International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.858 (SJIF-2019), e-ISSN: 2455-2585
Volume 6 , Issue 7 , July -2020

Durability Studies on Modified Concrete Using LECA and Sintered Fly-ash Aggregate and Blended Cement With Pozzolanic and Nano Materials

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ABSTRACT: In the contemporary LPG (Liberalisation Privatisation & Globalisation) trend application of light weight concrete is souring up day by day. The lightweight concrete has many advantages compared to conventional concrete like providing thermal acoustic insulation, and producing of light weight structures with the less number of structural components and steel reinforcement. This gradually minimise the construction cost. In addition to the sound mechanical strength properties, longstanding durability properties also regulate the efficiency and effectiveness of the concrete. Durability of lightweight aggregate concrete is its resistance against the atmospheric and human induced gases, various chemicals and fluctuations in temperature etc. which reacts vigorously or moderately with the various binder elements of the concrete causing degradation. In general Concrete structures will get expose to various environments under certain circumstances such as proximity to industries which releases chemicals and emits various gases; acid rains, hot springs etc., and the course of interaction may vary from few seconds to many years. While coming to resistance to various environments, the durability of lightweight concrete is mostly influenced by materials that are under acid, chloride and sulphate environment.

In this study, an attempt is made to study the impact and effect on the specimens of modified concrete which are demoulded after 24 hours of casting and placed in the 5% of acidic solutions such as i) Hydrochloric Acid (HCl), ii) Sulfuric Acid (H_2SO_4) to study acid attack and 5% of alkaline solutions such as i)Sodium Sulphate (Na_2SO_4), ii) Sodium Chloride (NaCl) solution to study sulphate and chloride attack after 28 days and 90 days of curing and the results are compared with those cured in plain water . Modified concrete is obtained by 100% replacement of naturally available coarse aggregate with light weight aggregates like Sintered fly-ash aggregates and LECA (Light Expandable Clay Aggregates) in equal proportions along with 3 no's of pozzolanic materials i.e., silica fume, fly ash and slag in equal proportions which collectively replaces 11% of cement in addition to the varying percentages i.e., 0%, 0.5%, 1.0%, 1.5% of Nano materials(TiO_2 & SiO_2) on 11% weight of cement in equal proportions. Various tests have been carried out on the above samples like density variation, cube compressive strength, split tensile strength, and Sorptivity. Results indicate that the concretes containing pozzolans have better performance in comparison to the concretes which are produced without pozzolans and also the resistance of concrete increased with addition up to 1% of TiO_2 & SiO_2 in equal proportions and decreased beyond that.

Keywords: Sintered fly-ash, LECA (Light Expandable Clay Aggregate), Silica fume, fly ash and molten slag, Sulphuric acid (H_2SO_4), Hydrochloric acid (HCl), Sodium chloride (NaCl) and Sodium sulphate (Na_2SO_4)

1. INTRODUCTION

In current scenario, the usage of light weight concrete has drastically increased. This material is generally durable and has good mechanical properties.

Various materials that are used for preparation of light weight concrete in this study are Portland cement, LECA, and sintered fly ash. The durability properties of concrete specimens are quite influenced by the chemical solutions when they got exposed to respective environments as it was widely accepted that concrete deteriorates when exposed to chemical attacks such as acid, Sulphate and Chloride.

The spectrum of these attacks is wide. These attacks originate from urban activity and industrial processes. Occasionally natural exposure conditions like water and soils may cause chemical attack. Acids such as sulphuric acid and hydrochloric acid are very spontaneous as they forms calcium salts by reacting with free lime of concrete and reacts with the hydro aluminates and hydro silicates whose solubility will decides the extremity of deterioration caused to the concrete. In the acidic environment, concrete is mostly influenced during the hardening stage of fresh concrete.

2. LITERATURE REVIEW

The literature survey is oriented around the study of effect of acid attack on performance of concrete, strength of concrete and durability of concrete.

K. Kawai et.al., [1], in their research, proposed a course of deterioration of concrete in the diluted solution of sulphuric acid. Cylindrical specimens were immersed in various concentrations of sulphuric acid. They found that the rate of deterioration by sulphuric acid depended on pH value of acid and time of exposure of specimens also decides the rate of deterioration.

In the study of **Emmanuel K et.al.,** [2], the authors made four different concrete mixes to get exposed acid attack for different time periods of immersion. The length of deterioration of concrete was observed under Scanning Electron Microscope. They concluded that the decrease in density of concrete was due to higher acidity.

Shin taro Miyamoto et.al, [3], in their study, it was attempted to bring a relation between deterioration in concrete, mixed acids and sulphuric acid. Cylindrical specimens were immersed in acid solutions in plastic containers of acid free. The specimen surfaces are scrubbed for every 20, 40, 60 and 120 minutes during the test. They found that the rate of deterioration depends on amount of potlandite dissolution.

As per Prahallada & M Beulah M., [4], it is understood that the researchers made an attempt to study the performance of concrete by 20% Metakaolin replacement with cement under hydrochloric acid. Specimens were immersed in various concentrations of Hydrochloric acid. The resistance of concrete was found to decreases with increase in acidic concentration.

3. MATERIALS USED

The following materials are used for preparing the concrete mix of M20.

Ultratech cement of 53 grade, Coarse aggregate (Light expandable clay aggregate (LECA) and Sintered Fly-ash aggregate in equal proportions), Fine aggregate i.e., sand , pozzolanic materials like Silica fume, Fly ash and Slag, Water , Nano Titanium Dioxide (TiO_2) & Nano Silicon Dioxide(SiO_2), 5% concentrated solutions of Sulphuric acid, Hydrochloric acid, Sodium sulphate, Sodium chloride.

A. Cement: Ordinary Portland cement Ultratech 53 grade is used as binder.

B. Coarse aggregate:

1) Light weight Expandable Clay aggregate (LECA): Typical physical characteristics of LECA aggregates procured from Nexus Buildcon Solution Company, Ahmadabad used in this investigation are as follows.

Specific gravity : 1.18
Aggregate Size mm : 10-12mm Bulk
Density : 645kg/m3
Shape : Round pellets

2) Sintered fly ash aggregate: Sintered fly ash aggregate procured from India Mart Company, Ahmedabad is used in this investigation. Typical physical characteristics of Sintered fly ash aggregates (As given by the supplier)

Specific gravity : 1.7
Aggregate Size mm : 8-12
Bulk Density : 800 kg/m3
Bulk Porosity : 35-40%
Aggregate Strength : >4.0 MPa
Water Absorption : < 16 %
Shape : Round pellets

D. Pozzolanic materials

1) Fly ash: The fly ash is obtained from Rayalaseema Thermal plant, Muddanur. The test results are shown as below.

Fineness (Retained on 90 micron sieve)	0%
Bulk density in loosest state	800 kg/m^3
Bulk density in densest state	960 kg/m^3

2) Silica Fume: The silica fume admixture is procured from ferro silica unit at Ahmadabad. The test results are shown below.

Property	**Test results**
Specific gravity	2.1
Fineness (Retained on 90 micron sieve)	0%
Bulk density in loosest state	420 kg/m3
Bulk density in compacted state	700 kg/m3

3) Slag: The source of slag is procured from Jindhal steel industries, Bellary. The test results are shown below.

Properties of Slag

Property	**Test results**
Specific gravity	2.86
Bulk density in loosest state	600 kg/m2
Bulk density in compacted state	980 kg/m3
Fineness (Retained on 90 micron sieve)	0%

Nano materials:

1. Nano Titanium Dioxide (TiO_2): It is a naturally occurring oxide of titanium. It has a wide range of applications from paint to sunscreen to food colouring. Generally it is sourced from ilmenite, rutile and anatase. The use of Nano titanium dioxide gives favourable results by increasing compressive strength and tensile strength of concrete. Nano titanium dioxide is procured from AVANSA technologies, KHANPUR.

Physical Properties of Nano TiO_2 :(As given by the supplier)

Purity:	99.9%
SSA:	289 m^2/g - large surface area.
Colour:	White.
Bulk Density:	0.12-0.18g/cm3

2. Silicon dioxide (SiO_2): Nano-Silica is silicon dioxide nano particles (SiO_2), synthetic product of porous and nearly spherical particles, with great potential advantages especially in glass and concrete industries.

4. MIX DESIGN OF CONCRETE

M_{20} Mix design has been carried out using ISI methods i.e., IS 10262-2009 and IS 456-2000.

The mix proportion obtained is 1:1.58:2.88 with constant water cement ratio 0.5.

5. EXPERIMENTAL PROCEDURE

In order to study the durability behaviour of modified concrete under the action of 5% concentrated of solutions like Sulphuric acid (H_2SO_4), Hydrochloric acid (HCl), Sodium chloride (NaCl) ,Sodium sulphate (Na_2SO_4) and Natural water, a total of 150 numbers of concrete cubes and 150 numbers of concrete cylinders are cast; cured, weighed and tested. These are made of modified concrete by replacing 100% natural aggregate along with sintered fly ash and LECA (Light expandable clay aggregate) in equal proportions along with replacement of cement with 11% of weight by 3 different Pozzolanic materials i.e., fly ash, silica fume slag in equal proportions along with varying percentages i.e., 0%, 0.5%, 1.0%, 1.5% of Nano silicon dioxide and Nano titanium dioxide in equal proportions on 11% of cement. For experimental programme, cube specimens have been cast as per standard procedure and allowed to curing for 28 days and 90 days. After curing period, specimens are taken out from water and chemical solutions, recorded their respective weight, failure loads under compression and tension on cubes and cylinders to find compressive strength, split tensile strength. The various mix proportions used for one random solution are presented in **Table 5.1**.

Table 5.1.

Age	Mix	%volume Replacement of natural coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	No.of cubes	No.of cylinders
		LECA	SFA				
28 Days	M1	50	50	0	0	3	3
	M2	50	50	11	0	3	3
	M3	50	50	11	0.5	3	3
	M4	50	50	11	1.0	3	3
	M5	50	50	11	1.5	3	3
90 Days	M1	50	50	0	0	3	3
	M2	50	50	11	0	3	3
	M3	50	50	11	0.5	3	3
	M4	50	50	11	1.0	3	3
	M5	50	50	11	1.5	3	3

Note: LECA: Light expandable clay aggregate and SFA: Sintered fly ash aggregate

6. TESTING OF SPECIMENS:

6.1 Compressive strength: To find the Compressive strength of concrete cubes, the test specimens are removed from water and other chemical solutions after specified curing time and wiped out excess water from the surface. The specimens are placed in the machine in such a manner that the load shall be applied concentrically. Specimens are aligned centrally on the base plate of the machine. The load is applied gradually without shock and continuously at the rate of 140 $kg/cm^2/min$ till the specimen fails. The maximum load is recorded. Compressive strength of cubes is calculated and are shown vide tables 6.1.1. to 6.1.5.

Table 6.1.1: Compressive strength results for cubes cured in Normal water

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	% of cement	Compressive Strength N/mm^2	Percentage increase of compressive strength
		LECA	SFA					
28 Days	M1	50	50	0	0	100	26.83	0.0
	M2	50	50	11	0	89	28.20	5.10
	M3	50	50	11	0.5	88.945	29.80	11.06
	M4	50	50	11	1.0	88.89	32.00	19.26
	M5	50	50	11	1.5	88.835	29.90	11.44
90 Days	M1	50	50	0	0	100	27.76	0
	M2	50	50	11	0	89	29.40	5.9
	M3	50	50	11	0.5	88.945	30.46	9.7
	M4	50	50	11	1.0	88.89	33.40	20.31
	M5	50	50	11	1.5	88.835	30.70	10.59

Table 6.1.2: Compressive strength results for cubes cured in Sodium Chloride (NaCl)

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	% of cement	Compressive Strength N/mm^2	Percentage increase of compressive strength
		LECA	SFA					
28 Days	M1	50	50	0	0	100	21.33	0.0
	M2	50	50	11	0	89	22.93	7.5
	M3	50	50	11	0.5	88.945	23.40	9.7
	M4	50	50	11	1.0	88.89	24.90	16.7
	M5	50	50	11	1.5	88.835	23.06	8.11
90 Days	M1	50	50	0	0	100	17.53	0
	M2	50	50	11	0	89	18.06	3.02
	M3	50	50	11	0.5	88.945	18.53	5.7
	M4	50	50	11	1.0	88.89	19.13	9.13
	M5	50	50	11	1.5	88.835	18.10	3.25

Table 6.1.3: Compressive strength results for cubes cured in Sodium Sulphate (Na_2SO_4)

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	% of cement	Compressive Strength N/mm^2	Percentage increase of compressive strength
		LECA	SFA					
28 Days	M1	50	50	0	0	100	17.76	0
	M2	50	50	11	0	89	19.06	7.31
	M3	50	50	11	0.5	88.945	20.56	15.76
	M4	50	50	11	1.0	88.89	22.23	25.16
	M5	50	50	11	1.5	88.835	21.23	19.53
90 Days	M1	50	50	0	0	100	15.26	0
	M2	50	50	11	0	89	16.76	9.8
	M3	50	50	11	0.5	88.945	16.86	10.4
	M4	50	50	11	1.0	88.89	17.60	15.3
	M5	50	50	11	1.5	88.835	17.53	14.8

Table 6.1.4: Compressive strength results for cubes cured in Hydrochloric acid (HCl)

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	% of cement	Compressive Strength N/mm^2	Percentage increase of compressive strength
		LECA	SFA					
28 Days	M1	50	50	0	0	100	11.63	0.0
	M2	50	50	11	0	89	12.76	9.71
	M3	50	50	11	0.5	88.945	12.93	11.17
	M4	50	50	11	1.0	88.89	13.56	16.59
	M5	50	50	11	1.5	88.835	12.43	6.87
90 Days	M1	50	50	0	0	100	5.26	00
	M2	50	50	11	0	89	5.80	10.26
	M3	50	50	11	0.5	88.945	6.23	18.44
	M4	50	50	11	1.0	88.89	6.50	23.57
	M5	50	50	11	1.5	88.835	6.03	14.63

Table 6.1.5: Compressive strength results for cubes cured in Sulphuric acid(H_2SO_4)

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	% of cement	Compressive Strength N/mm^2	Percentage increase of compressive strength
		LECA	SFA					
28 Days	M1	50	50	0	0	100	7.73	0.0
	M2	50	50	11	0	89	8.93	15.52
	M3	50	50	11	0.5	88.945	9.10	17.72
	M4	50	50	11	1.0	88.89	10.0	29.36
	M5	50	50	11	1.5	88.835	9.43	21.99
90 Days	M1	50	50	0	0	100	2.56	0
	M2	50	50	11	0	89	2.93	14.45
	M3	50	50	11	0.5	88.945	3.23	26.17
	M4	50	50	11	1.0	88.89	4.16	62.50
	M5	50	50	11	1.5	88.835	3.86	50.78

6.2: Split tensile strength: In this test the cylindrical specimens are kept horizontally so that its axis is parallel to the plates of the 3000KN digital compression testing machine. Narrow strips of the packing material i.e., plywood is placed between the plates and the cylinder to receive compressive stress. The load is applied uniformly until the cylinder fails, by cracks occurred on top and bottom. Split tensile strength results of cylinder are tabulated as follows:

Table 6.2.1: Split Tensile strength results for Cylinders cured in Normal water

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	% of cement	Split Tensile Strength N/mm^2	Percentage increase or decrease of compressive strength
		LECA	SFA					
28 Days	M1	50	50	0	0	100	1.52	0.0
	M2	50	50	11	0	89	1.95	28.2
	M3	50	50	11	0.5	88.945	2.07	36.18
	M4	50	50	11	1.0	88.89	2.31	51.97
	M5	50	50	11	1.5	88.835	2.25	48.02
90 Days	M1	50	50	0	0	100	1.72	0
	M2	50	50	11	0	89	2.12	23.25
	M3	50	50	11	0.5	88.945	2.24	30.23
	M4	50	50	11	1.0	88.89	2.40	39.53
	M5	50	50	11	1.5	88.835	2.37	37.79

Table 6.2.2: Split Tensile Strength results for Cylinders cured in Sodium Chloride (NaCl)

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	% of cement	Split Tensile Strength N/mm^2	Percentage increase or decrease of compressive strength
		LECA	SFA					
28 Days	M1	50	50	0	0	100	1.42	0.0
	M2	50	50	11	0	89	1.67	17.6
	M3	50	50	11	0.5	88.945	1.92	35.2
	M4	50	50	11	1.0	88.89	2.24	57.7
	M5	50	50	11	1.5	88.835	2.11	48.59
90 Days	M1	50	50	0	0	100	1.26	0
	M2	50	50	11	0	89	1.42	12.69
	M3	50	50	11	0.5	88.945	1.76	39.68
	M4	50	50	11	1.0	88.89	1.88	49.2
	M5	50	50	11	1.5	88.835	1.79	42.06

Table 6.2.3: Split Tensile strength results for Cylinders cured in Sodium Sulphate (Na_2SO_4)

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	% of cement	Split Tensile Strength N/mm^2	Percentage increase or decrease of compressive strength
		LECA	SFA					
28 Days	M1	50	50	0	0	100	1.10	0.0
	M2	50	50	11	0	89	1.11	0.9
	M3	50	50	11	0.5	88.945	1.16	5.4
	M4	50	50	11	1.0	88.89	1.21	10
	M5	50	50	11	1.5	88.835	1.18	7.27
90 Days	M1	50	50	0	0	100	0.77	0
	M2	50	50	11	0	89	0.87	12.98
	M3	50	50	11	0.5	88.945	0.91	18.18
	M4	50	50	11	1.0	88.89	1.15	49.35
	M5	50	50	11	1.5	88.835	1.13	46.75

Table 6.2.4: Split Tensile strength results for Cylinders cured in HydroChloric acid (HCl)

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	% of cement	Split Tensile Strength N/mm^2	Percentage increase or decrease of compressive strength
		LECA	SFA					
28 Days	M1	50	50	0	0	100	1.21	0.0
	M2	50	50	11	0	89	1.31	8.2
	M3	50	50	11	0.5	88.945	1.42	17.35
	M4	50	50	11	1.0	88.89	1.57	29.75
	M5	50	50	11	1.5	88.835	1.47	21.48
90 Days	M1	50	50	0	0	100	1.06	0
	M2	50	50	11	0	89	1.33	25.4
	M3	50	50	11	0.5	88.945	1.34	26.41
	M4	50	50	11	1.0	88.89	1.45	36.79
	M5	50	50	11	1.5	88.835	1.38	30.18

Table 6.2.5: Split Tensile strength results for Cylinders cured in Sulphuric acid (H_2SO_4)

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	% of cement	Split Tensile Strength N/mm^2	Percentage increase or decrease of compressive strength
		LECA	SFA					
28 Days	M1	50	50	0	0	100	1.34	0
	M2	50	50	11	0	89	1.41	5.22
	M3	50	50	11	0.5	88.945	1.82	35.8
	M4	50	50	11	1.0	88.89	2.12	58.2
	M5	50	50	11	1.5	88.835	2.04	52.23
90 Days	M1	50	50	0	0	100	1.19	0
	M2	50	50	11	0	89	1.22	2.52
	M3	50	50	11	0.5	88.945	1.36	14.28
	M4	50	50	11	1.0	88.89	1.50	26.05
	M5	50	50	11	1.5	88.835	1.46	22.68

6.3 Density: Densities of the specimens immersed under various solutions are calculated and tabulated by taking average weight of 3 specimens after the immersio

Table 6.3.1: DENSITY VALUES CONCRETE SPECIMENS IMMERSED IN NATURAL WATER

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	Density in Kg/cum	Percentage increase or decrease in density
		LECA	SFA				
28 Days	M1	50	50	0	0	1650.12	0
	M2	50	50	11	0	1676.46	1.575
	M3	50	50	11	0.5	1699.52	3.001
	M4	50	50	11	1.0	1750.95	6.118
	M5	50	50	11	1.5	1732.75	5.015
90 Days	M1	50	50	0	0	1674.89	0
	M2	50	50	11	0	1699.69	1.480
	M3	50	50	11	0.5	1721.18	2.763
	M4	50	50	11	1.0	1765.83	5.429
	M5	50	50	11	1.5	1739.37	3.849

Table 6.3.2: DENSITY VALUES CONCRETE SPECIMENS IMMERSED IN SODIUM CHLORIDE

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	Density in Kg/cum	Percentage increase or decrease in density
		LECA	SFA				
28 Days	M1	50	50	0	0	1632.28	0
	M2	50	50	11	0	1657.71	1.557
	M3	50	50	11	0.5	1672.96	2.492
	M4	50	50	11	1.0	1733.98	6.230
	M5	50	50	11	1.5	1696.69	3.946
90 Days	M1	50	50	0	0	1620.41	0
	M2	50	50	11	0	1635.67	0.941
	M3	50	50	11	0.5	1654.31	2.092
	M4	50	50	11	1.0	1715.33	5.857
	M5	50	50	11	1.5	1683.13	3.870

Table 6.3.3: DENSITY VALUES OF SPECIMENS IMMERSED IN SODIUM SULPHATE

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	Density in Kg/cum	Percentage increase or decrease in density
		LECA	SFA				
28 Days	M1	50	50	0	0	1643.37	0
	M2	50	50	11	0	1676.61	2.022
	M3	50	50	11	0.5	1693.21	3.032
	M4	50	50	11	1.0	1744.67	6.164
	M5	50	50	11	1.5	1718.11	4.547
90 Days	M1	50	50	0	0	1663.33	0
	M2	50	50	11	0	1696.53	1.995
	M3	50	50	11	0.5	1704.83	2.494
	M4	50	50	11	1.0	1756.29	5.588
	M5	50	50	11	1.5	1739.71	4.591

Table 6.3.4: DENSITY VALUES OF SPECIMENS IMMERSED IN HYDRO CHLORIC ACID

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	Density in Kg/cum	Percentage increase or decrease in density
		LECA	SFA				
28 Days	M1	50	50	0	0	1557.86	0
	M2	50	50	11	0	1582.44	1.577
	M3	50	50	11	0.5	1608.79	3.269
	M4	50	50	11	1.0	1626.36	4.397
	M5	50	50	11	1.5	1612.31	3.495
90 Days	M1	50	50	0	0	1491.12	0
	M2	50	50	11	0	1506.93	1.060
	M3	50	50	11	0.5	1528.01	2.473
	M4	50	50	11	1.0	1594.74	6.949
	M5	50	50	11	1.5	1550.83	4.004

Table 6.3.5: DENSITY VALUES OF CONCRETE SPECIMENS IMMERSED IN SULPHURIC ACID

Age	Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano (TiO_2+SiO_2) on 11% of cement	Density in Kg/cum	Percentage increase or decrease in density
		LECA	SFA				
28 Days	M1	50	50	0	0	1537.91	0
	M2	50	50	11	0	1599.51	4.005
	M3	50	50	11	0.5	1667.72	8.440
	M4	50	50	11	1.0	1689.72	9.871
	M5	50	50	11	1.5	1669.92	8.583
90 Days	M1	50	50	0	0	1320.11	0
	M2	50	50	11	0	1370.69	3.831
	M3	50	50	11	0.5	1427.89	8.164
	M4	50	50	11	1.0	1467.5	11.164
	M5	50	50	11	1.5	1434.49	8.664

7. DISCUSSION OF TEST RESULTS

7.1] Influence of chemicals on Cube compressive strength of modified concrete specimens:

In the present study natural aggregate has been fully replaced with LECA and Sintered fly ash aggregate in equal proportions. The cube compressive strength results are tabulated in Table 6.1.1 to 6.1.5. From the tables it is observed that cube compressive strengths of modified concrete with 100% replacement of natural aggregate by Sintered fly ash aggregates, and LECA in equal proportions under natural water , sodium chloride, sodium sulphate , hydrochloric acid and sulphuric acid are 26.83 N/mm^2, 21.33 N/mm^2, 17.76 N/mm^2,11.63 $N/mm^2$and 7.73 N/mm^2 respectively for 28 days of curing and 27.76 N/mm^2,17.53 N/mm^2,15.26 N/mm^2,5.26 N/mm^2 and 2.56 N/mm^2respectively for 90 days of curing. After the replacement of cement by 11% of its weight with three numbers of pozzolanic materials i.e., Silica fume, fly ash and slag in equal proportions along with addition of two numbers of Nano materials i.e., Nano SiO_2, and TiO_2 in equal proportions at 1% on 11% weight of cement, the cube compressive strength of the specimens under natural water, sodium chloride, sodium sulphate, hydrochloric acid, sulphuric acid rises to 32.00 N/mm^2, 24.90 N/mm^2, 22.23 N/mm^2,13.56 N/mm^2 and 10.00 N/mm^2 respectively for 28 days and further rises to 33.40 N/mm^2 when placed in normal water but decreased to 19.13 N/mm^2,17.60 N/mm^2, 6.50 N/mm^2 and 4.16 N/mm^2 respectively for 90 days exposure and with further addition of Nano materials the compressive strength of all specimens is decreased for both periods.

7.2] Influence of chemicals on split tensile strength of modified concrete specimens:

In the present study natural aggregate has been fully replaced with LECA and Sintered fly ash aggregate in equal proportions. The Split tensile strength results are tabulated in Table 6.2.1 to 6.2.5. From the tables it is observed that the split tensile strength of specimens under natural water, sodium chloride, sodium sulphate, hydrochloric acid, sulphuric acid are 1.52 N/mm^2, 1.42 N/mm^2, 1.34 N/mm^2, 1.21 N/mm^2 and 1.10 N/mm^2 respectively for 28 days and 1.72 N/mm^2, 1.26 N/mm^2, 1.19 N/mm^2, 1.06 N/mm^2 and 1.11 N/mm^2 respectively for 90 days. After the replacement of cement by 11% of its weight with three numbers of pozzolanic materials i.e., Silica fume, fly ash and slag in equal proportions along with addition of two numbers of Nano materials i.e., Nano SiO_2, and TiO_2 in equal proportions on at 1% on 11% weight of cement, the split tensile strength of the specimens under natural water , sodium chloride, sodium sulphate , hydrochloric acid, sulphuric acid rises to 2.31 N/mm^2, 2.24 N/mm^2, 2.12 N/mm^2 and 1.21 N/mm^2 for 28 days and 2.40 N/mm^2, 1.88 N/mm^2,1.5 N/mm^2 and 1.15 N/mm^2 for 90 days respectively and it follows the same trend as that of compressive strength.

7.3] Influence of chemicals on Density of modified concrete specimens:

In the present study natural aggregate has been fully replaced with LECA and Sintered fly ash aggregate in equal proportions. The density results are tabulated in Table 6.3.1 to 6.3.5. From the tables it is observed that the density of specimens cured under natural water, sodium chloride, sodium sulphate, hydrochloric acid and sulphuric acid are 1650.12 Kg/cum, 1632.28 Kg/cum, 1643.37 Kg/cum, 1557.86 Kg/cum and 1537.91 Kg/cum respectively for 28 days and increased to 1674.89 Kg/cum and 1663.33 Kg/cum when placed in water and Sodium Sulphate solution but density is decreased to 1620.41 Kg/cum, 1491.12 Kg/cum and 1320.11 Kg/cum respectively for Sodium Chloride, hydrochloric acid and sulphuric acid after 90 days exposure. After the replacement of cement by 11% of its weight with three numbers of pozzolanic materials i.e., Silica fume, fly ash and slag in equal proportions along with addition of two numbers of Nano materials i.e., Nano SiO_2, and TiO_2 in equal proportions at 1% on 11% weight of cement under natural water , sodium chloride, sodium sulphate , hydrochloric acid and sulphuric acid rises to 1750.95 Kg/cum, 1733.98 Kg/cum, 1744.67 Kg/cum,1626.36 Kg/cum and 1689.72 Kg/cum respectively for 28 days and after 90 days exposure it further rises to 1765.83 Kg/cum and 1756.29 Kg/cum

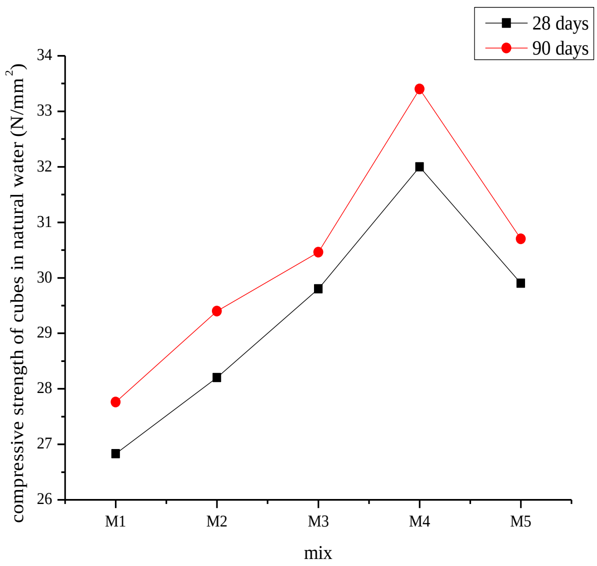

Fig 6.1.1: Compressive Strength for Natural Water

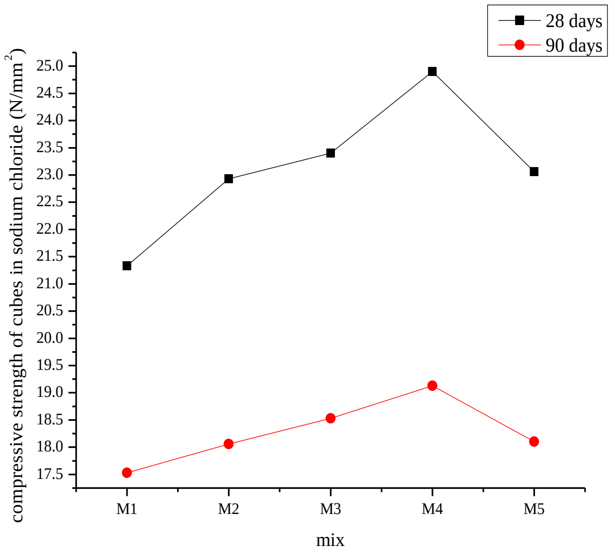

Fig 6.1.2: Compressive Strength for Sodium Chloride

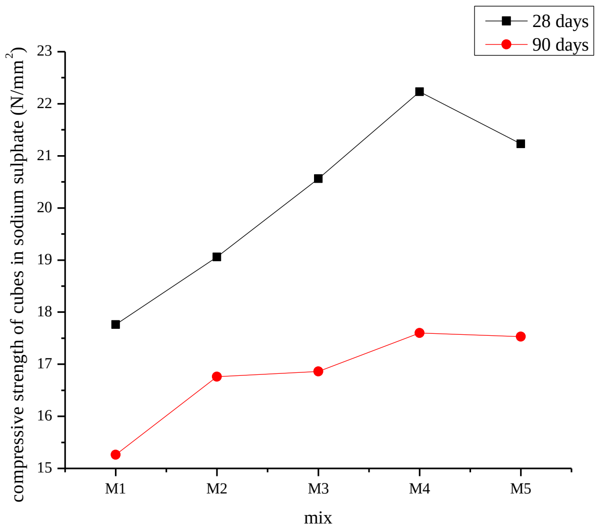

Fig 6.1.3: Compressive Strength for Sodium Sulphate

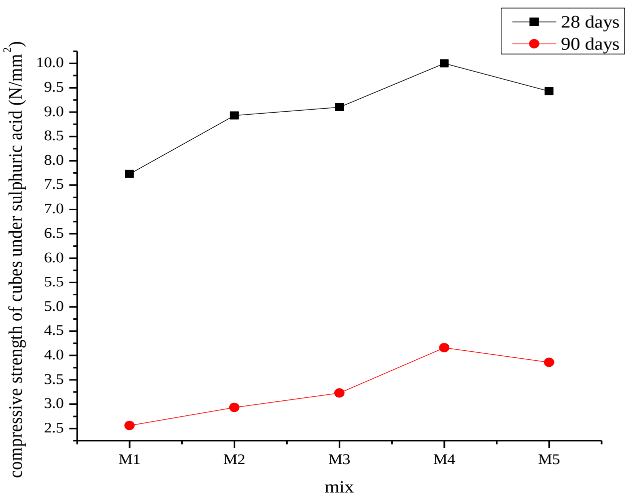

Fig 6.1.4: Compressive Strength for Sulphuric Acid

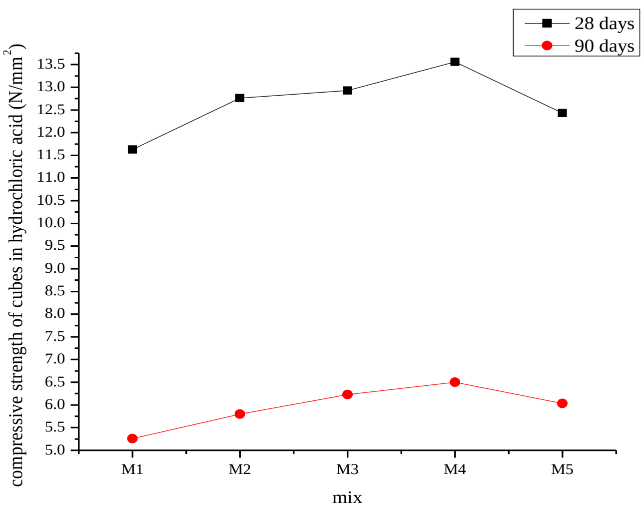

Fig 6.1.5: Compressive Strength for Hydrochloric Acid

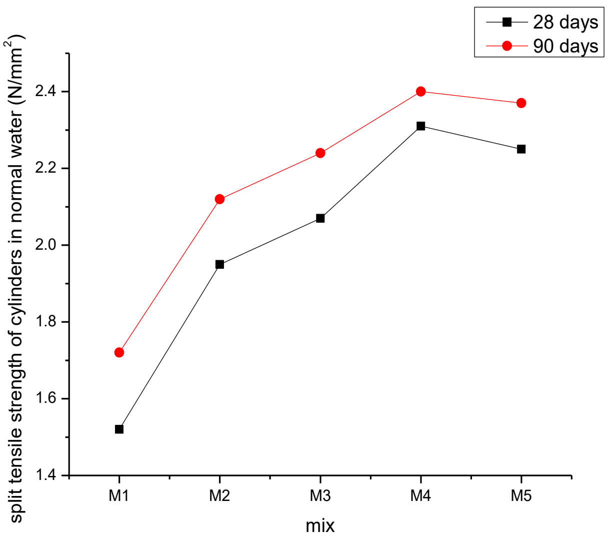

Fig 6.2.1: Split Tensile Strength for Natural Water

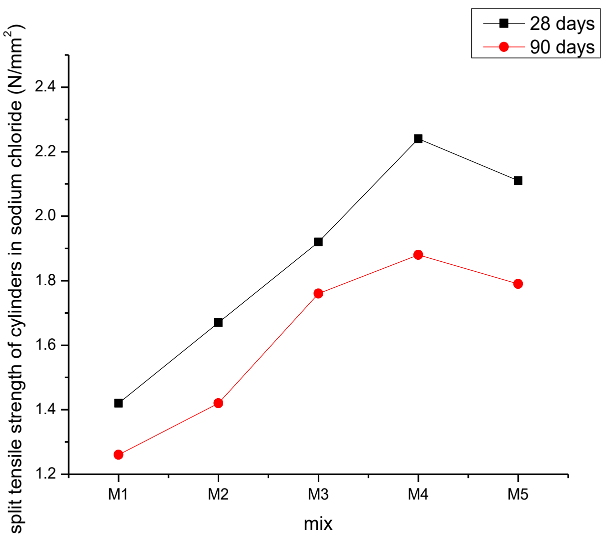

Fig 6.2.2: Split Tensile Strength for Sodium Chloride

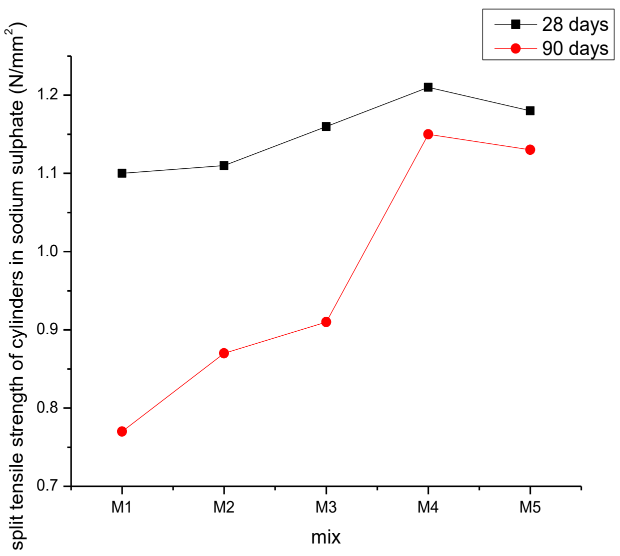

Fig 6.2.3: Split Tensile Strength for Sodium Sulphate

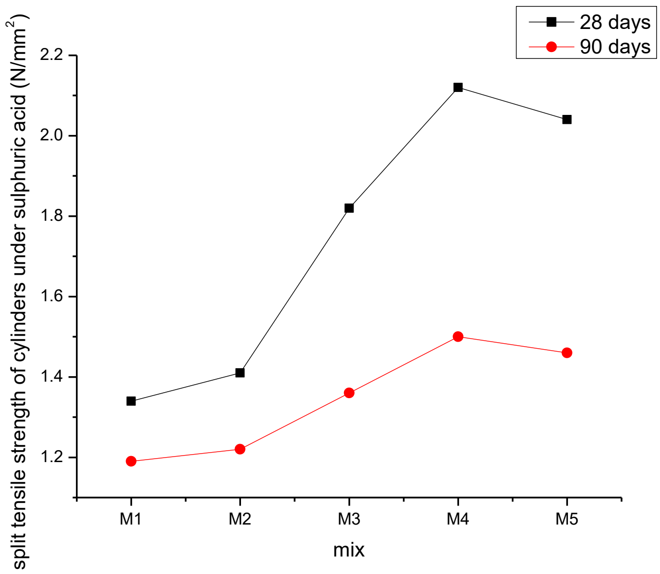

Fig 6.2.4: Split Tensile Strength for Sulphuric Acid

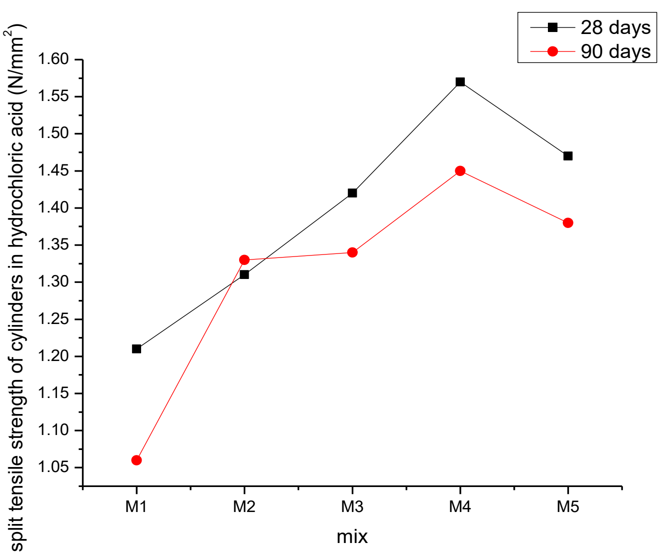

Fig 6.2.5: Split Tensile Strength for Hydrochloric Acid

8. CONCLUSIONS:

1) There is reduction in Compressive strength and Split tensile strength when the specimens are cured in 5% concentrated solutions of Sulphuric acid, Hydrochloric acid, Sodium Chloride and Sodium Sulphate when compared to those cured in normal water after 28 and 90 days of curing. The reduction in strengths is more with Sulphuric acid and Hydrochloric acid when compared to that with Sodium Chloride and Sodium Sulphate after 28 and 90 days of immersion periods.

2) The density of all specimens is decreased with all 5% concentrated solutions compared to that of water for 28 days and 90 days exposure. The density of the specimens cured in Sodium Sulphate is increased where as further reduction in density is observed for all the specimens placed in remaining solutions for 90 days exposure when compared to that of 28 days exposure. When the specimens are immersed in Na_2SO_4 solution, incorporation of pozzolanic material reduces the sulphate attack. The pozzolanic material is responsible for conversion of leachable calcium hydroxide to non leachable cementitious product, which is responsible for impermeability of concrete.

3) It is also observed that when the cement is replaced with 11% of its weight by three numbers of pozzolanic materials, increase in density, compressive strength and split tensile strength is observed for all the specimens. These values are continuously increasing with replacement of cement by two Nano materials i.e., Nano SiO_2 and TiO_2 in equal proportions at 0%, 0.5%, 1% on 11% of cement and with further addition of Nano materials all the strength parameters are reduced. The resistance of modified concrete for all chemical solutions studied is increased with addition of pozzolanic materials and the optimum percentage replacement of cement by Nano materials is 1% on 11% of weight of cement/Nano materials. This phenomenon of increase in strength is not only due to more pozzolanic action of admixtures in the presence of Nano materials. With further addition of Nano materials reduction of strength of modified concrete is observed due to agglomeration of Nano materials which may lead to the micro cracking and deterioration of strength in the cement composites.

9. REFERENCES:

[1] K. Kawai et.al.,; "Concrete Deterioration Caused by Sulfuric Acid Attack":10DBMC International Conference On Durability of Building Materials and Components [April 2005].

[2] Emmanuel K et.al.,; "Response of Concrete to Sulfuric Acid Attack ": ACI Material Journal. Title no. 85-M46.

[3] Shintaro Miyamoto, et,al; "Deterioration rate of hardened cement caused by high concentrated mixed acid attack": Construction and Building Materials, Elsevier Publications [2005] .

[4] Beulah M., Prahallada M. C; "Effect Of Replacement Of Cement By Metakalion On The Properties Of High Performance Concrete Subjected To Hydrochloric Acid Attack": International Journal of Engineering Research and Applications. Vol. 2, Issue 6, November- December 2012, pp.033-038.h