 5 % Na_2So_4 solution at 28, 56, 90 and 180 days

S.No	W/C ratio	% Weight loss of Specimen			
		28 Days	56 Days	90 Days	180 Days
1	0.215	0.77	1.24	2.17	3.39

Table XIII Rapid Chloride Permeability test of HSSCC

S.No	28 days	90 days	180 days	Chloride Ion Penetrability
	Coulombs	Coulombs	Coulombs	
HSSC1	431	333	191	Very low
HSSC2	378	277	145	Very low

VI - CONCULSIONS

[1] Percentage increase in Compressive Strength, Split Tensile Strength and Flexural Strength are 3.26, 3.81 and 3.59 at 56 days with respect to 28 days strength

[2] Percentage increase in Compressive Strength, Split Tensile Strength and Flexural Strength are 6.05, 9.54 and 8.46 at 56 days with respect to 28 days strength

[3] Percentage increase in Compressive Strength, Split Tensile Strength and Flexural Strength are 9.74, 14.83 and 15.42 at 56 days with respect to 28 days strength

[5] Percentage increase in Weight loss of Concrete Specimens immersed in 5 % HCl Solution is varying from 4.59 to 13.37 % from 28 to 180 days.

[6] Percentage increase in Weight loss of Concrete Specimens immersed in 5 % H_2So_4 Solution is varying from 1.27 to 7.39 % from 28 to 180 days.

[7] Percentage increase in Weight loss of Concrete Specimens immersed in 5 % Na_2So_4 Solution is varying from 0.77 to 3.39 % from 28 to 180 days.

[8] Chloride permeability of High Strength Self Compacting concrete shows less permeability of chlorides into concrete resulting into reduction the cracks causing interconnecting voids to be minimum

[9] Denser microstructure of HSSCC contribute for a lower plastic settlement, higher bond between steel and concrete matrix, lower permeability to oxygen and lower chloride diffusion coefficient and higher tensile strength

[10] Chloride ion penetration depends on chloride binding capacity of the constituent materials. Usually chlorides penetrate into concrete by diffusion along water-conveyance paths or open pores. The resistance to such diffusion can be increased by refining the pore-structure of the concrete. The implications of such substantial decreases in chloride ion penetrability can be considered in the design of offshore structures, bridge decks, parking garages and other structures that are vulnerable to corrosion of reinforcing steel under chloride ion attack

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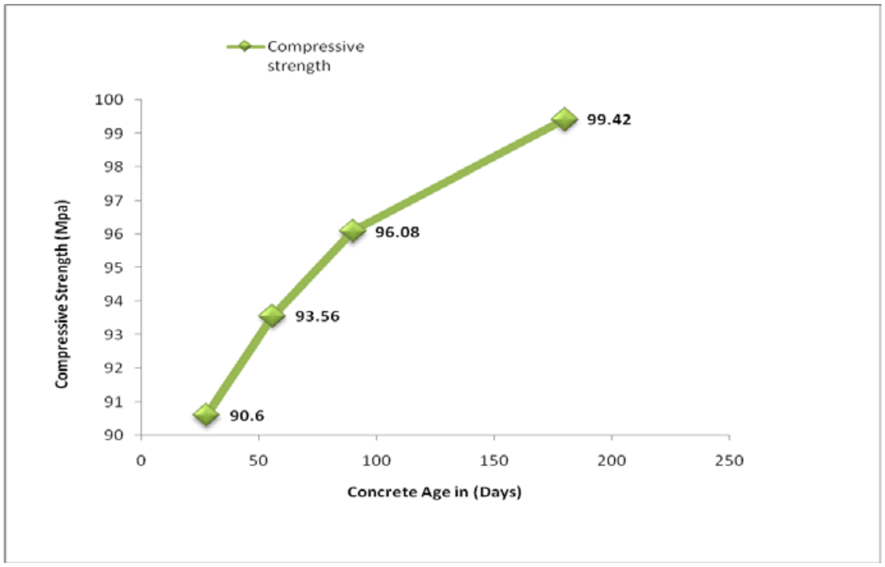

Fig 5.0 Variation of Compressive Strength of HSSCC Specimen with (w/b= 0.215) at 28, 56, 90 and 180 days

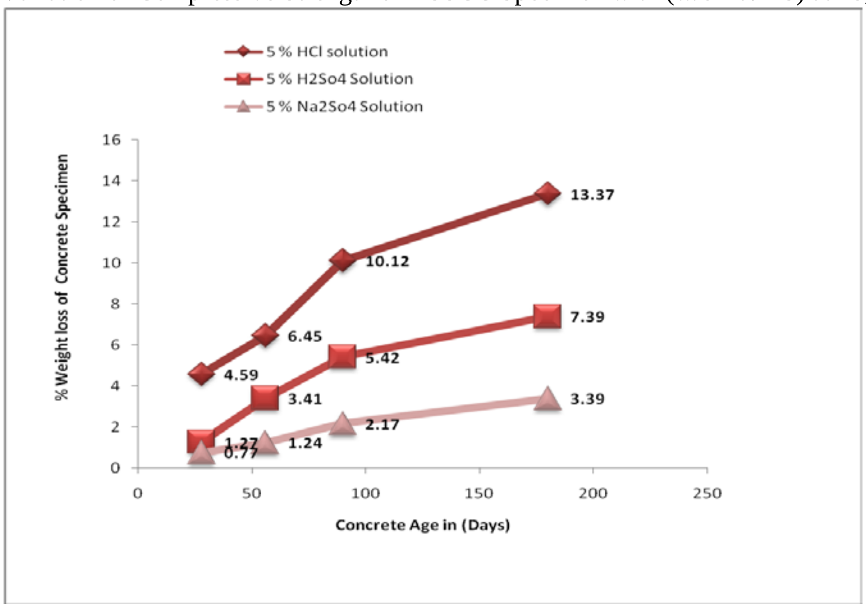

Fig 6.0 Percentage weight loss of HSSCC Specimen immersed in 5 % HCl, H_2So_4, Na_2So_4 at 28, 56, 90 and 180 days

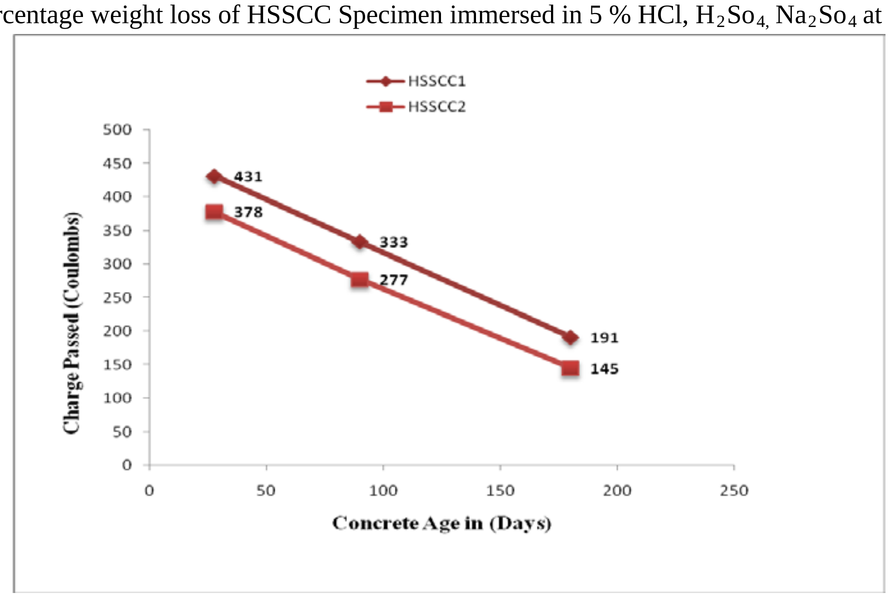

Fig 7.0 Variation of Chloride Ion Penetrability of HSSCC Specimen with (w/b= 0.215) at 28, 90 and 180 days

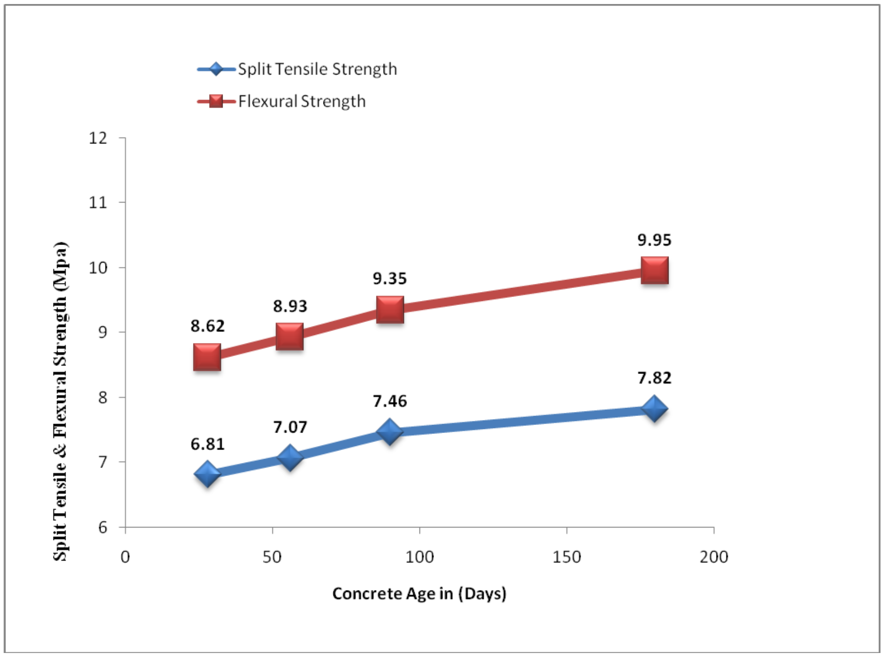

Fig 8.0 Variation of Split Tensile Strength and Flexural Strength of HSSCC Specimen with (w/b= 0.215) at 28, 90 and 180 days

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