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Rapid Chloride Permeability Test on Concrete with Nano Materials

Jemimah Carmichael. M, Prince Arulraj. G

ABSTRACT--- Nanotechnology has received a lot of attention for its ability to make use of the unique properties of nano-sized materials. Nanotechnology is a very active research field and has applications in a number of areas. Currently this technology is being used for the creation of new materials, devices and systems at molecular, nano and micro-level. Recently, nanotechnology has attracted considerable scientific interest in civil engineering field due to the new potential uses of particles in nano-scale. Concrete with nano materials has some remarkable properties. In this experimental work, an attempt has been made to determine the influence of nano-materials on the durability of concrete. Chloride permeability of concrete in which cement was replaced partially with nano-cement, nano-flyash, nano-silica, nano- silica fume were found. Different grades of concrete viz., M20, M30, M40 and M50 were cast with nano materials. For each grade of concrete, 0%, 10%, 20%, 30%, 40% and 50% of cement was replaced with nano materials. Nanomaterials were obtained by grinding the micro sized materials in a ball grinding machine and the particle size was determined by using Scanning Electron microscope. The chloride permeability of concrete with nano-cement, nano-fly ash, nano-silica and nano- silica fume were determined using a Rapid Chloride Permeability Test (RCPT) apparatus and the results are compared with that of the Normal Cement Concrete (NCC).

Keywords: Chloride permeability, nano-cement, nano-flyash, nano-silica, nano-silicafume, RCPT.

I. INTRODUCTION

Concrete is a versatile and one of the most widely used construction materials in the world. Durability represents one of the key characteristics of concrete that determines the life span of structures. The durability of cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality, and serviceability when exposed to harmful effects of environment. Durability of cement concrete is determined by its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Properly designed, proportioned, placed, finished, tested, inspected, and cured concrete is capable of providing decades of service with little or no maintenance. Certain conditions and hostile environment may lead to the deterioration of concrete. Attacking mechanisms can be chemical, physical, or mechanical in nature, and originate from external or internal sources. Depending on the nature of attack, distress may be concentrated in the paste or aggregate, or reinforcing components of the concrete or in a combination of the above. The various factors influencing the durability and the particular mechanism of deterioration should be considered in the context of the environmental conditions to which the concrete would be subjected. In addition, consideration should be given to the microclimate to which the specific structural element is exposed. Deterioration, or the severity of deterioration, of a given structure may be affected by its orientation to wind, precipitation, or temperature. The factor responsible for the severity of deterioration has to be given careful consideration. Required service life, design requirements, and expected exposure environments (macro and micro) should be determined before selecting the appropriate materials and mixture proportions necessary to produce concrete suitable for a particular application. The use of good materials and proper mix proportioning alone will not necessarily ensure durable concrete. Appropriate measures of quality control, testing, inspection, placement practices, and workmanship are essential for the production of durable concrete. Properly designed testing and inspection programs that use trained and certified personnel are also important to ensure that durable concrete is produced. The causes of deterioration of concrete and measures to prevent such damage enhances the durability of concrete structures. Freezing and thawing, alkali-aggregate reaction (AAR), aggressive chemical exposure, corrosion of metals, abrasion, fire resistance of concrete and cracking should be taken care of at all stages. In this paper, an attempt has been made to study the resistance to chloride permeability of concrete with nano materials.

In this experimental study, Rapid Chloride permeability test (RCPT) was used to determine the resistance to penetration of chloride ions. This test determines the electrical conductance of the different grades of concrete mixes and provides a rapid indication of its resistance to the penetration of chloride ions. The test consists of monitoring the amount of electrical current passed through concrete specimens for a specified time. Movement of ions in a porous medium under a concentration gradient is called diffusion. It is often necessary to ascertain the impermeability of concrete to chloride ions as a quality control measure and also for assessment of improvements effected in properties of new concretes. Measurement of chloride diffusion co-efficient requires a long time for establishment of steady state conditions. Therefore, a direct current potential is usually applied to accelerate the migration of ions.

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II. REVIEW OF LITERATURE

Bhuvaneswari.B. et al (2007) explained the role of nano technology for the construction applications in the area of cement based materials and their composites. It was reported that the inclusion of nano particles would improve the shear, tensile and flexural strengths of cement based materials and result in new generation construction material with enhanced strength and durability properties. They also reported that natural minerals can be used as nano materials in concrete. Perumalsamy Balaguru and Ken Chong (2006) highlighted the research opportunities of nanotechnology in the field of concrete technology. They also reported that nano-cement had a more rapid hydration rate than Portland cement. Konstantin Sobolev et al. (2006) discussed the use of nano materials in high performance concrete. Various methods available to produce nano materials were also discussed. Monteiro P.J.M. et al.(2008) studied the nano and microstructure of cement paste and concrete exposed to aggressive environments using high resolution full-field soft X-ray imaging and Hard X-ray microtomography images. Jemimah Carmichael.M and Prince Arulraj.G. (2017) studied the strength and permeability of concrete in which a portion of cement was replaced with nano-cement. They found that addition of nano material increases the compressive strength and decrease the permeability. Prince Arulraj.G and Jemimah Carmichael.M. (2011) studied the effect of replacement of cement and coarse aggregate with nano-fly ash on the compressive strength of concrete. They reported that due to the high specific surface area of nano materials, the strength increased. Stanish et al. (1997) overviewed the various test methods like salt ponding test, bulk diffusion test, Rapid Chloride Permeability test, electrical Migration Techniques, Rapid Migration Test, Resistivity techniques, pressure penetration Techniques, Indirect Measurement Technique, Sorptivity tests to find the chloride penetration resistance of concrete. It was concluded that a proper understanding and selection of the testing procedure is essential to study chloride penetration resistance of concrete. Subbulakshmi.T and Vidivelli.B., (2016) conducted tests to determine the mechanical properties and permeability of high performance concrete with silica fume, bottom ash, steel slag aggregate and superplasticizer. They concluded that proper curing will significantly reduce the chloride permeability. Krishnakumar.S et al. (2013) studied the effect of silica fume on the resistance to chloride ion penetration in high performance concrete. The total current passed through the concrete specimens was found to be decreasing with increase in percentage of replacement. Considering the increase in strength and resistance to chloride ion penetration of the concrete, the optimum replacement percentage of cement with silica fume was suggested as 7.5 percent. Madhavi.T.Ch. et al studied the chloride penetration of fly ash concrete. The methodology adopted was Rapid Chloride Permeability Test as per ASTM C1202. It was concluded that with the increase in fly ash content, the permeability of concrete decreased. At 28 days, the chloride penetration reduced to the extent of 33.36% which further reduced to a maximum of 82.2% at 90 days on 60% replacement of cement with fly ash. Tao Ji (2005) presented the details of a preliminary study on the water permeability and micro structure of concrete with nano-SiO_2. Nano-SiO_2 was found to improve the micro structure of the interfacial transition zone between aggregate and binding paste material and reduced the permeability of concrete. Celih Ozyildirium and Caroline Zegetosky (2010) experimentally investigated the permeability and strength behaviour of air entrained concrete with nano-materials. It was concluded that nano-silica reduced the drying shrinkage cracking but not effective in lowering the permeability. Maile Aiu (2006) explained the chemistry and physics of nano-cement. Nano-cement was produced by sol-gel process from Portland Cement. The compressive strength of nano-cement was found to be less than that of Portland cement. This may be due to agglomeration and lack of gypsum in nano-cement. Tao Ji et al. (2009) carried out an experimental investigation on the infiltration characteristics of concrete containing nano-SiO_2 and Silicone. It was reported that the lower water-cement ratio and addition of nano silica improved the infiltration resistance and compressive strength of concrete. It was reported that nano-silica filled the voids of C-S-H gel and nano pores in concrete. The alkyl groups in silicone decreased the molecular attraction between water and concrete and filled some pores in concrete and hence the absorption rate decreased. Xiodong He and Xianming Shi (2008) studied the chloride permeability and micro structure of Portland cement mortars incorporating nano-materials. The electro migration test was done on concrete with nano-material such as Fe_2O_3, Al_2O_3, TiO_2, SiO_2 and nano clay. It was concluded that nano-materials acted as fillers and led to a denser and less permeable cement mortar. An attempt has been made during the present investigation to determine the effect of nano materials on the chloride permeability of concrete.

III. EXPERIMENTAL INVESTIGATION

The primary objective of the present work is to determine experimentally the influence of nano- cement, nano-fly ash, nano- silica and nano-silica fume on the durability of concrete. The experimental programme consisted of making concrete cylinders with and without nano materials and testing them.

Nano-cement was made by grinding the commercially available 53 grade Portland cement in a high energy ball grinding mill. Similarly flyash, silica and silica fume are converted to nano sized particles by grinding. A scanning electron microscope (SEM) shown in Figure.1 was used to determine the particle size and the structure of the nano-cement produced. Figure.2, Figure.3, Figure.4 and Figure.5 show the SEM images of nano-cement, nano-flyash, nano-silica and nano- silica fume particles.

Figure.1

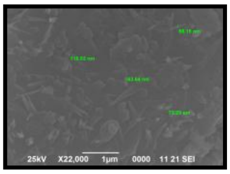

Figure.2

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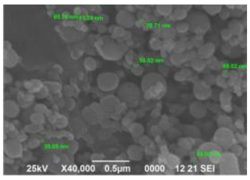
Figure.3

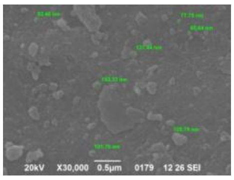
Figure.4

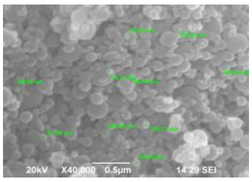
Figure.5

Fig.1-Scanning Electron Microscope. Fig.2-SEM Image of Nano-Cement, Fig.3-Nano-fly ash, Fig.4-nano-silica and Fig.5-nano-silica fume Particles

From the SEM images, it can be seen that the micro sized cement particles have been scaled down to nano sized cement particles. The size of the nano particles were found to be in the range of 30nm to 170nm. Eight hundred and sixty four specimens were cast during the experimental investigation. Conventional cement concrete of grades M20, M30, M40 and M50 were designed as per IS 10262:2009. For all the mixes, 0%, 10%, 20%, 30%, 40%, and 50% of cement was replaced with nano materials. For each of these mixes, the rapid chloride permeability tests were carried out on 28^{th}, 56^{th} and 90^{th} days.

IV. TESTS ON CONCRETE

The Rapid Chloride penetration Test was carried out using three cell RCPT apparatus shown in Figure.6. It is a standard rapid method to determine chlorine penetrability of concrete and adopted by the American Association of State Highway and Transport Officials (AASHTO) T277 in 1989 and method is given in ASTM C1202. The concrete specimens of size 100mm diameter and 50mm thick were kept in vacuum desiccator to remove all the air particles and to completely saturate the concrete specimen. The concrete specimens were kept between the cells without any air gap and the edges were sealed with silicon compound to arrest the leakage of chemical solutions. The positive of the terminal was connected to Sodium hydroxide solution of 0.3M strength and the negative terminal was connected to sodium chloride solution of 2.4M strength and connected to the 60 volt positive supply of the apparatus. Each cell will hold approximately 250 ml of solution. A DC of 60 V was applied across the specimen using two stainless steel electrodes (meshes) and the current across the specimens were recorded in coulombs at 30 minutes interval for a duration of 6 hours and 30 minutes. The total charge passed, in coulombs, was used as an indicator of the resistance of the concrete to chloride ion penetration. The chloride ion penetrability based on charges passed are given in Table 1.


Figure 6. RCPT apparatus

Charge passed	Chloride ion penetrability
>4,000	High
2,000–4,000	Moderate
1,000–2,000	Low
100–1,000	Very Low
<100	Negligible

Table 1. Chloride penetrability based on charge passed

The total charge passed during this period can be calculated in terms of coulombs using the trapezoidal rule as given in the ASTM C 1202. Average current flowing through one cell is calculated by, $I = 900 *(i0+i360) *2(I_{CUMMULATIVE})$ coulombs.

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

I = charge passed (coulombs)

i_0 = current (amperes) immediately after voltage is applied.

i_t = current (amperes) at ‘t’ minutes after voltage is applied.

V. RESULTS AND DISCUSSION

The results of rapid chloride permeability test on specimens in which cement is replaced with nano- cement, nano-flyash, nano- silica and nano-silica fume are discussed. Regression analysis was done and equations are formed for each replacement level to predict the RCPT values.

VI. RAPID CHLORIDE PERMEABILITY TEST ON CONCRETE SPECIMENS IN WHICH CEMENT IS REPLACED WITH NANO MATERIALS.

The RCPT values of concrete specimens in which cement is replaced with nano particles is given in Table 2

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Table.2. RCPT values of concrete specimens with nano particles.

RCPT values when Cement is replaced with nano-materials													
Grade of concrete	% replacement of nano particles	RCPT value in coulombs											
		Nano-flyash			Nano-silica			Nano-silica fume			Nano-Cement		
		28 days	56 days	90 days	28 days	56 days	90 days	28 days	56 days	90 days	28 days	56 days	90 days
20	0	1645	1540	1460	1645	1540	1460	1645	1540	1460	1645	1540	1460
	10	1300	1254	900	1500	1324	1136	1341	1200	1176	1345	980	811
	20	1098	1010	730	1167	1030	883	1025	918	899	807	653	541
	30	659	765	451	1296	1144	981	784	702	688	538	436	360
	40	395	417	246	1440	1271	1090	896	802	786	359	290	240
	50	150	228	134	1600	1413	1212	1024	917	898	239	194	160
30	0	1435	1410	1360	1435	1410	1360	1435	1410	1360	1435	1410	1360
	10	861	820	750	1116	1035	965	1100	1021	958	957	840	764
	20	517	547	450	868	805	751	841	781	733	638	560	509
	30	310	364	270	965	894	834	643	597	560	425	373	340
	40	186	243	162	1072	994	927	735	682	640	283	249	226
	50	112	162	97	1191	1104	1030	840	780	732	189	166	151
40	0	1360	1330	1310	1360	1330	1310	1360	1330	1310	1360	1330	1310
	10	777	665	600	1058	990	930	1040	945	900	777	680	600
	20	444	333	318	823	770	723	795	723	688	444	407	318
	30	254	166	150	914	856	804	608	553	526	254	223	150
	40	145	83	90	1016	951	893	695	632	601	145	149	90
	50	83	76	54	1129	1056	992	794	722	687	83	79	54
50	0	1090	1075	1060	1090	1075	1060	1090	1075	1060	1090	1075	1060
	10	672	753	636	848	780	730	834	780	720	727	678	610
	20	338	527	382	659	607	568	637	596	551	484	452	407
	30	170	369	229	733	674	631	487	456	421	323	301	271
	40	136	258	137	814	749	701	557	521	481	215	201	181
	50	109	181	82	905	832	779	637	596	550	144	134	120

Graph are drawn between RCPT values (charges passed in coulombs) and percentage replacement of cement with nano-cement, nano-fly ash, nano-silica, nano-silica fume. The graphs are shown in Figure.7, Figure 8, Figure.9 and Figure.10.

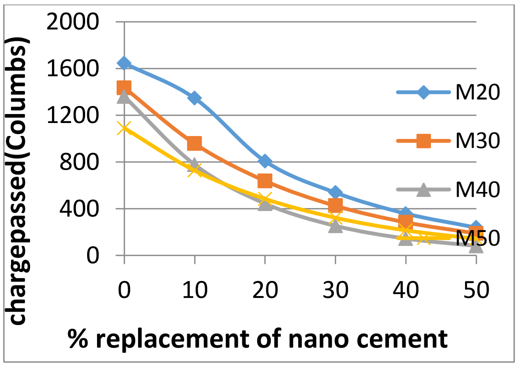

Figure 7.RCPT values at 28 days when cement is replaced with nano-cement

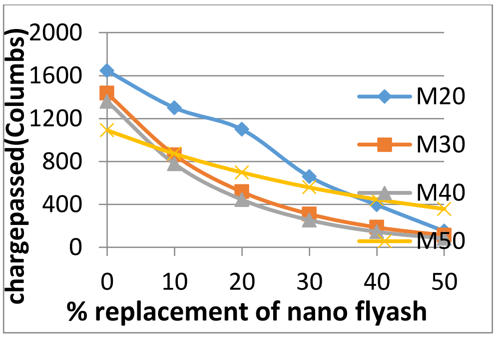

Figure 8.RCPT values at 28 days when cement is replaced with nano-flyash

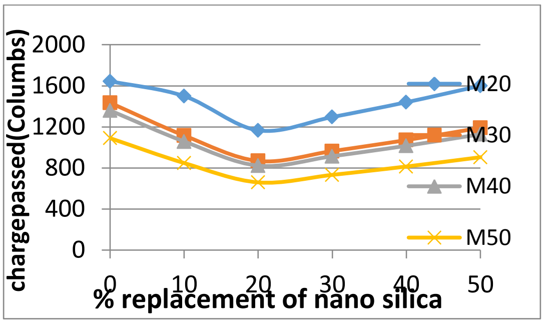

Figure 9.RCPT values at 28 days when cement is replaced with nano silica

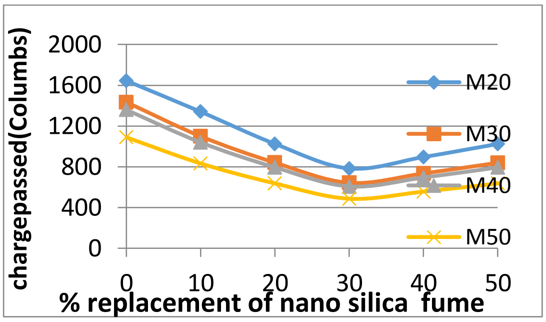

Figure.10.RCPT values at 28 days when cement is replaced with nano silica fume

From the table and graph, it can be seen that the replacement of cement with nano-materials reduces the penetration of chloride ion. In case of replacement of cement with nano-cement and nano-fly ash, the reduction in penetration of chloride ions continues even upto 50% replacement level. It can be seen that increase in percentage of nano cement reduces the chloride penetrability upto 90% when compared with Normal cement concrete. However in case of replacement of cement with nano silica and nano silica fume, maximum reduction in the chloride ion penetration is found at 20% and 30% replacement level respectively.

VII. PERCENTAGE DECREASE IN CHLORIDE ION PENETRATION ON CONCRETE SPECIMENS IN WHICH CEMENT IS REPLACED WITH NANO MATERIALS.

The percentage decrease in chloride ion penetration for different replacement levels of cement with nano materials were compared with the RCPT values of normal cement concrete. The percentage decrease in values of chloride ion penetration are given in Table 2.

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Table.2. Percentage Decrease in chloride ion penetration

Grade	% replacement of nano particles	Percentage Decrease in chloride ion penetration											
		Nano-fly-ash			Nano-silica			Nano-silica fume			Nano Cement		
		28 days	56 days	90 days	28 days	56 days	90 days	28 days	56 days	90 days	28 days	56 days	90 days
20	10	20.97	18.57	38.35	8.81	14.02	22.19	18.48	22.07	19.45	18.23	36.36	44.45
	20	33.25	34.41	50	29.1	33.11	39.52	37.68	40.39	38.42	50.94	57.59	62.95
	30	59.93	50.32	69.11	21.21	25.71	32.81	52.34	54.41	52.88	73.49	71.68	75.34
	40	75.98	72.92	83.15	12.4	17.47	25.34	45.53	47.92	46.16	78.18	81.16	83.56
	50	90.88	85.19	90.8	2.7	8.24	16.98	37.75	40.45	38.49	85.47	87.4	89.04
30	10	40	41.84	44.85	22.22	26.59	29.04	23.34	27.58	29.56	33.31	40.42	43.82
	20	63.97	61.2	66.91	39.51	42.9	44.78	41.39	44.6	46.1	55.54	60.28	62.57
	30	78.39	74.18	80.14	32.75	36.52	38.67	55.19	57.66	58.82	70.38	73.55	75
	40	87	82.76	88	25.27	29.5	31.83	48.78	51.63	52.94	80.28	82.34	83.38
	50	92.2	88.51	92.86	17	21.7	24.26	41.46	44.68	46.18	86.68	88.22	88.89
40	10	42.86	50	54.2	22.21	22.22	25.56	23.52	28.94	31.29	42.86	48.87	43.82
	20	67.35	74.96	75.72	39.49	39.48	42.1	41.54	45.63	47.48	67.35	69.39	75.72
	30	81.32	87.52	88.55	32.79	32.79	35.64	55.29	58.42	59.84	81.32	83.23	88.55
	40	89.33	93.76	93.13	25.29	25.29	28.49	48.89	52.48	54.12	89.33	88.79	93.13
	50	93.89	94.3	93.9	16.99	16.98	20.6	41.49	45.71	47.55	93.89	94.06	95.88
50	10	38.3	29.95	40	22.22	27.44	31.13	23.49	27.44	32.07	33.3	36.93	42.45
	20	68.99	50.97	63.96	39.54	43.53	46.41	41.55	44.56	48.01	55.59	57.95	61.6
	30	84.4	65.67	78.39	32.75	37.3	40.47	55.32	57.58	60.28	70.36	72	74.43
	40	87.52	76	87.07	25.32	30.32	33.86	48.89	51.53	54.62	80.27	81.3	82.92
	50	90	83.16	92.26	16.97	22.6	26.51	41.55	44.55	48.11	86.78	87.75	88.68

The percentage decrease in chloride ion penetration for different replacement levels of cement with nano materials are shown in Figure11, Figure 12, Figure 13 and Figure.14 for nano flyash, nano silica, nano silica fume and nano cement respectively.

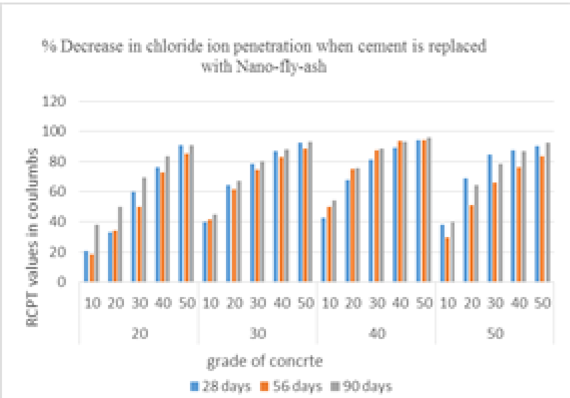

Fig.11 % Decrease in chloride ion penetration when cement is replaced with Nano-fly-ash

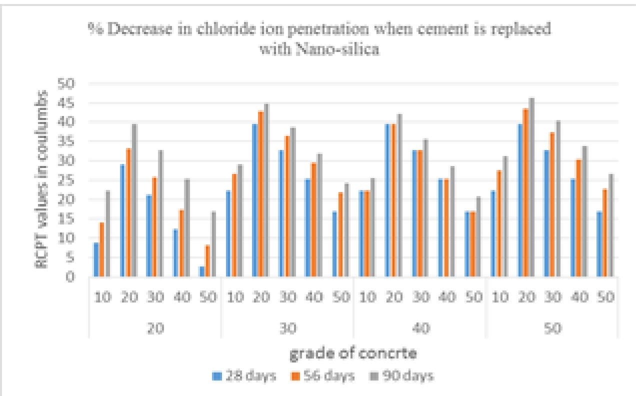

Fig.12 % Decrease in chloride ion penetration when cement is replaced with Nano-silica

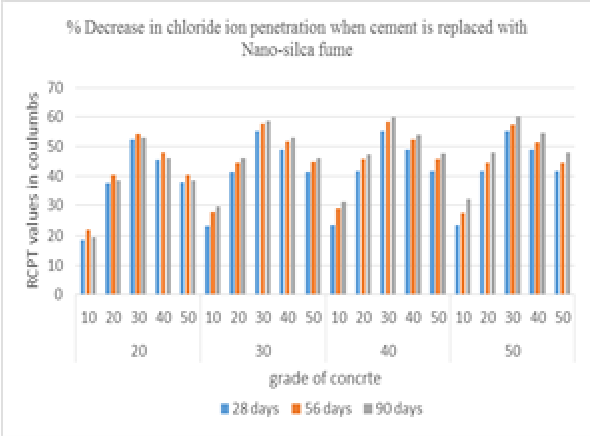

Fig.13 % Decrease in chloride ion penetration when cement is replaced with Nano-silica fume

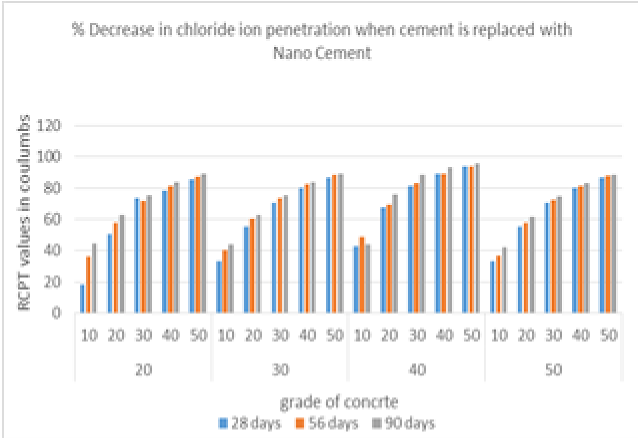

Fig.14 % Decrease in chloride ion penetration when cement is replaced with Nano Cement

VIII. EFFECT OF REPLACEMENT OF CEMENT WITH NANO PARTICLES ON THE RESISTANCE TO CHLORIDE ION PENETRATION.

It can be seen from Table 2 that the percentage decrease in chloride ion penetration decreases as the replacement percentage of nano-particles increases. The percentage decrease of chloride ion penetration was found to range from 18% to 49% for 10% replacement of cement with nano-cement, 50% to 76% for 20% replacement of cement with nano-cement, 70% to 89% for 30% replacement of cement with nano-cement, 78% to 94% for 40% replacement of cement with nano-cement and 85% to 96% for 50% replacement of cement with nano-cement. The percentage decrease of chloride ion penetration was found to range from 18% to 55% for 10% replacement of cement with nano-flyash, 33% to 76% for 20% replacement of cement with nano-flyash, 50% to 89% for 30% replacement of cement b with nano-flyash, 72% to 94% for 40% replacement of cement with nano-flyash and 85% to 95% for 50% replacement of cement with nano-flyash. The percentage decrease of chloride ion penetration was found to range from 8% to 32% for 10%

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replacement of cement with nano-silica, 29% to 47% for 20% replacement of cement with nano- silica, 21% to 41% for 30% replacement of cement with nano- silica, 12% to 34% for 40% replacement of cement with nano-silica and 2% to 27% for 50% replacement of cement with nano- silica. The percentage decrease of chloride ion penetration was found to range from 18% to 33% for 10% replacement of cement with nano-silica fume, 37% to 48% for 20% replacement of cement with nano- silica fume, 52% to 61% for 30% replacement of cement with nano- silica fume, 45% to 55% for 40% replacement of cement with nano- silica fume and 37% to 49% for 50% replacement of cement with nano- silica fume. The chloride ion penetration was found to be in minimum incase of nano silica and nano silica fume at replacement level of 20%. In case of nano flyash and nano cement replacement, the chloride ion penetration continue to decrease even upto replacement level of 50%. The replacement level cannot be further increased since that will affect the setting time incase of replacement with nano cement and strength incase of replacement with nano flyash.

IX. EFFECT OF AGE OF CONCRETE ON THE RESISTANCE TO CHLORIDE ION PENETRATION.

The chloride ion penetration test was carried at 28thday, 56thday and 90thday. The percentage decrease in chloride ion penetration for different replacement levels of cement with nano materials was compared with RCPT value of normal cement concrete. It can be seen that as the age increases, the penetration to chloride ion decreases. The percentage decrease in chloride ion penetration was found to range from 2% to 94% for 28days, 14% to 95% for 56 days and 19% to 96 % for 90 days.

X. EFFECT OF GRADE OF CONCRETE ON THE RESISTANCE TO CHLORIDE ION PENETRATION.

It can be seen from Table 2 that as the grade of concrete increases, the penetration of chloride ion decreases. The percentage decrease in chloride ion penetration was found to range from 8% to 91% for M20 grade of concrete, 22% to 93% for M30 grade of concrete, 22% to 96% for M40 grade of concrete and 22% to 93% for M50 grade of concrete.

XI. REGRESSION ANALYSIS & RESULTS

The regression analysis was carried at for RCPT values of concrete when cement is replaced with nano cement, nano-fly ash, nano-silica and nano-silica fume. Table 3 gives the details of the regression analysis for the RCPT values of concrete when cement was replaced with nano materials.

Table 3.Regression Analysis for the RCPT values of concrete when cement is replaced with nano-materials.

Regression Statistics	Cement replaced with			
	Nano-cement	Nano-fly ash	Nano-Silica	Nano-silica fume
Multiple R	0.92994	0.918847	0.74902	0.830294
R Square	0.864788	0.84428	0.561031	0.689387
Adjusted R Square	0.858823	0.83741	0.541665	0.675684
Standard Error	163.4541	180.8484	175.4438	165.8037
Observations	72	72	72	72
Coefficients				
Intercept	1526.065	1615.79	1801.663	1644.626
Grade of Concrete	-8.22175	-8.79764	-15.3042	-11.6076
% Replacement	-22.7281	-22.9613	-3.47031	-11.5736
No of days	-1.87926	-2.50282	-2.60594	-1.63323

From the regression analysis the following equations are formed for the RCPT values of concrete when cement is replaced with nano-materials are given in Table 4

Table.4. Mathematical equation formed for the RCPT

		RCPT values
cement replaced with	Nano-cement	1526.065- (8.22*X) - (22.728*Y) - (1.879*Z)
	Nano-fly ash	1615.79 - (8.79*X) - (22.96*Y) - (2.5*Z)
	Nano-silica	1801.66- (15.304*X) - (3.47*Y) - (2.6*Z)
	Nano-silica fume	1644.62- (11.607*X) - (11.57*Y) - (1.63*Z)

Where X- Grade of Concrete, Y- % replacement, Z- No of Days. The ranges of X,Y and Z are given in Table.5

Table.5. Ranges of X,Y,Z

Parameter		Range
X	Grade of concrete	20, 30, 40, 50
Y	% replacement	0, 10, 20, 30, 40, 50
Z	No.of. days	28, 56, 90

XII. CONCLUSIONS

An attempt has been made to find out the effect of replacement of nano-materials in concrete on chloride ion penetrability based on RCPT test as per ASTM C1202. From the microstructure studies using SEM, it is found out that 80% of the nano particles used has been scaled down to nano sized particles. It is found that replacement of cement with nano materials reduced the chloride ion penetration. In case of replacement of cement with nano-silica and

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nano-silica fume, 30% replacement level resulted in minimum chloride ion penetration.

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