Experimental and Durability Investigation on High Performance Concrete with Partial Replacement of Cement by Alccofine

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Abstract: Concrete is the most widely used building material. It has desirable Engineering properties, can be moulded into any shape and more importantly is produced with cost effective materials. Large numbers of mineral admixtures, which are waste products of other industries, are being beneficially used in making quality concrete. The increase in durability along with strength of concrete will lead to the use of high-performance concrete which will be more beneficial for environmental attacks on the structure. High-performance concrete involves variation of different parameters like water-cement ratio, use of mineral admixture, chemical admixture, temperature, curing regime, etc. The mechanical and environmental performance of concrete was observed to be depending on various types of material used in the concrete. The properties of concrete depend on packing of grains and type of curing regime. Alternative concretes are needed to reduce the significant environmental impact of ordinary Portland cement concrete construction. Although fly ash as a partial replacement for cement has been utilized for many years, it has been almost exclusively used in low volume percentages, such as 10 or 20% cement replacement which reduces the cost of concreting but it effects on concrete inversely. In this study cement is partially replaced by ALCCOFINE and fly ash for M_{60} grade of concrete. The compressive strength of concrete with OPC and ALCCOFINE and it has been found that the strength of concrete got increased by 10% with partial replacement of cement by ALCCOFINE and the cost also reduced. HPC is designed to have better mechanical properties and a higher resistance to chemicals than conventional concrete. This study is focused to investigate the strength parameters of HPC with partial replacement of cement by Alccofine with optimum 10%. Poly Carboxylic Ether is a type of super plasticizer which is used to improve flow and workability characteristics. For the optimization of mixtures, compression strength was tested.

Index terms: HPC, Alccofine, Sorptivity, Acid Resistance, Chloride Resistance, Sulphate Resistance.

I. INTRODUCTION

A. General

The increasing demand of infrastructure due to continuous rise in population and high rate of urban drift, concrete has more consumed because of industrialization and urbanization. Concrete is the most widely consumed resource in construction industry. The continuous global demand for concrete implies that, more aggregate and cement would be required in the production of concrete, thereby leading to more extraction and depletion of deposits of natural gravel, and increased CO2 emission from quarrying activities. Also the continuous use of conventional concrete, (that is concrete produced with virgin aggregates and ordinary Portland cement) has proved to be very unfriendly to the environment. Concrete is primarily comprised of Portland cement, aggregate, and water. Although Portland cement typically only comprises 12% of the concrete mass, it accounts for approximately 93% of the total embodied energy of concrete and 6 to 7% of the worldwide CO2 emissions (Mehta 1998). A large number of papers available with replacement of cement with fly ash in this paper strength of concrete is investigatedalongwithcostcomparisonbetweenOPCco ncreteandconcrete with fly ash and ALCCOFINE. In high performance concrete applications, Silica Fume is generally proposed as the appropriate cement extender where high strength, low permeability are the prime requirements.

Though Silica fume is known to improve durability, its addition in concrete is often negated by the increase water and/or admixture dosage required to improve the workability and handling properties of the fresh concrete. This paper focuses on partial replacement of cement with fly ash and ALCCOFINE 1203. This replacement increases the strength, durability, resistance to chemical attack of concrete. Concrete is the most widely used construction material in India with annual consumption exceeding 100 million cubic meters. It is well known that conventional concrete designed on the basis of compressive strength does not meet many functional requirements such as impermeability, resistance to frost, thermal cracking adequately

High performance concrete is a concrete mixture, which possess high durability & high strength when compared to conventional concrete. This concrete contains one or more of cementitious materials such as fly ash, silica fume or ground granulated blast furnace slag & usually a super plasticizer. High performance concrete (HPC) is a specialized series of concrete designed to provide several benefits in the construction of concrete structures that cannot always be achieved routinely using conventional ingredients, normal mixing & curing practices. High performance concrete should have at least one property like high strength, high durability, acid resistance, self-compaction, low permeability to water as compared to normal concrete, to qualify as high-performance concrete.

B. Alccofine

ALCCOFINE 1203 performs in superior manner than all other mineral admixtures used in concrete within India. Due to its inbuilt CaO content, ALCCOFINE 1203 triggers two way reactions during hydration Primary reaction of cement hydration. Pozzolanic reaction: ALCCOFINE also consumes by product calcium hydroxide from the hydration of cement to form additional C-S-H gel, similar to pozzolans. This results in denser pore structure and ultimately higher strength gain.

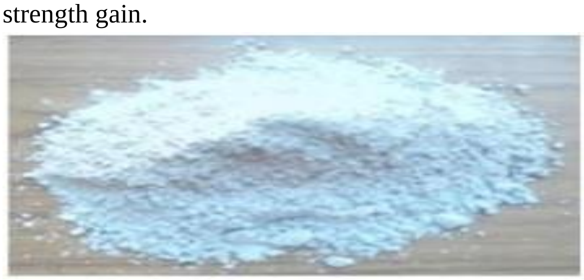

Fig.1 Alccofine-1203

B.1. Properties of Alccofine

TABLE I PROPERTIES OF ALCCOFINE-1203

Chemical Analysis	Mass %	Physical Analysis	Range
CaO	32-34	Bulk Density	600-700 kg/m^3
Al_2O_3	18-20	Surface Area	12000 cm^2/gm
Fe_2O_3	1.8-2	Particle Shape	Irregular
SO_3	0.3-0.7	ParticleSize,d10	< 2 μ
MgO	8-10	D50	< 5 μ
SiO_2	33-35	D90	< 9 μ

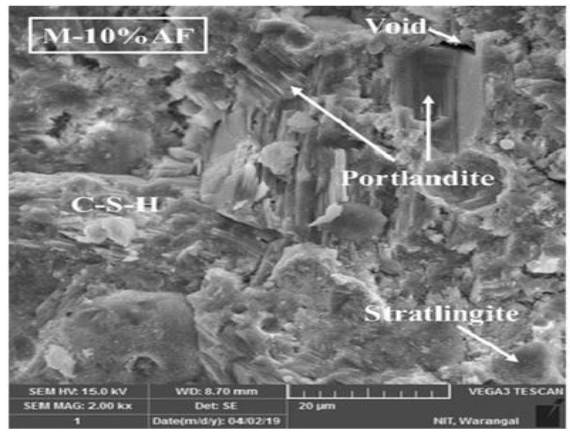

Fig.2 SEM of Alccofine in Concrete

C. Durability Tests

C.1. Water Absorption

The water absorption test results provide information about the concrete's permeability and its ability to resist water penetration. Lower water absorption values indicate improved resistance to moisture ingress and better durability. This test is useful for assessing the quality and durability of concrete mixes.

C.2.Sorptivity

The sorptivity test provides a measurement of how quickly water is absorbed into the surface of concrete. The sorptivity value (S) is typically expressed in units of millimeters per second (mm/sec) and represents the rate of water absorption. Lower sorptivity values indicate lower permeability and better resistance to water penetration, which is desirable for concrete's durability and longevity.

C.3. Acid Attack

The results of the acid attack test provide information about the concrete's resistance to chemical deterioration by acids. Lower mass loss values and slower rates of deterioration indicate better acid resistance. The test helps assess the suitability of the concrete mix for specific environments.

C.4. Sulphate Attack

The results of the sulphate attack test provide information about the concrete's resistance to sulphate-induced deterioration. Lower change in mass values and slower rates of deterioration indicate better sulphate resistance. Exposure of concrete made with Portland cement to sulphate salts can cause damage due to an expansive reaction between the cement and the sulphate salt to form crystals of ettringite. Given adequate space to form, the ettringite forms needle like crystals, but in confined space causes an expansive reaction.

C.5. Chloride Attack

The test for chloride content in concrete is very significant as when chloride is present in reinforced concrete it can cause very severe corrosion of the steel reinforcement. Chlorides can originate from two main sources: a) “Internal” Chloride, i.e. chloride added to the concrete at the time of mixing. This includes calcium chloride accelerating admixtures, contamination of aggregates and the use of sea water or other saline contaminated water. b) “External” chloride, i.e. chloride increasing into the concrete post-hardening. In this category, we find both rock-salt (used on roads) which gets into concrete structures such as flyovers and sea salt, either directly from sea water in structures such as bridges, or in the form of air-borne salt spray in structures adjacent to the coast.

II. MATERIALS AND METHODS

A. Cement

Cement is a binder, a substance used in construction that sets and hardened and can bind other materials together. The main composition of Ordinary Portland Cement (OPC) is lime, silica, alumina and iron oxide. Ordinary Portland Cement-53 grade have used in this investigation.

TABLE II PRIMARY TEST RESULT FOR CEMENT

S. No.	Properties	Value	IS Specifications
1.	Specific Gravity	3.15	IS4031
2.	Normal Consistency	33%	IS4031
3.	Initial Setting time	34min	IS4031
4.	Final Setting time	410min	IS269-1976
5.	Fineness (By Sieve Method)	4% of Residue	IS269-1976

B. Fine Aggregate

When the aggregate is sieved through 4.75mm sieve, the aggregate passed through it called as fine aggregate. It included sand, silt & clay. Natural sand have used, its property is given below.

TABLE III PRIMARY TEST RESULT FOR FINE AGGREGATE

S. No.	Properties	Value	IS Specifications
1.	Specific Gravity	2.63	IS383-1970
2.	Sieve Analysis	Zone-II	IS383-1970

C. Coarse Aggregate

When the aggregate is sieved through 4.75mm sieve, the aggregate retained is called coarse aggregate. It is a material used in construction, including sand, gravel, and crushed stone.

TABLE IV PRIMARY TEST RESULT FOR COARSE AGGREGATE

S. No.	Properties	Value	IS Specifications
1.	Specific Gravity	2.67	IS2386 –1963
2.	Impact Value	21.29%	IS2386–1963
3.	Crushing Value	25.22%	IS2386–1963

D. Compressive Strength

The compressive strength is the capacity of a material or structure to withstand loads. Some materials fracture at their compressive strength limit, others deform irreversibly. All the test specimens cast for compressive strength were tested using a compressive testing machine.

TABLE V 7 DAYS COMPRESSIVE STRENGTH

Alccofine Content in Cube	Sample 1	Sample 2	Sample 3	Average Compressive Strength (N/mm^2)
5%	42.14	43.22	44.46	43.27
10%	45.22	45.67	43.45	44.78
15%	39.61	39.45	39.89	44.78

TABLE VI 28 DAYS COMPRESSIVE STRENGTH

Alccofine Content in Cube	Sample 1	Sample 2	Sample 3	Average Compressive Strength (N/mm^2)
5%	66.45	68.75	66.31	67.17
10%	72.04	71.22	71.56	71.60
15%	61.22	62.13	61.44	61.59

E. Dimensions of Strength

For strength study, Cube mould = 150x150x150mm & 100x100x100mm Cylindrical mould = 300mm height and 150mm diameter Beam mould = 1000mm in length with cross-section of 150x150mm.

For durability study, Cube mould = 100x100x100mm Cylindrical mould = 100 mm diameter and 50 mm height.

E.1. Compressive Strength

Concrete is designed for M60 (Alccofine–10%)

TABLE VII 7 DAYS COMPRESSIVE STRENGTH

Designation	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
OPC+ALCCOFINE	43.90	44.74
OPC+ALCCOFINE	44.67	
OPC+ALCCOFINE	45.67	
OPC	54.56	54.78
OPC	53.10	
OPC	56.70	

TABLE VIII 28 DAYS COMPRESSIVE STRENGTH

Designation	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
OPC+ALCCOFINE	71.13	72.15
OPC+ALCCOFINE	71.96	
OPC+ALCCOFINE	73.37	
OPC	66.09	65.94
OPC	65.23	
OPC	66.52	

III. DURABILITY TESTING

A. Durability Tests

The present study deals with durability of cube specimens subjected to sodium chloride (NaCl), Sodium sulphate acid (Na2SO4) attack, HCl attack, water absorption and sorptivity tests. Concrete cubes of 100 x 100 x 100 mm3 size were casted for durability studies of M20 grade concrete. Compressive strength of cubes which were immersed in the solution of Na2SO4, NaCl, HCl are tested and their corresponding results were represented.

Fig.4 Preparation of Test Specimens

B. Test Results

B.1. Sulphate Resistance Test

TABLE IX PERCENTAGE CHANGE IN WEIGHT (SULPHATE ATTACK)

Exposure Days	Specimen No	CONVENTIONAL				10% ALCCOFINE			
		Initial Weight (Kg)	Final Weight (Kg)	Change in Weight (%)	Avg (%)	Initial Weight (Kg)	Final Weight (Kg)	Change in Weight (%)	Avg (%)
15	1	2.753	2.712	1.49	1.52	2.946	2.909	1.26	1.26
	2	2.784	2.742	1.51		2.975	2.937	1.28	
	3	2.816	2.772	1.56		2.984	2.947	1.24	
30	4	2.905	2.859	1.58	1.61	3.021	2.978	1.42	1.40
	5	2.935	2.887	1.64		3.001	2.959	1.40	
	6	2.869	2.823	1.60		2.981	2.94	1.38	
45	7	2.921	2.867	1.85	1.85	3.051	3.001	1.64	1.63
	8	2.848	2.796	1.83		2.994	2.944	1.67	
	9	2.863	2.809	1.89		2.985	2.938	1.57	
60	10	2.931	2.874	1.94	2.09	3.031	2.971	1.98	1.86
	11	2.874	2.813	2.12		2.997	2.944	1.77	
	12	2.854	2.791	2.21		2.978	2.923	1.85	

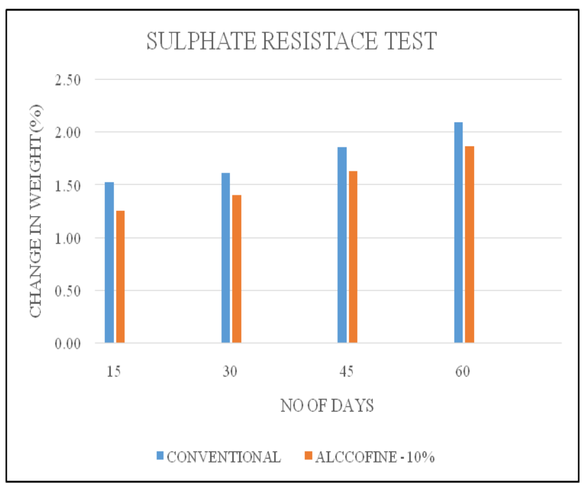

Fig.5 Comparison of Change in Weight (Sulphate Attack)

B.2.Acid Resistance Test

TABLE X PERCENTAGE CHANGE IN WEIGHT (ACID ATTACK)

Exposure Days	Specimen No	CONVENTIONAL				10% ALCCOFINE			
		Initial Weight (Kg)	Final Weight (Kg)	Change in Weight (%)	Avg (%)	Initial Weight (Kg)	Final Weight (Kg)	Change in Weight (%)	Avg (%)
15	1	2.892	2.845	1.652	1.64	2.946	2.901	1.551	1.458
	2	2.858	2.81	1.708		2.975	2.935	1.362	
	3	2.86	2.816	1.562		2.984	2.941	1.462	
30	4	2.821	2.772	1.767	1.756	3.021	2.973	1.614	1.521
	5	2.935	2.881	1.874		3.001	2.956	1.522	
	6	2.869	2.823	1.629		2.981	2.939	1.429	
45	7	2.911	2.875	1.252	1.812	3.05	3.007	1.429	1.472
	8	2.848	2.786	2.225		2.994	2.952	1.422	
	9	2.86	2.805	1.96		2.985	2.939	1.565	
60	10	2.931	2.867	2.232	2.419	3.031	2.987	1.473	1.499
	11	2.894	2.814	2.842		2.997	2.954	1.455	
	12	2.854	2.793	2.184		2.978	2.932	1.568	

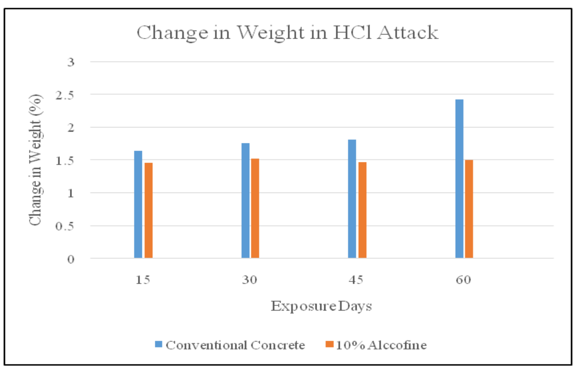

Fig.6 Comparison of Change in Weight (Acid Attack)

B.3.Chloride Resistance Test

TABLE XI PERCENTAGE CHANGE IN WEIGHT (CHLORIDE ATTACK)

Exposure Days	Specimen No	CONVENTIONAL				10% ALCCOFINE			
		Initial Weight (Kg)	Final Weight (Kg)	Change in Weight (%)	Avg (%)	Initial Weight (Kg)	Final Weight (Kg)	Change in Weight (%)	Avg (%)
15	1	2.808	2.784	0.862	1.316	3.001	2.994	0.5833	0.6855
	2	2.879	2.832	1.66		2.965	2.955	0.6873	
	3	2.854	2.813	1.458		2.982	2.969	0.7859	
30	4	2.945	2.905	1.377	1.339	2.948	2.94	0.6214	0.7458
	5	2.897	2.865	1.117		2.971	2.964	0.5856	
	6	2.935	2.885	1.733		2.939	2.919	1.0305	
45	7	2.886	2.851	1.398	1.457	3.004	2.989	0.8493	0.7734
	8	2.822	2.787	1.556		2.991	2.979	0.7512	
	9	2.865	2.825	1.416		2.975	2.964	0.7197	
60	10	2.871	2.847	1.543	1.525	3.021	3.01	0.7141	0.9993
	11	2.878	2.834	1.553		2.984	2.961	1.1208	
	12	2.814	2.773	1.479		2.952	2.928	1.1630	

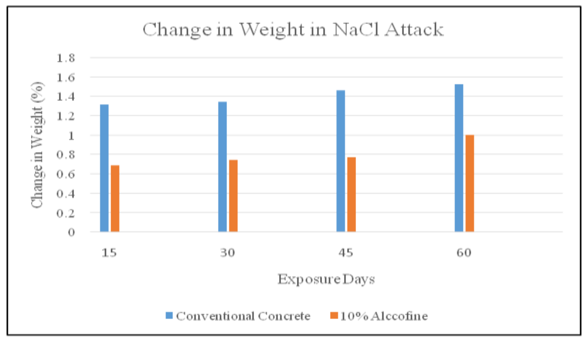

Fig.7 Comparison of Change in Weight (Chloride Attack)

B.4.Compressive Strength Result

TABLE XII PERCENTAGE LOSS OF COMPRESSIVE STRENGTH

Specimen	Age of Concrete	Compressive Strength (MPa)	Compressive Strength After Attack (MPa)	% Loss of Compressive Strength
	Nacl Attack			
Conventional	43	67.468	65.506	2.9080
	58	69.411	68.468	1.3585
	73	72.373	70.43	2.6847
	88	73.354	72.392	1.3114
10% Alccofine	43	69.392	68.43	1.3863
	58	72.335	71.278	1.4612
	73	74.259	72.335	2.5909
	88	75.202	73.278	2.5584
	Na_2SO_4			
Conventional	43	67.468	66.487	1.4540
	58	69.411	68.449	1.3859
	73	72.373	69.43	4.0664
	88	73.354	71.392	2.6747
10% Alccofine	43	69.392	69.449	0.0821
	58	72.335	71.411	1.2773
	73	74.259	73.354	1.2187
	88	75.202	74.297	1.2034
	HCl			
Conventional	43	67.468	66.487	1.4540
	58	69.411	69.43	0.0273
	73	72.373	70.411	2.7109
	88	73.354	72.392	1.3114
10% Alccofine	43	69.392	68.449	1.3589
	58	72.335	70.411	2.6598
	73	74.259	73.354	1.2187
	88	75.202	76.297	1.4560

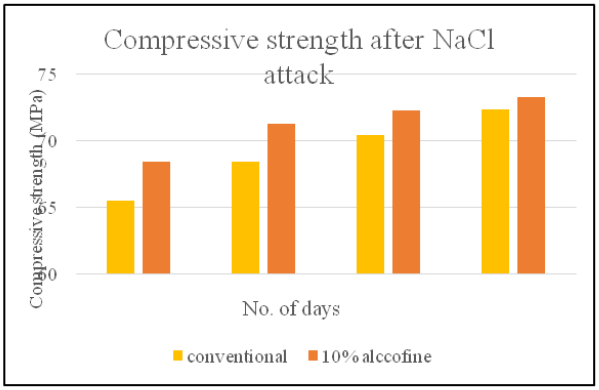

Fig.8 Comparison of Compressive Strength (Sodium Chloride Attack)

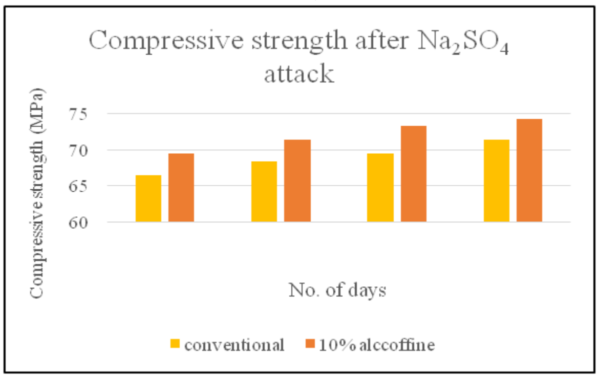

Fig.9 Comparison of Compressive Strength (Sodium Sulfate Attack)

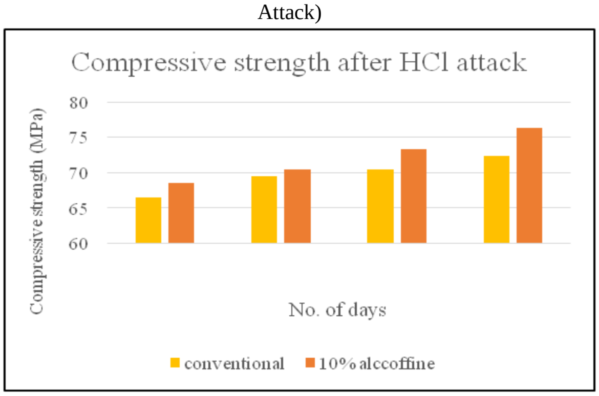

Fig.10 Comparison of Compressive Strength (Hydrochloric Attack)

C. Water Absorption Test Result

C.1. Water Absorption Test for Conventional Concrete

TABLE XIII WATER ABSORPTION OF CONVENTIONAL CONCRETE

Specimen	Days	Dry weight	Saturated weight	Water Absorption (%)
1	28	2.793	2.842	1.754
2	28	2.718	2.767	1.803
3	56	2.742	2.795	1.933
4	56	2.798	2.857	2.109

C.2. Water Absorption Test for 10% Replacement of Alccofine

TABLE XIV WATER ABSORPTION OF 10% REPLACEMENT OF ALCCOFINE

Specimen	Days	Dry weight	Saturated weight	Water Absorption (%)
1	28	2.856	2.891	1.225
2	28	2.807	2.842	1.247
3	56	2.869	2.907	1.325
4	56	2.825	2.863	1.345

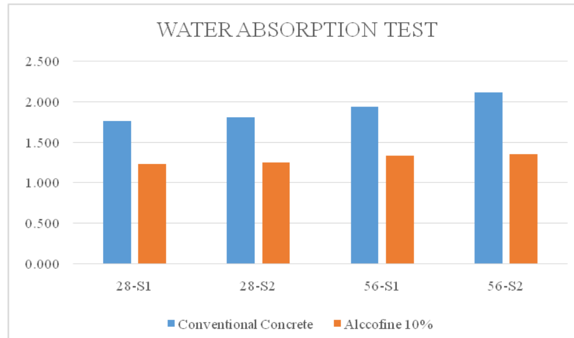

Fig.11 Comparison of Compressive Strength

D. Sorptivity

D.1. Sorptivity Test for Conventional Specimen-1

TABLE XV SORPTIVITY TEST FOR CONVENTIONAL SPECIMEN-1

Time	√Time	Initial Weight (g)	Final Weight (g)	Change in Weight (g)	Intensity (mm)
0	0.00	970	970	0	0.0000
60	7.75	970	972	2	0.2547
120	10.95	970	973	3	0.3820
180	13.42	970	974	4	0.5093
240	15.49	970	974	4	0.5093
300	17.32	970	974	4	0.5093
600	24.49	970	975	5	0.6366
900	30.00	970	977	7	0.8913
1200	34.64	970	977	7	0.8913
1500	38.73	970	978	8	1.0186
1800	42.43	970	978	8	1.0186
3600	60.00	970	982	12	1.5279
7200	84.85	970	983	13	1.6552
10800	103.92	970	984	14	1.7826
14400	120.00	970	986	16	2.0372
18000	134.16	970	988	18	2.2919
21600	146.97	970	989	19	2.4192

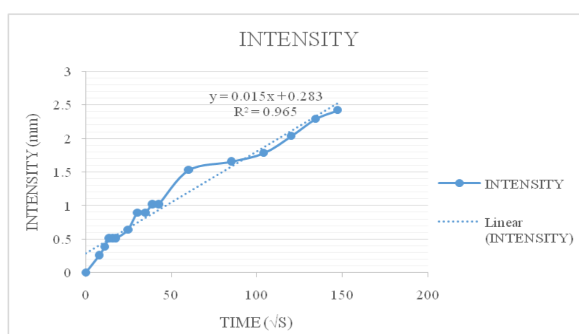

Fig.12 Sorptivity Test for Conventional Specimen-1

IV. CONCLUSION

The following conclusions can be drawn from this investigation:

1. In this study the effects of Alccofine as a supplementary cementing material and filling material on the strength of concrete was investigated. The maximum compressive strength of concrete is achieved by using Alccofine 10%.
2. The relative cost of Alccofine is cheaper than cement hence it is economic with higher strength.
3. The best result were achieved in HPC at 10% alccofine as a replacement for cement
4. When compared to conventional concrete, HPC strength is relatively high replacement for the partial replacement of cement by10% alccofine.
5. In flexural strength of HPC beam, the ultimate load is increased in comparison with conventional concrete.
6. HPC beam with optimum alccofine shows less deflection than the conventional concrete beam.
7. The research makes it clear that reinforced concrete beam built using 10% alccofine as a replacement of cement may perform more structurally well.
8. From the investigation, rate of water absorption of conventional mix was found to be higher than the 10% alccofine replaced concrete by weight of cement.
9. The sorptivity values decreased with minimum cumulative time period when compared to conventional concrete. Because of fineness of alccofine, it occupies remaining pores in the mix and cause low permeability and absorbing capacity.
10. From the investigation, HPC with 10% alccofine replacement for cement shows good durable result compare to conventional concrete by analyzing the result of acid attack
11. Sorptivity investigation was done and it showed better results
12. The partial replacement of cement with alccofine leads reduction in consumption of cement usage by natural resources and the environment is protected from waste disposal materials.
13. Thus the optimum percentage of 10% alccofine replacement by weight of cement was found to be effective in both mechanical and durability properties.

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