A COMPARATIVE STUDY OF NANO EMBEDMENTS ON DIFFERENT TYPES OF CEMENTS

Mainak Ghosal, Arun Kumar Chakraborty
Indian Institute of Engineering Science & Technology (IIEST), Shibpur, India

ABSTRACT

Nanotechnology is the engineering of functional systems at the molecular scale. One nanometer (nm) is one billionth, or 10−9, of a meter. Several phenomena become pronounced as the size of the system decreases. These include statistical mechanical effects, as well as quantum mechanical effects. Addition of Nano materials gives excellent results in the mechanical properties of cement mortar but in the long term its effect is however not so pronounced. The experimental work is on the basic cement mortar(of different cements like OPC,PPC,PSC) of suitable w/c ratios (based on cement's consistency) & sand: cement=3:1 which were initially mixed and then modified with Nanosilica(nS)(in proportions ranging from 0%,0.5%,0.75%,1%,1.25% & 1.5% by wt. of cement) and Multiwalled carbon Nanotubes(CNT) (0.01% to 0.05% by wt. of cement dispersed in suitable medium e.g. Superplastcizer).The results obtained so far compared with ordinary mortar are:(i)For OPC, there was no gain in early strength(at 1 day) but with increase in age the gain in strength grew(more than 30% increase found at 7 and 28 days) and the maximum strength was found to be optimized at 0.75%nS for all ages. At 90 days for these optimisation, the gain in strength was found to be 59.78% and at 180 days the gain in strength was around 8.36% over ordinary controlled cement mortar.(ii)For PPC, there was a gain in early strength(at 1 day) and with increase in age the gain in strength grew(more than 100% increase observed at 7 days) and the maximum strength was found to be optimized at 0.75%nS for all ages. At 90 days for these optimisation, the gain in strength was found to be 27.77% and at 180 days there was no gain in strength, over ordinary controlled cement mortar.(iii)For PSC, there was appreciable gain in early strength(at 1 day) but with increase in age the gain decreased and the maximum strength was found to be optimized at 1.0%nS for all ages. At 90 days for these optimisation, the gain in strength was found to be 14.55% and at 180 days the gain in strength was around 3.41% over ordinary controlled cement mortar.(iv)For CNTs, only OPC was tried & the optimum dosage was found to be 0.02% CNTs w.r.to cement weight at all ages & though the strength gain w.r.to ordinary cement mortar developed from 28 days(37%,) onwards & at 90 days the increase was 14% & at 180 days the gain reduced to 3%.

KEYWORDS: *Nano, cement, strength, optimized, sonification.*

I. INTRODUCTION

'Nano' is a Greek word and means "Dwarf". The new ISO working definition says that Nano technology (NT) is the application of scientific knowledge to the control and use of matter at the nanoscale (10^{-9}m), where size related phenomenon & processes may occur. Carbon Nanotubes was first invented by a Russian scientist S. Iijima in 1991. The Nanoparticle size which is below One billionth of a meter are produced as nano-additives are from traditional cement, silica (quartzite sand) or even fly ash. For larger scale, nano-Silica(nS)[the first nanomaterial to be used in construction] are produced from vaporization of silica or by feeding worms with rice husk or by precipitation method while techniques have been developed to produce nanotubes in sizeable quantities, including arc discharge, laser ablation, high-pressure carbon monoxide disproportionation (HiPco), and chemical vapor deposition (CVD).

Figure 1: Damascus Steel Sword with Nano-Material

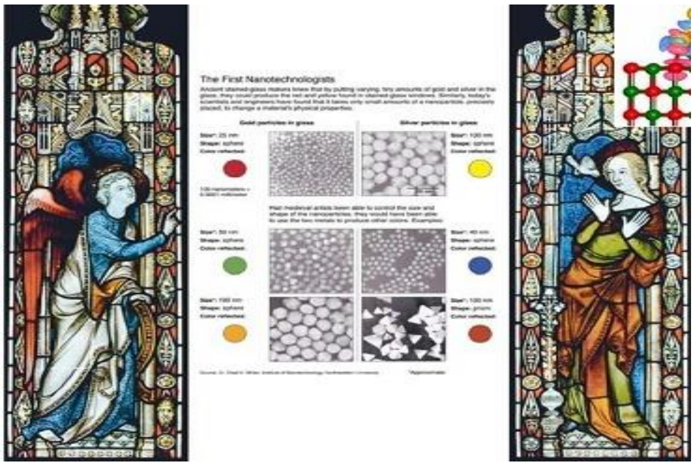

Figure 2: Casements withNano-incorporated Glass

Many authors claim that Nano-technology (NT) has been a recent development but for others it is nothing at all new. It can revolutionize construction in the very near future. The emergence of this technology was caused in 1980s due to the convergence of experimental advances like invention of Scanning Tunneling Microscope (1981) & discovery of Fullerenes(1985).In fact it was Nanotechnology that allowed creation of iPods, iPhones and all sort of these "i" products which in a way completely changed the IT and electronics sectors. So why can't applications of Nanotechnology do the same to our conservative construction sector now? The objects produced using NT have unique characteristics such as super connectivity, high strength, low friction, high thermal insulation, specific beam frequency selectivity, quantum effects, extreme water repellence & self-assembling geometric patterns like nanotubes, nano spheres & nano octagons. There have been many successful NT based applications which could have been almost impossible without utility of nano sized particles. For example, anti-scratch paints, anti-bacterial paints, anti-fouling concrete, dirt repellant textiles, clothes that need no ironing, non-reflective glasses, wonder drugs etc. are only the tip of the ice-berg. It is a surprise to learn that the Romans and Chinese were using nanoparticles thousands of years ago. Carbon black the substance that makes our tyres black and improves the wear resistance of the rubber was known since 1920s.Of course they were not aware that they were using nanotechnology, as they had no control over particle size, or even any knowledge of the nanoscale as currently defined. Someone has rightly quoted

-- "Nanotechnology is the base technology of an industrial revolution in the 21st century. Those who control nanotechnology will lead the industry."

-- *Michiharu Nakamura, Executive VP at Hitachi*

Additionally, the rheology of paste, mortar & concrete is influenced with nano-additions. It also improves the microstructure of the concrete system. Work presented by many authors reveals that the nano-additives improve the performance of concrete resulting in High Performance Concrete (HPC) or Ultra High Performance Concrete(UHPC) and in turn making concrete durable. The first patent on nano-enabled cement was published in 1996 and since then it has seen an exponential rise after 2007. China has emerged as the major contributor in this area with 41% of global patents filings. The emergence of nanotechnology in cement industry has already shown a remarkable impact on mechanical and other properties of cementitious materials with patented commercial products such as NanoCrete, Cor-Tuf®, HuberCrete®, Alpol, Nycon-G Nano, TioCem, TxActive, MC-Special DM etc. are already available in market. Naga Nanotech etc. apart from big commercial houses like Reliance, Tata Group, Mahindra & Mahindra exploring NT options. Many scientists believe that R&D in nanoscience and technology must be promoted at central and state universities since that allows an opportunity for students undertaking bachelors and masters programs. Accordingly, Dr Kalam, the nations' then president and renowned space scientist assumed the role of promoting nanotechnology at several national academic and other forums. His pro nanotechnology oratory and stance coupled with vision for establishing India as a "nanotechnology hub" has influenced policy makers and academia to strenuously emphasize on this emerging science and technology. The Budget allocation for (National Nano Science & Technology Mission) NSTM amongst all the schemes in the 10th five year plan was second.

Figure 3: Nano products in the market.

Figure 4: Difference between Normal applications and Nano applications.

Construction projects today are increasingly required to meet stringent building codes and energy regulations which is fuelling an industry transition to use the next generation *nanomaterials.*The Twelfth Five Year Plan emphasized use of new materials & technology for the Ministry of Roads & Surface Transport (MORSTH).The proposed National Building Code also places emphasis on new advanced materials in its Part 11:Approach to sustainability(under print). The emergence of nanotechnology in India has witnessed a diverse set of players ranging from domains like agriculture, water, health, energy, & environment to industries like pharmaceuticals, automobiles, electronics, textiles, chemicals & manufacturing (of which construction is a small part),IT & biotechnology. Among the government agencies, besides Department of Science & Technology (DST) other agencies include Council of Scientific & Industrial Research (CSIR), Dep't of Bio-Technology (DBT), and agencies under Ministry of Information & Communication Technology, Ministry of Family Health & Welfare, Ministry of Defence, and Ministry of New & Renewable Energy are engaged with the promotion of NT in terms of R&D activities. Also there are private companies in India those are engaged in NT such as Bee chems, NanoBeach, MonadNanotech, NanoShell, NagaNanotech, Qtech Nanosystems, apart from big commercial houses like Reliance, Tata Group, Mahindra & Mahindra exploring NT options.

Work presented by many authors reveals that the nano-additions improve the performance of concrete resulting in High Performance Concrete (HPC) or Ultra High Performance Concrete (UHPC) and in turn making concrete durable. The contribution on nS & silica fume (SF) to various micro structural properties of cement paste, mortar & concrete **[11]** was reported. Also the possibility of modifying the matrix of a cement mortar mixes with and without SF by incorporation of nS solids during the mixing stage **[15]** was studied. The wonder material, CNT, the strongest material in earth, has a wonderful application in the mechanical strength properties of cement mortar**[6,13]**.

Consider the headlines which appeared on leading dailies few months back – Delhi building collapse, Mumbai building collapse, Chennai Building collapse, Thane building collapse, Bangladesh building collapse, Pune building collapse, Goa building collapse, Vadodra building collapse…. few dead. All these constructions were completed recently. The cement companies nowadays increase C_3S at the cost of C_2S. In addition, alkali content of today's cement in India is far too high and exceeding the limits of IS: 456, 2000.It is necessary to examine whether nano-materials like nano-silica, nano carbon tubes or nano titanium oxide can improve the performance of cement mortar & concrete in terms of its strength & durability. Thus, the present study aims to explore the possibility of application of Nano technology in all types of Cements including OPC(Ordinary Portland Cement),PPC(Portland Pozzolona Cement),PSC(Portland Slag Cement) in India. This paper is organized with a brief literature review in section 2. Section 3 introduces the material proportion and mix design employed in this investigation. Section 4 and 5 presents the experimental programme & test results and section 6 deals with conclusion respectively. Lastly, section 7 gives the future scope of work.

II. LITERATURE REVIEW

[A]On Effect of Nano-Silica :-

Belkowitz, S.J.& Armentrout.D.(2) developed relationships to distinguish the benefits when using different sizes of nano-silica(nS) in cement hydration paste through experimenting & measuring the heat of hydration of multiple mix designs and showed that as silica particles decreased in size with increased size distribution the C-S-H became more rigid and in turn increasing the compressive strength.
Quercia, G.& Brouwers, H.J.H (3) aimed to present in their paper the nS production process from olivine dissolution, their addition and their application in concrete.
Valipour. M et al(4) studied the influence of nS addition on properties of concrete when compared with silica fumes(SF) through measurement of compressive strength, electrical resistivity & gas permeability. The results show that replacement of a portion of SF with nS is more active in early age due to larger specific surface & fineness and will also improve the durability aspects of HPC.
Jemimath, C.M. &Arulraj, G.(5) reported that cement replaced with nanocement (NC), nanoflyash (NFA) and nanosilica fume(NSF) showed a unaffected consistency but it was found that addition of NC decreases the initial & final setting times while the addition of NFA & NSF increases the initial & final setting time.
Maheswaran, S et al(7) attempted to highlight the influence of Ns towards pore filling effect and its pozzolonic activity with cement for improvement of mechanical properties and durability aspects. The paper also says that there is a scope for development of crack free concrete.
Yang,H(8) presented the laboratory investigations that when nano silicon powder mixing content is 0.5%,0.75% & 1.0% compared with ordinary concrete ,the bending tensile strength at 28 days were increased by 3.2%,7.5% & 4.0% and the shrinkage rate at the same age reported increase by 75.5%,127.1% & 163.0%.
Yuvraj,S(9) described when nS is added it makes the concrete less alkaline as C-H in concrete is reduced which reduces the corrosion of steel bars. He also added that more C-S-H is produced at the Nano scale thus increasing the compressive strength.
Abyaneh, M.R.J. et al(10) investigated the compressive strength, electrical resistivity and water absorption of the concrete containing nS and micro-silica at 7,14,28 days and reported that concrete with micro-silica and nS have high compressive strength than with concrete with only mico-silica. He further deliberated that that specimens with 2% nS and 10% micro-silica have less water absorption and more electrical resistance in comparison with others.
Rajmane, N.P. et al(14) showed that nS cannot be used as an admixture to improve the microstructure of the cement composites(with and without 5% SF) at the w/c ratio of 0.5.

[B]On Effect of Carbon Nano Tubes :-

Kumar,S. et al(6) discussed the effect of Multiwalled Carbon Nanotubes(MWCNT) on strength characteristics of hydrated Portland cement paste by mixing various proportions of MWCNT and found an increase in compressive and tensile strength of 15% and 36% at 28 days.
Madhavi,T. et al(13) found an increase in compressive and split-tensile strengths of samples with increasing MWCNT.0.045% of MWCNT has improved the 28 days compressive strength by 27% while the split tensile strength increased by 45%.Crack propagation was reduced and water absorption decreased by 17% at 28 days curing.

III. MATERIAL USED

The materials used were cement-OPC (43 Grade),PPC,PSC, Fine Aggregate (FA)-River sand, Potable water, Admixture(SuperPlastcizer)- PolyCarboxylate Ether(PCE) and Nano Materials(viz. Nano Silica, Carbon Nanotubes).The following Tables (1 to 3) below shows the specific properties of Nano Silica & Carbon Nanotubes respectively.

Table 1 Specific properties of Nano Silica (SiO_2) used

SAMPLE (BRAND)	% CONTENT(LIT.)	SPECIFIC GRAVITY(LAB)	% CONTENT(LAB)	SPECIFIC GRAVITY(LIT.)
XLP	14-16%	1.12	21.4%	1.08-1.11
XTX	30-32%	1.16	40.74%	1.20-1.22
XFXLa	40-43%	1.24	41.935%	1.30-1.32

Table2 Specific properties of Industrial Grade Multiwalled Carbon NanoTubes (MWCNT) used

DIAMETER	20-40nm
LENGTH	25-45nm
PURITY	80-85%(a/c Raman Spectrometer & SEM analysis)
AMORPHOUS CARBON	5-8%
RESIDUE(CALCINATION IN AIR)	5-6% by Wt.
AVERAGE INTERLAYER DISTANCE	0.34nm
SPECIFIC SURFACE AREA	90-220 m^2/g
BULK DENSITY	0.07-0.32gm/cc
REAL DENSITY	1-8 gm/cc
VOLUME RESISTIVITY	0.1-0.15 ohm.cm(measured at pressure in powder)

And the following Figures (5 and 6) below shows the characterizations (XRD images) of Nano Silica & Carbon Nanotubes respectively.

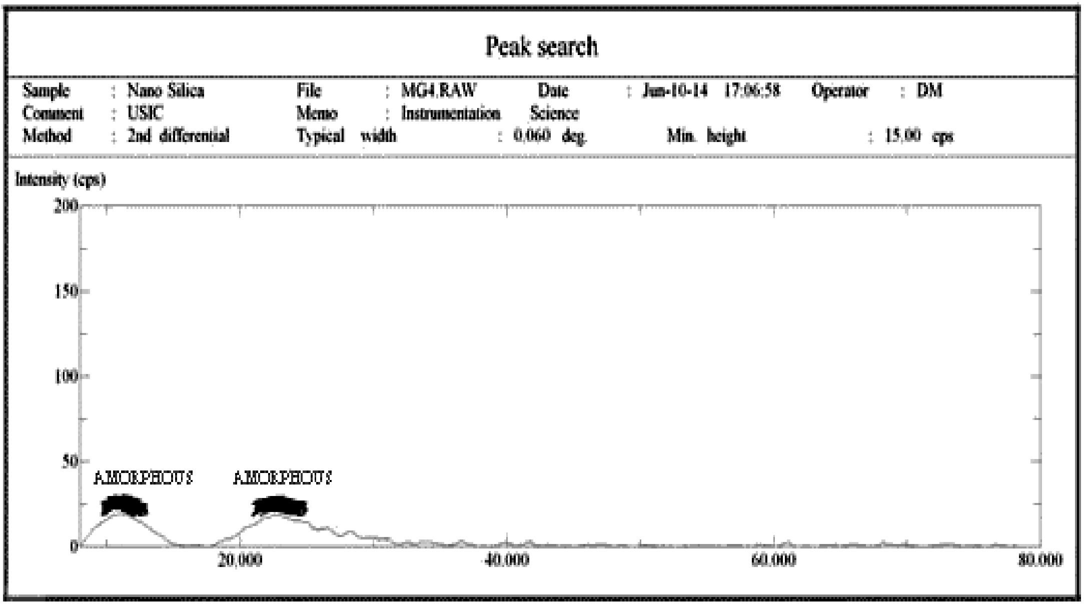

Figure 5: XRD image of Nano Silica used

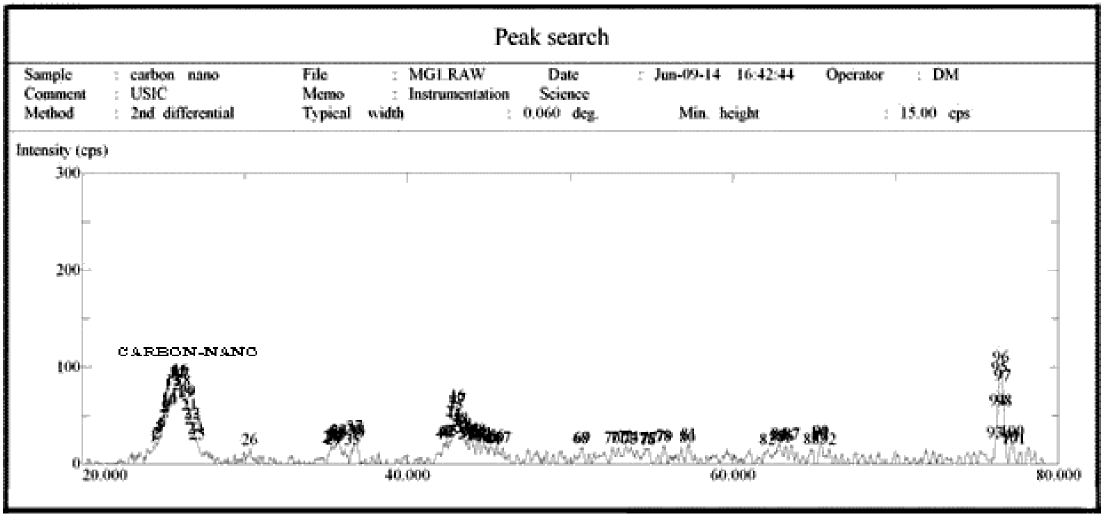

Figure 6: XRD image of Carbon Nano Tubes used

IV. EXPERIMENTAL PROGRAMME

(I)The first test procedure involved testing Nano-Silica(XLP,XTX,XFxLa—Supplied by M/s BEE CHEMS, Kanpur, India) in variable quantities(0%,0.5%,0.75%,1.0%,1.25%,1.5% by cement wt.) in Portland Slag Cement(PSC-ACC make),Portland Pozzolona Cement(PPC-Ambuja make) & Ordinary Portland Cement(OPC-Ambuja make) in a compression testing machine.

Test Procedure(I):

Standard Mortar cubes are filled with 1 part of Cement + 3parts of River Sand with Water added, according to the standard consistency formula. Now we would be testing the Compressive Strength of both composite & ordinary Cement Mortar after 1 day, 3days, 7days, 28days, 90days, 180days ordinary curing in a COMPRESSION CUBE CRUSHING/TESTING M/C.

Figure 7: Some Apparatus used for Mortar castings

Figure 8: Compression Testing Machine

Figure 9 : Curing Chamber

(II)The second test procedure involved testing Carbon-Nanotubes(Multiwalled, Industrial Grade—Supplied by M/s NANOSHEL, Panchkula, Haryana, India) dispersed in Super plasticizer (Sikament® NNSP3 Supplied by Sika Chemicals at 1% by wt. of cement) in an optimum dosage(0.02% by wt. of cement as per Literature Review) in Ordinary Portland Cement(OPC-Ambuja make) in a compression testing machine.

Test Procedure(II):

Standard Mortar cubes are filled with 1 part of Cement + 3parts of River Sand with Water added, according to the standard consistency formula. Now we would be testing the Compressive Strength of both composite & ordinary Cement Mortar after 1 day, 3days, 7days, 28days, 90days, 180days ordinary curing in a COMPRESSION CUBE CRUSHING/TESTING M/C. As Carbon Nanotubes(CNT) couldn't be dispersed in distilled water, a 1% Superplastcizer (Sikament® NNSP3) by wt. of cement was tried with 0.02% Carbon Nanotubes by wt. of cement after ultrasonication for about 30 minutes in an external ultra sonicator bath(250W Piezo-U-Sonic Ultrasonic Cleaner).

V. TEST RESULTS

Table 3 Test Results for Compressive Strength at various ages of OPC using nS in N/mm^2:

Sl. No	Cement Type	**1 day**			**3 days**			**7 days**			**28 days**			**90 days**			**180 days**		
		Strength	Strength (Avg.)	%Increase	Strength	Strength (Avg.)	%Increase	Strength	Strength (Avg.)	% Incre	Strength	Strength (Avg.)	%Increase	Strength	Strength (Avg.)	% Increase	Strength	Strength (Avg.)	% Increase

.			Density (Kg/m^3)			Density (Kg/m^3)			Density (Kg/m^3)	ase		Density (Kg/m^3)			Density (Kg/m^3)			Density (Kg/m^3)	
1.	**OPC (0%)**	17.36 (C)	19.59	—	23.47 (C)	23.72	—	21.33 (C)	21.08	— —	35.20	31.89	—	24.14 (C)	31.20	—	23.81 (C)	30.01	--
		21.82 (C)	2305.44		23.98 (C)	2269.6		20.83 (C)	2264.08		28.57	2315.46		38.26 (C)	2290.12		36.22 (C)	2309.27	
2.	**OPC (0.5%)**	13.69 (E)	16.28	-16.89	29.67 (C)	27.16	+14.50	21.82 (C)	23.85	13.14	29.68	35.51	+11.35	41.93 (C)	41.30	32.37	28.17 (C)	27.47	-9.24
		18.87 (C)	2258.45		24.65 (C)	2240.5		25.87 (C)	2348.17		41.33	2290.75		40.67 (C)	2323.95		26.79 (C)	2394.01	
3.	**OPC (0.75 %)**	18.35 (C)	16.83	-14.08	30.10 (C)	30.10	+26.89	28.06 (C)	27.73	31.54	46.28	42.27	+32.55	51.75 (C)	49.85	59.78	40.24 (C)	32.52	8.36
		15.31 (C)	2212.23		30.10 (C)	2241.21		27.39 (C)	2266.49		38.26	2233.07		47.95 (C)	2264.08		24.80 (C)	2327.62	
4.	**OPC (1.0%)**	17.35 (C)	18.36	-6.27	18.88 (E)	19.38	-18.29	25.15 (C)	25.07	18.93	31.57	37.36	+17.15	41.32 (C)	42.98	37.76	29.59 (C)	33.68	12.23
		19.38 (C)	2242.02		19.89 (C)	2234.64		25.00 (C)	2293.64		43.15	2256.65		44.64 (C)	2399.17		37.78 (C)	2304.9	
5.	**OPC (1.25 %)**	19.11 (C)	20.16	+2.91	28.17 (C)	27.54	+16.10	21.52	23.17	9.91	23.47	30.85	-3.26	33.27 (C)	39.45	26.44	44.46 (C)	35.24	17.43
		21.22 (C)	2186.11		26.92 (C)	2270.24		24.73	2221.69		38.23	2300.16		45.63 (C)	2267.77		26.02 (C)	2320.24	
6.	**OPC (1.5%)**	19.38 (C)	20.69	+5.62	22.45 (C)	23.35	-1.56	24.15	23.81	12.95	40.89	37.79	+18.50	34.69 (C)	33.42	7.12	31.63©	31.23	4.07
		22.00 (C)	2243.97		24.26 (C)	2259.84		23.47	2223.23		34.70	2278.54		32.14 (C)	2240.59		30.82 (C)	2314.41	

Table4 Test Results for Compressive Strength at various ages of PPC using nS in N/mm^2:

Sl. No.	Cement Type	**1 day**			**3 days**			**7 days**			**28 days**			**90 days**			**180 days**		
		Strength	Strength (Avg.) / Density (Kg/m^3)	% Increase	Strength	Strength (Avg.) / Density (Kg/m^3)	% Increase	Strength	Strength (Avg.) / Density (Kg/m^3)	%Increase	Strength	Strength (Avg.) / Density (Kg/m^3)	%Increase	Strength	Strength (Avg.) / Density (Kg/m^3)	% Increase	Strength	Strength (Avg.) / Density (Kg/m^3)	% Increase
1.	**PPC (0%)**	8.05 (C)	7.55	—	11.9 (C)	9.97	—	13.21 (C)	11.36	—	26.78 (E)	22.44	—	24.14 (C)	25.96	—	22.98 (C)	27.08	--
		7.04 (C)	2073.53		8.05 (C)	2060.06		9.56 (C)	2103.57		18.11 (C)	2129.21		27.77 (C)	2113.27		31.18 (C)	2245.61	
2.	**PPC (0.5 %)**	8.92 (C)	7.98	5.69	13.46 (C)	12.68	27.18	7.44 (C)	8.93	-21.39	27.16 (C)	27.16	21.0	19.89 (C)	22.45	-13.52	20.70 (C)	26.11	-3.58
		7.04 (C)	2054.68		11.90 (C)	2152.07		10.41 (C)	2035.87		27.16 (C)	2192.08		25.0 (C)	2119.42		31.51 (C)	2267.01	
3.	**PPC (0.75 %)**	9.78 (C)	10.27	36.02	16.18 (C)	18.36	84.15	25.0 (C)	23.66	108.27	28.98(C)	27.45	22.32	36.23 (C)	33.17	27.77	23.81 (C)	27.0	-0.29
		10.76(C)	2117.12		20.54 (C)	2125.01		22.32 (C)	2143.77		25.92 (C)	2220.97		30.10 (C)	2193.88		30.18 (C)	2296.60	

4.	**PPC (1.0 %)**	7.25 (C)	6.68	-11.52	18.88 (C)	17.37	74.22	18.33 (C)	18.97	66.99	20.41 (C)	27.56	22.81	36.40 (C)	32.08	23.57	27.48 (C)	31.35	15.77
		6.12(C)	2133.80		15.87 (C)	2112.8		19.62 (C)	2164.85		34.72 (C)	2152.41		27.78 (C)	2153.56		35.21 (C)	2123.42	
5.	**PPC (1.25 %)**	10.06(C)	9.87	30.73	16.33 (C)	16.10	61.48	18.91 (C)	19.15	68.57	27.04 (C)	26.20	16.75	29.83 (C)	28.11	8.28	24.14 (C)	22.78	-15.88
		9.69(C)	2108.86		15.87 (C)	2022.93		19.39 (C)	2205.32		23.36 (C)	2221.30		26.39 (C)	2146.66		21.43 (C)	2193.79	
6.	**PPC (1.5 %)**	9.92(C)	9.74	29.00	17.08 (C)	16.96	70.11	17.61 (C)	19.26	69.54	20.83 (C)	22.92	2.14	33.67 (C)	32.30	24.42	25.51 (C)	26.53	-2.03
		9.56(C)	2115.74		16.84 (C)	2257.90		20.92 (C)	2177.24		25.0 (C)	2227.09		30.92 (C)	2180		27.55 (C)	2265.3	

Table5 Test Results for Compressive Strength at various ages of PSC using nS in N/mm^2:

Sl. No.	Cement Type	1 day			3 days			7 days			28 days			90 days			180 days		
		Strength	Strength (Avg.) / Density (Kg/m^3)	% Increase	Strength	Strength (Avg.) / Density (Kg/m^3)	% Increase	Strength	Strength (Avg.) / Density (Kg/m^3)	%Increase	Strength	Strength (Avg.) / Density (Kg/m^3)	%Increase	Strength	Strength (Avg.) / Density (Kg/m^3)	% Increase	Strength	Strength (Avg.) / Density (Kg/m^3)	% Increase
1.	**PSC (0%)**	6.5 (C)	7.25	—	16.09 (C)	16.21	—	22.32 (C)	22.89	—	24.13 (C)	28.93	—	26.92	26.79	—	23.63 (E)	19.95	--
		8.0 ©	2164.72		16.32 (C)	2246.52		23.47 (C)	2221.80		33.73 (E)	2217.13		26.66	2273.7		16.28 (E)	2293.93	
2.	**PSC (0.5 %)**	8.0 (C)	8.50	17.24	18.35 (C)	17.98	10.2	25.0 (C)	22.81	-0.35	32.27 (E)	30.56	5.63	28.98	26.31	-1.79	23.47 (E)	24.63	23.46
		9.0 (C)	2183.12		17.61 (C)	2233.12		20.63 (C)	2210.76		28.85 (E)	2223.35		23.63	2291.0		25.79 (E)	2260.69	
3.	**PSC (0.75 %)**	9.83 (C)	9.76	34.62	18.33 (C)	18.58	14.62	18.85 (C)	19.45	-15.02	24.94 (C)	27.56	-4.73	22.64	22.89	14.55	23.14 (C)	20.63	3.41
		9.69 (C)	2105.29		18.85 (C)	2201.36		20.05 (C)	2232.82		30.18 (C)	2177.26		23.14	2183.42		18.11 (C)	2323.31	
4.	**PSC (1.0 %)**	8.8 (C)	9.57	32.0	18.85 (C)	18.47	13.94	23.47 (C)	21.54	-5.89	31.18 (E)	29.88	3.28	35.71	36.22	35.20	24.14 (C)	23.48	17.69
		10.35(C)	2276.56		18.12 (C)	2203.44		19.62 (C)	2234.72		28.57 (C)	2252.41		36.72	2217.45		22.82 (C)	2210.84	
5.	**PSC (1.25 %)**	9.69 (C)	9.04	24.69	16.40 (C)	14.93	-7.89	24.14 (C)	19.62	-14.28	21.94 (C)	18.62	-35.63	21.88 (E)	22.84	-14.74	14.38 (C)	14.74	-26.12
		8.40 (C)	2173.21		13.45 (C)	2113.4		15.09 (C)	2169.94		15.31 (E)	2209.31		23.81 (C)	2125.34		15.09 (C)	2198.65	
6.	**PSC (1.5 %)**	7.14 (C)	7.19	-0.83	11.06 (C)	10.38	-35.96	14.29 (C)	14.39	-37.13	15.52 (C)	14.80	-48.83	18.09 (C)	18.74	-42.96	12.89 (C)	14.86	-25.51
		7.20 (C)	2051.53		9.69 (C)	2127.27		14.50 (C)	2119.43		14.08 (E)	2155.38		19.38 (C)	2072.56		16.84 (C)	2095.58	

Table 6 Test Results for Compressive Strengths at various ages of OPC using CNT in N/mm^2:

Sl. No.	Cement Type	1 day			3 days			7 days			28 days			90 days		
		Strength	Strength (Avg.) Density (Kg/m^3)	% Increase	Strength	Strength (Avg.) Density (Kg/m^3)	% Increase	Strength	Strength (Avg.) Density (Kg/m^3)	% Increase	Strength	Strength (Avg.) Density (Kg/m^3)	% Increase	Strength	Strength (Avg.) Density (Kg/m^3)	% Increase
1.	**OPC**	17.36(C) 21.82(C)	19.59 (Avg.) 2305.44	_	23.47(C) 23.98(C) 14.08(C) 15.59(C) 18.11(C) 11.42(C)	23.72 (Avg.) 2269.6 2222.68 2162.29	—	21.33(C) 20.83(C) 33.25(C) 28.57(C) 40.67(C) 35.21©	21.08 (Avg.) 2264.08 2217.91 2283.12	—	35.2 (C) 28.57 (C) 43.76 (C) 44.51 (C) 32.2 (C) 33.12 (C)	31.89 (Avg.) 2315.46 2333.18 2295.98	—	24.14(C) 38.26(C) 34.69(C) 35.20(C) 52.31(C) 37.76(C)	31.20 (Avg.) 2290.12 2327.8 2326.72	--
2.	**OPC (1%PCE)**	Tests couldn't be performed as Sample was not set.		-100	Tests couldn't be performed as Sample was not set.	—	-100	14.59(C) 22.00(C) 20.05(C)	18.88 (Avg.) 2216.35	-10.44	22.96 (C) 32.04 (C) 31.18 (C)	28.73 (Avg.) 2364.52	-9.91	34.69(C) 35.71(C) 37.69(C)	36.03 (Avg.) 2372.77	15.48
3.	**OPC (1%PCE+ 0.02%CNT)**	Tests couldn't be performed as Sample was not set.		-100	11.07 (C) 12.24 (C) 9.78(C)	11.03 (Avg.) 2335.03	-53.5	16.86(C) 20.12(C) 16.10(C)	17.69 (Avg.) 2327.21	-16.08	42.35 (C) 44.63 (C) 44.27 (C)	43.75 (Avg.) 2356.24	37.19	16.5(C) 17.5(C) 19(C)	35.59 (Avg.) 2337.79	14.07
4.	**OPC (1%PCE+ 0.05%CNT)**	Tests couldn't be performed as Sample was not set.		-100	9.91(C) 5.38(C) 9.29(C)	7.98 (Avg.) 2201.45	-66.36	32.56(C) 24.86(C) 24.14(C)	27.19 (Avg.) 2316.75	28.98	41.95 (C) 31.35 (C) 31.35 (C)	34.88 (Avg.) 2159.42	9.37	41.24(C) 24.13(C) 30.18(C)	31.85 (Avg.) 2306.64	2.08
5.	**OPC (1%PCE+ 0.1%CNT)**	Tests couldn't be performed as Sample was not set.		-100	14.58 (C) 15.26 (C) 12.23 (C)	14.21 (Avg.) 2298.37	-40.09	24.14(C) 20.54(C) 20.41(C)	21.69 (Avg.) 2301.98	2.89	23.00 (C) 27.00 (C) 24.49 (C)	24.83 (Avg.) 2267.23	-22.14	28.17 30.61 35.71	31.50 (Avg.) 2314.7	0.96

				25.0(C)			26.79(C)								
				27.95(C)	2310.16		32.65(C)	2343.06							

VI. Conclusions

The results showed that the optimizations for addition of nano materials are nS=0.75% ,CNT=0.02% for ordinary Portland cement(OPC) & these optimizations showed good results for upto 28 days but contradicted at later ages.For Portland pozzolona cement(PPC) & Portland slag cement(PSC) the optimised proportion of nS is 0.75% for PPC & 1.0% for PSC The later variations may be attributed to the fact that the control of degree of freedom of valence electrons of nano materials are still not so developed. Also at later ages the nano materials has a tendency to get oxidised, thus releasing their valence electrons in the process. Further research on micro structural studies are necessary for characterization of nano materials in concrete.

VII. Future Scope Of Work

The future is immensely bright for Nano technologists and their domain. The control of degree of freedom of valence electrons is of utmost importance for the nano materials generally have the tendency to oxidize itself by releasing their outermost valence electrons at the slightest cost to a lesser known valley. Further research work is necessary to find out how the control could be achieved through characterization studies of nano materials and also micro structural studies will reveal the hydration of the cement paste easier.

"Valleytronics (an application of Nanotechnology)….. that refers to the technology of control over the degree of freedom of valence….will spin off and become new age technology" – Prof.(Dr.)C.N.R.Rao at ICNM-2014, in The New Sunday Express.

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AUTHORS

Mainak Ghosal is a Research Scholar in the Civil Engineering Department, Institute of Engineering Science & Technology, Shibpur having more than 17 years' experience in construction sector & academia and his research interest includes structural engineering, management, geopolymers, nanoconcrete and its performance.

Arun Kumar Chakraborty, Associate Professor of Civil Engineering Department, Indian Institute of Engineering Science & Technology, Shibpur. He has published more than sixty papers in International & National Journals & Conferences mainly in the area of high strength concrete, fibre reinforced concrete, corrosion in concrete, geopolymer concrete.