COMPRESSIVE STRENGTH BEHAVIOUR OF CONCRETE USING NANOSILICA(SiO_2), NANO ALUMINA(Al_2O_3) & FERRIC OXIDE(Fe_2O_3)

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Abstract: **The most active research areas dealing with cement and concrete understand of the hydration of cement particles and use of nano size ingredients such as nano silica, nano alumina, ferric oxide. If cement with nano size particles can be manufactured and processed, it will open up a large number of opportunities in the field of ceramics and high strength composites etc. The main objective of this paper is to outline some of the application of nanotechnology in concrete and comparing this concrete with ordinary concrete.**

Keyword: Compressive Strength, Tensile Strength, Flexural Strength, Nano alumina, Ferric oxide.

I.INTRODUCTION

I.1 GENERAL

The main advances have been in the nano science of cementitious materials with an increase in the knowledge and understanding of basic phenomena in cement at the nano scale (e.g., structure and mechanical properties of the main hydrate phases, origins of cement cohesion, cement hydration, interfaces in concrete, and mechanisms of degradation). Recent strides in instrumentation for observation and measurement at the nano scale are providing a wealth of new and unprecedented information about concrete, some of which is confounding previous conventional thinking. Important earlier summaries and compilations of nanotechnology in construction can be found in this paper reviews the main developments in the field of nanotechnology and nano science research in concrete, along with their implications and key findings. The paper is divided into three main sections: (i) definitions of nanotechnology in concrete, (ii) advances in instrumentation and computational materials science.

The American physicist, Richards P. Feynman raised and put forward nanotechnology in his famous lecture at the California Institute of Technology in 1959. The word “Nano”, which is evolved from the Greek word for dwarf, indicates a billionth. Nanotechnology is the use of minute particles of material either by themselves or by their manipulation to generate new large scale materials. The size of molecule, though, is very significant because at the length scale of the nanometer, 10-9 m, the properties of material affects considerably. A billionth of a meter corresponds to a single nanometer. It concerns with particles ranging between 1 to100 nanometer in size.

$$1 \text{ Nanometer (nm)} = 1 \times 10^{-9} \text{ m.}$$

Nanotechnology is not a new science or technology, it is rather an augmentation of the sciences and technologies which already exist from many years and it is logical progression of the work that has been done to analyze the nature of our world at an even smaller scale.

Nanotechnology has changed and will pursue to change our perception, expectations and abilities to control the materials world. Several applications have been developed for this specific sector to improve the energy efficiency, durability of construction elements, and safety of the buildings, delivering the ease of maintenance and to provide increased living comfort. The role of nanotechnology in conceiving of innovative infrastructure systems has the potential to transform the civil engineering practice and dilate thevisionofcivilengineering.Manydisciplinesof civil engineering, in conjunction with design and construction processes can be benefited from this technology. For example, new structural materials with unique properties, stronger and lighter composites, sound absorber, fire insulator, low maintenance coating, nano-clay filled polymers, self-disinfecting surfaces, water repellents, aircleaners, nanosizedsensors, solarcells, ultrathin-strong-conductive wafersetc.

I.2 OBJECTIVE

The main objective of this project is to determine experimental investigation on behaviour of Nano material with various ratios. Nano technology can modify the molecular structure of the concrete material to improve the material properties. Effect of Nano silica, aluminium oxide, ferric oxide dosages on compressive strength.

The Nano materials such as Nano silica (SiO_2) aluminium oxide (Al_2O_3) ferric oxide (Fe_2O_3) of varying percentage are used to determine the strength ofconcrete specimens.(Cube)betweencontrolconcreteandNanomaterial%.

I.3 BENEFITS OF NANOCONCRETE

- Cessationofcontaminationcausedbymicrosilicasolidparticles.
- Lower cost per building site.
- Concretewithhighinitialandfinalcompressiveandtensilestrengths.
- Concrete with good workability.
- Cessation of super plasticizing utilization.
- Cessation of silicosis risk.

I.4 NANO ALUMINA

The role of nano Alumina in increasing the mechanical properties of cement has been carried out by few researchers. The optimized level of usage of nano particles to attain the ultimate strength was reported. Further, the potential of nano materials for activation of the initial strength of belite cements. The study concluded that an addition of nano particles notably increases the early strength (7 days) and the nano particle can be used as an agent for activating hydraulic properties of belite cement thereby changes in microstructure causes improved mechanical property. The nano Alumina fill the ITZ of cement- sand and some capillary in the matrix and hence the elastic modulus and compressive strength of mortars were increased. But, no significant improvement in compressive strength was noticed due to insufficient filling of pores in the cement matrix under experiment condition. Alumina imparts quick setting properties to the cement. It acts as a flux and it lowers the clinkering temperature.

I.5 NANO SILICA

Nano silica having a low cost budget, high compressive & tensile strength, high surface area, ability to prevent silicosis, reducing percentage of CO2, nano silica also helps in checking solid waste pollution when mixed with recycled concrete aggregates. As micro silica fumes are added in concrete to fill in the voids, decrease the concrete alkalinity, and increases its resistance against the chemical attack. Cement and water undergo chemical reactions known as hydration reactions: A cement particle is composed of four chemical compounds namely, Tricalcium sulfide (C3S), Dicalcium sulfide (C2S), Tricalcium Aluminate (C3A), and Tetra calcium Alumino-ferrite (C4AF). The hydrations of the first two compounds with water lead to the formation of calcium-silicate-hydrate (CSH) gel and calcium hydroxide (CH) also known as Portlandite. The CSH gel is a strong bond and forms strong connection between the concrete particles. On the other hand, Portlandite is a soluble product and leaches out in water. It is a weak link between the concrete particles. The addition of silica particles in concrete mix converts the weak CH into stronger CSH. Silica fumes refine the properties of concrete by two means: its fine size fills the voids between cement particles and the voids between cement particles and aggregates; and secondly they react Pozzolanically with CH to produce CSH gel, increasing the binding quality and decreasing the capillary porosity of concrete. Thus it is well established that silica fumes increase the strength of concrete and produce a denser and more homogeneous matrix. This effect of silica fume has been proved by electron microscopy measurements. Silica fumes as discussed above are micro particles. It imparts strength to the cement due to formation of dicalcium and tricalcium silicates. If silica is present in excess quantity, the strength of cement increases but at the same time it setting time is prolonged. It compacts concrete, making it more strong and more durable under alkaline conditions like marine environments. It can also be added to concrete to stabilize fillers like fly-ash, to a coating material resulting in a very strong matrix, or used as fire retardant agent. Typical applications are UHPC (Ultra High Performance Concrete), scratch resistant coatings and fire resistant glass.

II. MATERIAL PROPERTIES

II.1 CEMENT

In the most general sense of the word, cement is a binder, a substance which sets and hardens independently, and can bind other materials together. The word “cement” traces to the Romans, who used the term “opus caementicium” to describe masonry which resembled concrete and was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives which were added to the burnt lime to obtain a hydraulic binder were later referred to as cement. Important use of cement is mortor the bonding of natural or artificial aggregates to form strong building materials which is durable in the face of normal environmental effects. Unlike conventional cement concrete (CCC); the concrete incorporates chemical or mineral admixtures or both. Moreover, the effect of characteristics of cement on water demand is more noticeable in concrete. Hence selection of proper grade and quality of cement is important for obtaining concrete. Some of the important factors, which play a vital role in the selection of the type of the cement, are durability factors, compressive strength at various ages, fineness, and heat of hydration, alkali content, tricalcium aluminate (C_3A) content and tricalcium silicate (C_3S) content, dicalcium silicate (C_2S) content and compatibility with admixtures etc. Ordinary Portland Cement (OPC) is now available in three grades namely 33, 43, 53 grades, the number indicating the compressive strength of standard cement and mortar in MPa at 28 days curing period. Variation in chemical composition and physical properties of cement affects the concrete compressive strength, more than variation in any other single material. Among the chemical constituents of cement, the most important are C_3A, C_3S, C_2S and tetra calcium alumina ferrite (C_4AF). C_3S and C_2S are the most important components responsible for strength. The average C_3S content in modern cement is about 45% and that of C_2S is about 25%. The sum of the content of C_3A and C_4AF has been decreased slightly in modern cement. Fineness of the cement is also one of the parameters, as increasing the fineness will increase the early strength of the concrete, but as other may lead to ecological problems. In this investigation OPC (Penna) 53 grade cement has been used. The Chemical properties of cement have been given in Table 1

TABLE 1: CHEMICAL PROPERTIES OF 53 GRADE OPC

DESCRIPTION & UNITS	TEST RESULT	REQUIRMENTS OF BIS: 12269-1987
MgO %	1.22	6.0 (By Mass)
Insoluble Residue %	0.96	3.00 max
Content %	0.028	0.10 max
Sulphuric Anhydride %	1.91	3.00 max
Alumina Ratio	1.36	0.66 min
Lime saturation Factor Ratio	0.90	0.80 min & 1.20 max

II.2 FINE AGGREGATE

Fine aggregate / sand is an accumulation of grains of mineral matter derived from the disintegration of rocks. It is distinguished from gravel only by the size of the grains or particles, but is distinct from clays which contain organic materials. Sands that have been sorted out and separated by the organic material of water or by winds across arid lands are generally quite uniform in size of grains. Usually commercial sand is obtained from river beds or from sand dunes originally formed by the action of winds. The grading zone of fine aggregate was zone II as per Indian Standard specifications.

II.3 COARSE AGGREGATE

Coarse aggregate are the crushed stone is used for making concrete. The commercial stone is quarried, crushed, and graded. Much of the crushed stone used is granite, limestone, and trap rock. The last is a term used to designate basalt, gabbro, diorite, and other dark- coloured, fine-grained igneous rocks. Graded crushed stone usually consists of only one kind of rock and is broken with sharp edges. The sizes are from 6 mm to 12 mm, although larger sizes may be used for massive concrete aggregate. Machine crushed granite broken stone angular in shape was used as coarse aggregate. The maximum size of coarse aggregate was 20 mm and specific gravity of 2.71.

II.4 WATER

Water is an important ingredient of concrete as it chemically participates in the reactions with cement to form the hydration product, C-S-H gel. The strength of cement concrete depends mainly from the binding action of the hydrated cement paste gel. A higher water-cement ratio and water binder will decrease the strength, durability, water – tightness and other related properties of concrete. The quantity of water added should be minimum required for chemical reaction of hydrated cement, as any excess of water would lead end up only in the formation of undesirable voids (capillary pores) in the hardened cement concrete paste. The strength of cement paste is inversely proportional to the dilution of the paste. Hence, it is essential to use as little paste as possible consistent with the requirements of workability and chemical combination with cement.

II.5 NANO ALUMINIUM OXIDE

Aluminum oxide, commonly referred to as alumina, possesses strong ionic interatomic bonding giving rise to it's desirable material characteristics. It can exist in several crystalline phases which all revert to the most stable hexagonal alpha phase at elevated temperatures. This is the phase of particular interest for structural applications and the material available from Accuratus. Aluminium oxide is widely used to remove water from gas stream. It is widely used as an abrasive, because of its hardness and strength. It also have abrasion-resistant characteristics of coating originate from high strength of aluminium oxide. Aluminium oxide is used for its hardness and strength. It is widely used as an abrasive, including as a much less expensive substitute for industrial diamond. Many types of sandpaper use aluminium oxide crystals. In addition, its low heat retention and low specific heat make it widely used in grinding operations, particularly cutoff tools. Over 90% of the aluminium oxide, normally termed Smelter Grade Alumina (SGA), produced is consumed for the production of aluminium, usually by the Hall– Heroult process. The remainder, normally called specialty alumina is used in a wide variety of applications which reflect its inertness, temperature resistance and electrical resistance and construction purpose. Available in purity ranges from 94%, an easily metallizable composition, to 99.8% for the most demanding high temperature applications. High purity alumina is usable in both oxidizing and reducing atmospheres to 1925°C. Weight loss in vacuum ranges from 10–7 to 10–6 g/cm2.sec over a temperature range of 1700° to 2000°C.

TABLE 2: PHYSICAL AND CHEMICAL PROPERTIES

FORMULA	Al2O3
PHYSICAL STATE	Solid-granular
BOILING POINT	N/A
MELTING POINT	2100° C
pH at 20°	N/A
APPEARANCE	White
ODOUR	Odorless
FLASH POINT	N/A
DECOMPOSITION TEMPERATURE	N/A
VAPOUR PRESSURE	N/A
VAPOUR DENSITY	N/A
EXPLOSIVE PROPERTIES	None
SOLUBILITY	Insoluble
OXIDIZING PROPERTIES	N/A
GRAVITY SPECIFIC	3.6
BULK DENSITY	N/A

FIG.1 NANO ALUMINIUM OXIDE POWDER

FIG.2 CASTING AND TESTING OF CONCRETE

III. RESULT AND DISCUSSION

III.1 COMPRESSIVE STRENGTH

Compressive strength of M40 grade concrete with varying percentages of nano silica,nano alumina and ferric oxide as substitute for cement. Compressive Testing Machine (CTM) has been used for testing of concrete cubes. For every variation, three cubes of cross section 150 X 150mm were cast, average compressive strength was determined. To evaluate the compressive strength of concrete following formula has been used.

Compression Strength = (Failure Load / Area) N/mm^2

TABLE 3: COMPRESSIVE STRENGTH OF CONVENTIONAL CONCRETE

SL.NO	SPECIMEN CODE	CURING PERIOD (DAYS)	COMPRESSION LOAD (KN)	AVG COMP STRENGTH (N/MM^2)
1	C11	7	595	26.44
2	C11	28	620	27.55

TABLE 4: COMPRESSIVE STRENGTH OF NANO ALUMINIUM OXIDE FOR 7 DAYS

SL.NO	SPECIMEN CODE		CURING PERIOD (DAYS)	COMPRESSION LOAD (KN)	AVG COMP STRENGTH (N/MM^2)
	%	CODE			
1	1	A11	7	625	27.7
2	1.5	A12	7	665	29.5
3	2	A13	7	680	30.2

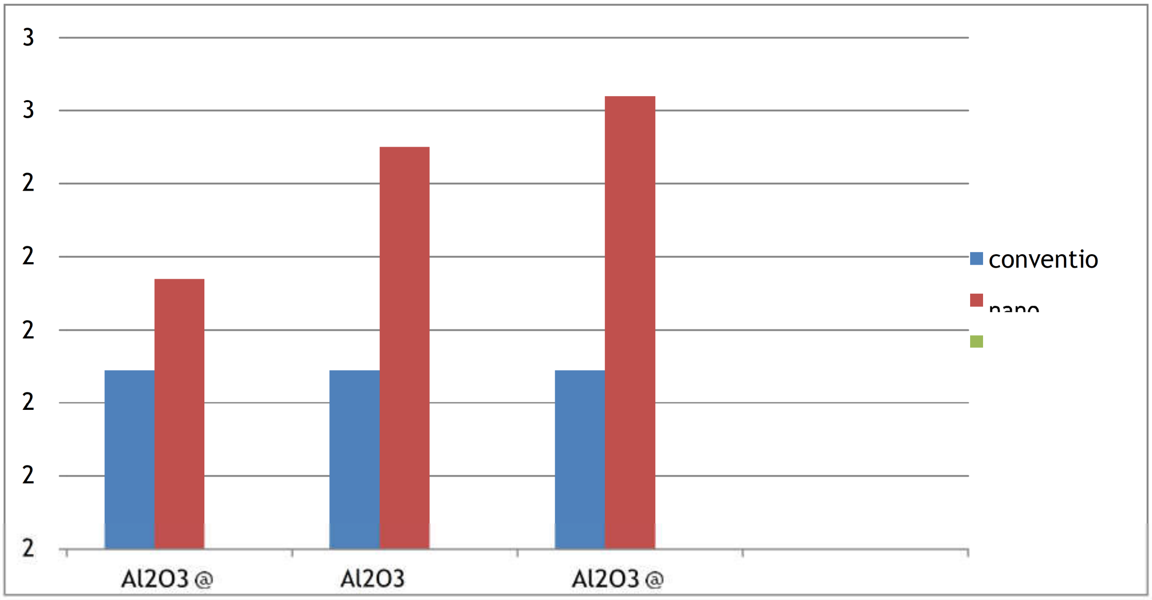

FIG.3 COMPARISON CHART OF CONVENTIONAL AND NANO ALUMINIUM OXIDE FOR 7DAY TEST

TABLE 5: COMPRESSIVE STRENGTH OF NANO ALUMINIUM OXIDE FOR 28 DAYS

SL.NO	SPECIMEN CODE		CURING PERIOD (DAYS)	COMPRESSION LOAD (KN)	AVG COMP STRENGTH (N/MM^2)
	%	CODE			
1	1	A11	28	1030	45.77
2	1.5	A12	28	1020	45.33
3	2	A13	28	1100	48.88

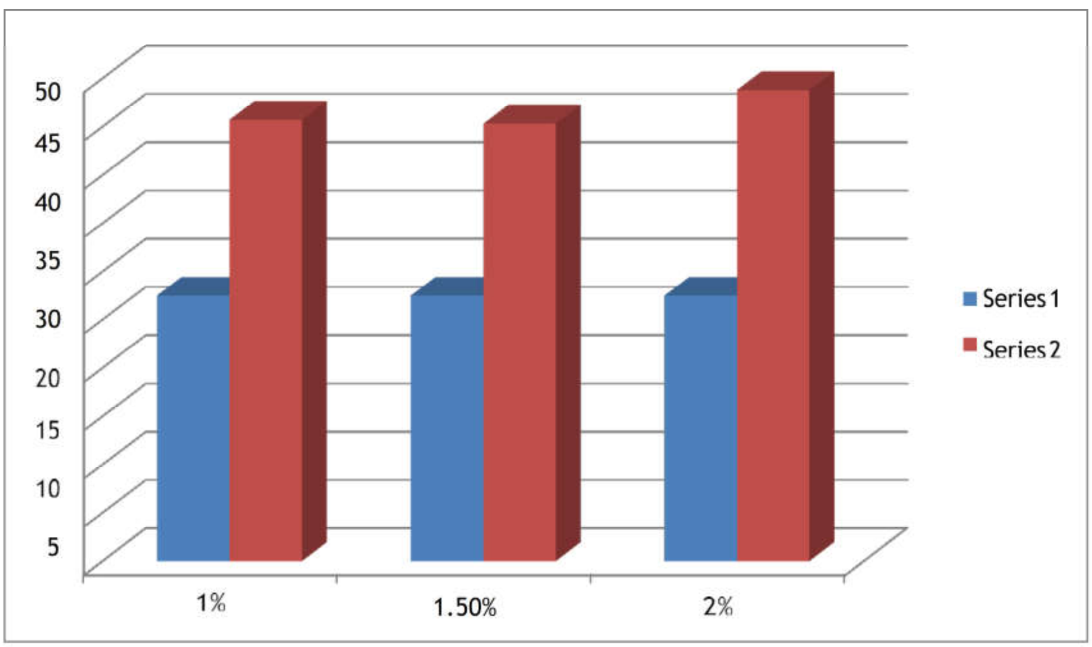

FIG.4 COMPARISON CHART OF CONVENTIONAL AND NANO ALUMINIUM OXIDE FOR 28 DAY TEST

TABLE 6: COMPRESSIVE STRENGTH OF NANO SILICA FOR 7 DAYS

SL.NO	SPECIMEN CODE		CURING PERIOD (DAYS)	COMPRESSION LOAD (KN)	AVG COMP STRENGTH (N/MM^2)
	%	CODE			
1	0.2	S11	7	800	35.5
2	0.5	S12	7	910	40.4
3	1	S13	7	890	39.56

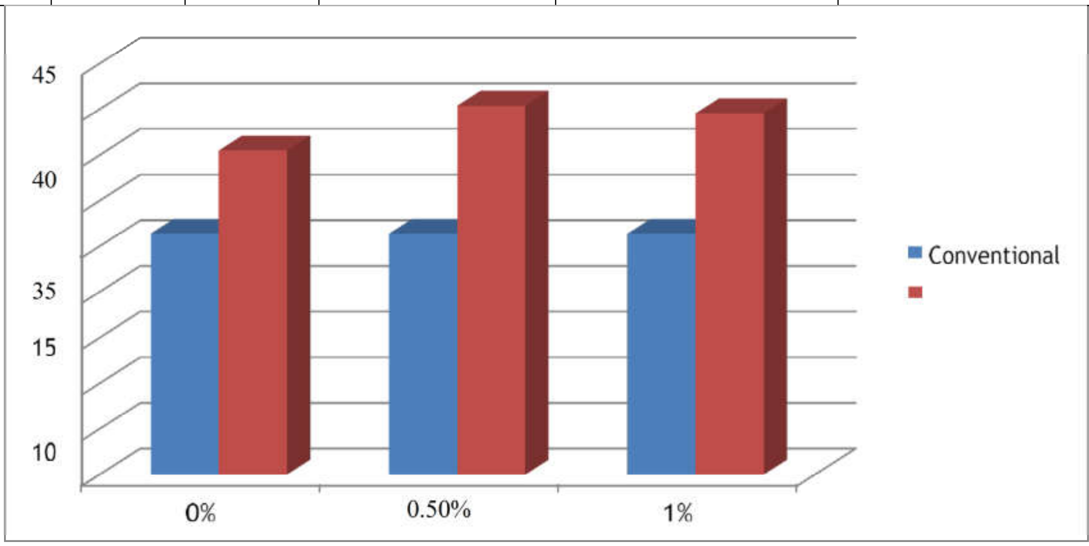

FIG.5 COMPARISON CHART OF CONVENTIONAL AND NANO SILICA FOR 7 DAY TEST

TABLE 7: COMPRESSIVE STRENGTH OF NANO SILICA FOR 28 DAYS

SL.NO	SPECIMEN CODE		CURING PERIOD (DAYS)	COMPRESSION LOAD (KN)	AVG COMP STRENGTH (N/MM^2)
	%	CODE			
1	0.2	S11	28	720	32.8
2	0.5	S12	28	1000	44.44
3	1	S13	28	1020	45.33

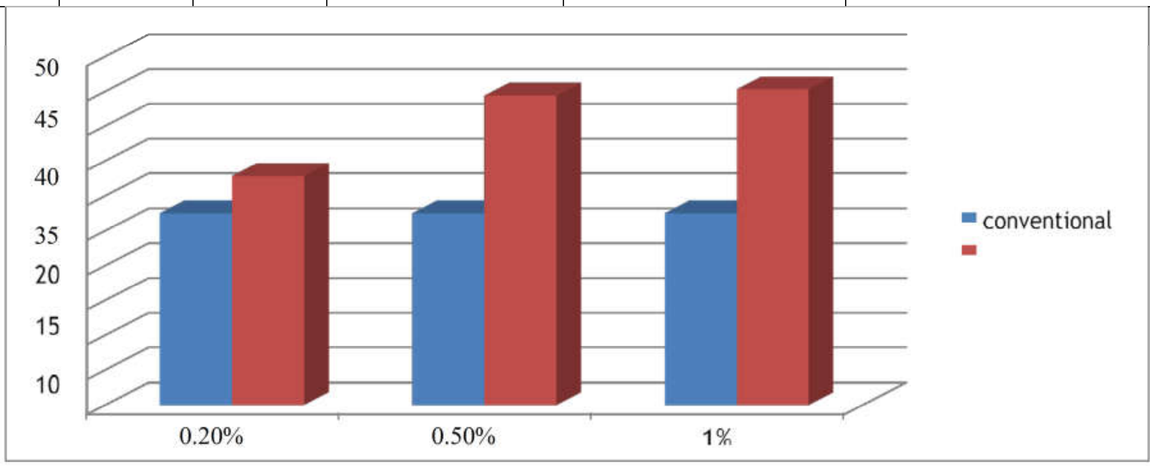

FIG.6 COMPARISON CHART OF CONVENTIONAL AND NANO SILICA FOR 28 DAY TEST

TABLE 8: COMPRESSIVE STRENGTH OF NANO IRON OXIDE FOR 7 DAYS

SL.NO	SPECIMEN CODE		CURING PERIOD (DAYS)	COMPRESSION LOAD (KN)	AVG COMP STRENGTH (N/MM^2)
	%	CODE			
1	1	F11	7	850	37.7
2	1.5	F12	7	1040	46.8
3	2	F13	7	1000	44.4

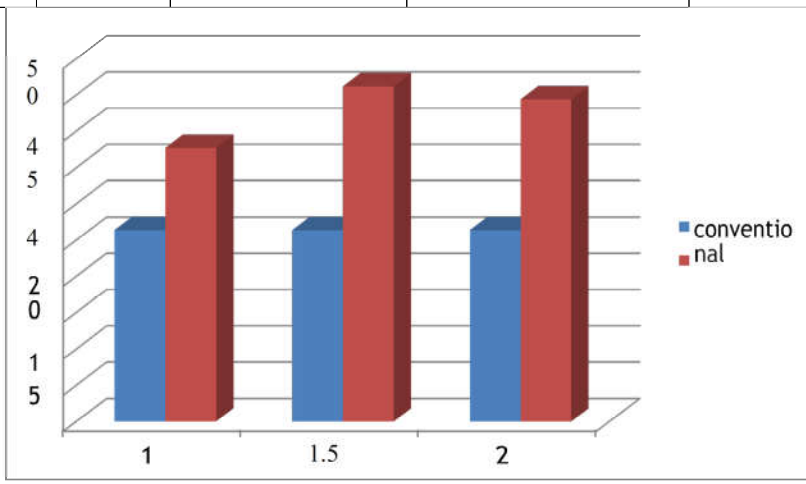

FIG.7 COMPARISON CHART OF CONVENTIONAL AND NANO IRON OXIDE FOR 7 DAY TEST

TABLE 9: COMPRESSIVE STRENGTH OF NANO IRON OXIDE FOR 28 DAYS

SL.NO	SPECIMEN CODE		CURING PERIOD (DAYS)	COMPRESSION LOAD (KN)	AVG COMP STRENGTH (N/MM^2)
	%	CODE			
1	1	F11	28	970	43.11
2	1.5	F12	28	1060	47.11
3	2	F13	28	1290	57.33

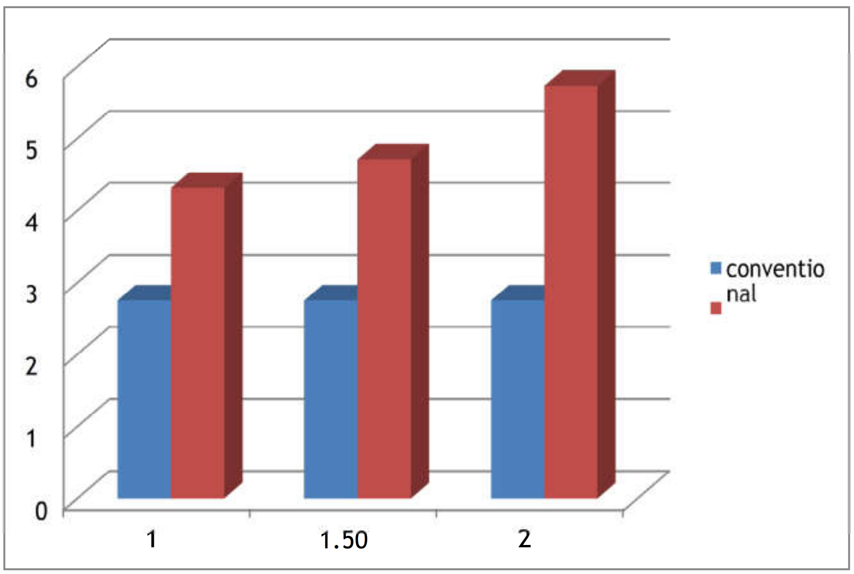

FIG.8 COMPARISON CHART OF CONVENTIONAL AND NANO IRON OXIDE FOR 28 DAY TEST

IV. CONCLUSION

As the percentage of chemical admixtures increases so the compressive strength of concrete decreases maximum compressive strength was observed for mix containing 2% of Fe_2O_3 for 28 days curing further chemical admixtures increases , decreases the strength of concrete.

By using nano material(Al_2O_3,Fe_2O_3 and SiO_2) in these 3 material the nano iron oxide is achieved the maximum compressive strength of 57.7 N/mm^2 while comparing to other nano materials

TABLE 10: MAXIMUM COMPRESSIVE STRENGTH OF CONVENTIONAL AND NANO CONCRETE FOR 7 DAYS

Sl.No	Specimen Code		Curing period (days)	Max Compression Load (KN)	Max comp strength (N/mm^2)
	%	code			
1	-	Conventional	7	595	26.44
2	2	Al_2O_3	7	680	30.2
3	0.5	SiO_2	7	910	40.4
4	1.5	Fe_2O_3	7	1040	46.2

TABLE 11: MAXIMUM COMPRESSIVE STRENGTH OF CONVENTIONAL AND NANO CONCRETE FOR 28 DAYS

Sl.No	Specimen Code		Curing period (days)	Max Compression Load (Kn)	Max Comp Strength (N/Mm^2)
	%	code			
1	-	Conventional	28	620	27.55
2	2	Al_2O_3	28	1100	48.88
3	1	SiO_2	28	1020	45.33
4	2	Fe_2O_3	28	1290	57.33

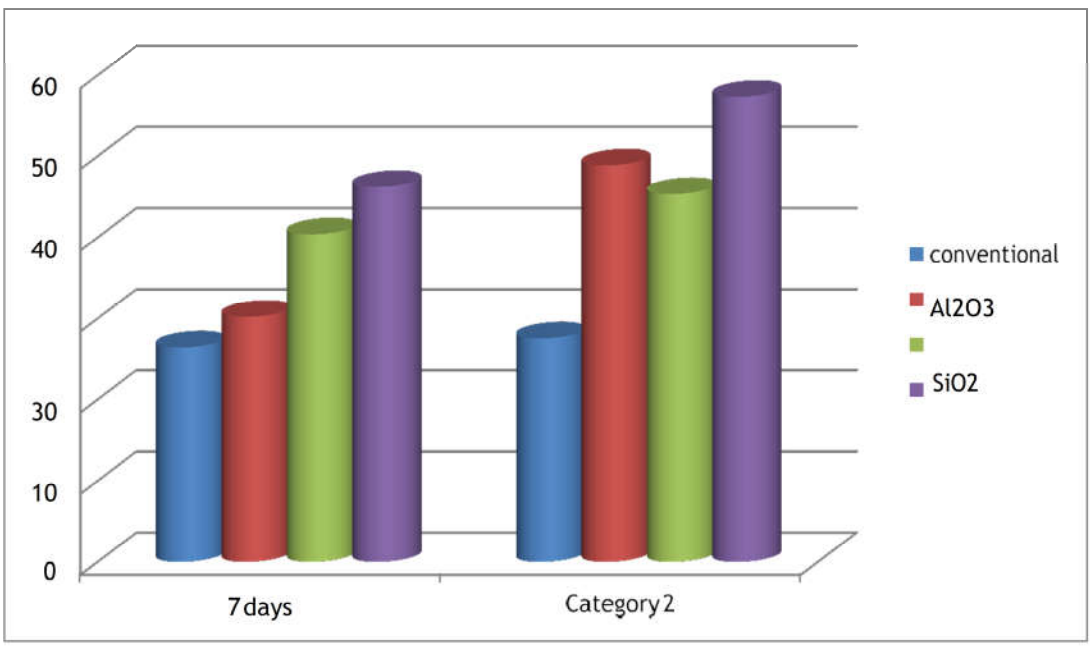

FIG.9 COMPARISON OF CONVENTIONAL AND NANO MATERIALS FOR 7 AND 28 DAYS

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