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Strength of Cement Mortar Using Nano Oxides: An Experimental Study

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***Abstract:** Cement mortar is one of the important materials which plays key role in maximising the durability of a building. Strength, permeability, thermal insulation, freeze and thaw resistance, Chloride-ion penetration, carbonation, hydration, weathering are the factors affecting the overall performance of the cement mortar. So many new ingredients are being used as admixture have been investigated for making the mortar of high performance. Various nano materials are constituting the advance engineering products with smart working. Some industrial waste like blast furnace slag, fly ash, silica fume, also incorporated in cement concrete for making mortar economical. In this Experimental study nano oxide of Zinc, aluminium, and silicon have been investigated in cement mortar and compared. It is found that all nano materials are not having the similar effect.*

***Key Words:** - Nano Zinc oxide, compressive strength, cement mortar.*

I. INTRODUCTION

In modern construction work cement is an essential component. In modern concrete technology nano particles are widely employed for getting noble properties. During Last 20-25 years the use of nano materials is increased tremendously, because of high specific surface area the reactivity of nano particles is very high. In other fields such as medicine, glass industry, paints nano technology has been already proved beneficial, nowadays, scientists' interest rapidly growing in use of nano particles in cementing materials for durability and engineering properties. During 20th century the strength of concrete up to 50 MPa was considered as High-performance concrete, but with advancement of construction technology now concrete 150 MPa is known as high performance concrete, now even Ultra high-performance concrete can be produced. Extensive research Has been done for making concrete more advance by many admixtures, pozzolans, polymers etc. Some researchers have shown that by adding nano particles the cement concrete become stronger and sensitive to temperature and strain. However, cost will also increase slightly. Generally, superplasticizers are used with nano materials because they reduce workability. Nano particles are very fine hence fill the micro-pores of the materials hence affect the properties of the material, due to pore filling, compressive strength and permeability affected.

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Nano material increases the crystallization in hydrates, water permeability decreases. Nano particles not only fills the voids, improves hydration reaction, also by pozzolanic reactions with calcium hydroxide make more CSH gel which improves the mechanical strength and durability. To understand the effect on hydration of cement many nano materials have been experimented by using ZnO_2, Cr_2O_3, TiO_2, Al_2O_3, SiO_2 Multiwalled carbon nanotube etc.

II. LITERATURE SURVEY

A. Addition of nano alumina in cement mortar

Many researchers have shown the improvement in mechanical properties by adding nano alumina. Compressive strength split tensile strength, workability, setting time etc varied while nano admixtures are used. Many properties of cement concrete may be corelated to compressive and tensile strength, hence measurement of these properties is mandatory.

M. R. Arefi et al (2011). In this work alumina is added to cement and found that up to 3 % improvement in strength is seen, then decreases. images for SEM also shows that calcium hydroxide reduces at 3% nano alumina. but at 5% alumina strength decreases, this may be due to nano particle are more than the required to combined with lime which liberated during hydration process. thus, excess silica leaches cause deficiency in strength. high surface area of nano to be added in correct quantity otherwise their agglomeration appears. Because of high surface area nano particles consume liberated $Ca(OH)_2$ and fill the voids of C-S-H gel denser microstructure produces more compressive strength.

Ali Nazari et al (2010). They have investigated that nano alumina in cement mortar improves the split tensile strength and flexural strength and setting time has decreased. Best results are found at 1 % of alumina while more than 2% strength decreases than control mix. Curing time was 7, 28, 90 days. higher percentage of admixture excess silica leaches cause strength deficiency. Increase in strength may be due to rapid consumption of calcium hydroxide which formed during hydration. Setting times decreases because of higher specific surface area has faster hydration reaction. In this paper nano alumina of average diameter 15 nm was used workability and compressive strength were found. Four samples of admixtures 0.5 %, 1.0%, 1.5 % and 2 % and concluded that at 1 % alumina best results in strength. Workability decreases at higher % of nano alumina giving low slump value. therefore, use of super plasticizer is necessary.

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B. Addition of nano Zinc Oxide in cement mortar

Using ZnO, and Al-ZnO, enhances mechanical properties.

ZnO particles are found suitable for photocatalytic properties and reducing corrosion rate of steel bars. Total organic carbon and Zeta potential were measured, to find rheological properties. ZnO is a versatile semiconductor material, photocatalyst, direct band gap 3.3eV, due to high photocatalytic degradation of organic compound strongly resist microorganism. It is widely used in various products like paints, ceramics glass etc. Other have shown the use of nano ZnO can also improve the strength of cementitious material. But decrement in hydration of cement is found by many researchers, their opinion is that an amorphous layer of Zn $(OH)_2$ is formed or crystalline $CaZn_2(OH)_2.2H_2O$ is formed around anhydrous cement grain. But nano ZnO can be used for photodegradation of pollutants and microorganism. there is very little information regarding use of nano ZnO in cement concrete, and Characterization of ZnO in cement paste. effect on setting time, pore size investigation, compressive strength is determined by various method XRD, TGA, etc. Zinc oxide affects setting time while not having much positive impact on compressive strength. Partial replacement of ZnO accelerate C-S-H gel formation at early stage of hydration, make more $Ca(OH)_2$. Some researchers showed by XRD analysis that Calcium zinc hydrate is formed with nano zinc oxide ($Ca[Zn(OH)H_2O]_2$) is formed which obstructed hydration process and less hydrate are formed. Therefore, less compressive strength is found. some researchers explained that with zinc oxide an amorphous layer of $Zn(OH)_2$ is formed during hydration of tricalcium silicate. They reduce porosity because due to fine size they work as filler and making microstructure denser. But the finer size also become problem to dispersion because of wander Val's effect. They can act as super sensor for temperature and strain. E. Ghafari et al (2012**):** Adding nano particles affect the workability of cement mortar, cement paste containing nano particle up to 0.4 % showed excellent workability. In this study rheological properties by adding superplasticizer and nano particles have been studied. It is found that after using nano particles the superplasticizer is more absorbed due to more specific surface area, the rate of absorption was more in Aluminium doped zinc oxide (AZO) Yield stress, viscosity considerably increased. Rheological properties were good agreement with adsorption isotherm and Zeta potential. D. Nivethitha et al (2010): Nano technology has been applied in multiple fields during last decade. Nano blended mortar has also given promising results. In this study 60 nm ZnO particles used in cement mortar. Cement sand ratio was taken 1:2, and samples were prepared by 1%, 3% and 5 % of wt. of cement. Split and compressive strength test conducted after 7 day and 28-day curing. Six specimens prepared for each test and result averaged. At 5 % strength reduces this may be due to more nano than required to react with lime of hydration process, than excess silica leaches cause the reduction in strength. At 3 % n ZnO compressive strength increases up to23 %, and split tensile strength increases up to 61 %. D Nivethitha et al (2010): Cement mortar prepared 1:1 and 1:2, water cement ratio 0.35 and curing 7 days and 28 days Compressive, split tensile strength were determined with 3 and 5 percent nano Zinc oxide as admixture. To study microstructure of cement SEM analysis is done and found that addition of n ZnO enhances the mechanical properties and durability of mortar up to 3 % of nano particles. In mix 1:1 comp strength 23.88 and in 1:2 23.05 %, split tensile strength 39.93 and 61.35 % increased. SEM observation also showed that nano particles enhances hydration reaction. however, nano particles decline the workability therefor use of super plasticizer is substantial S. Riahi, et al (2012): In this paper thermal properties and effect of curing medium is investigated by using ZnO2 nano particles in cement mortar. Average size was 15 nm. Special curing medium was lime water. Found that up to 2% used is beneficial for mortar. At 1 % maximum benefit to strength. Thermo gravimetric analysis showed that ZnO2 improve workability and increase the weight loss. T. Nochaiya et al (2011): Researcher has investigated porosity, compressive strength and setting time of concrete ZnO as admixture. Various Types of analysis is done to find the correct reasons of effect on hydration. scanning electron microscope, X-ray diffraction Thermal gravimetric Infrared spectrometer (SEM, XRD, TGA, FTIR) etc. setting time prolonged after use of nano ZnO. Compressive strength increases 15 % at 28 days. In early strength was less than the Plain Concrete.

K. Behfarnia et al (2010): In this paper effect of Nano zinc oxide and nano titanium dioxide in concrete have been studied and found that Zinc oxide retards the hydration process and setting time. From XRD diagrams reason found that an amorphous layer of zinc hydroxide formation may be the cause of reduction in hydration process, which prohibits C_3S phase to participate in the hydration process. Use of TiO_2 reduces the compressive strength, probably due to negative impact on C_2S hydration. In case of TiO_2 permeability slightly decreased. TiO_2 Nano material improves the pore structures hence permeability decreases. However, ZnO 5 % concrete showed highly permeable even not testable. In case of TiO_2 samples XRD diagram shows the peaks of $Ca(OH)_2$ was same as reference mortar means TiO2 particles do not reacts with Ca(OH)2, means more hydrated products will be there. While ZnO 4% and 5 % samples showed the presence of Alit (C_3S) (Ca_3SiO_5) and $Ca(OH)_2$ was totally absent even after 28 days curing means ZnO inhibited hydration reaction may be the formation of $Zn(OH)_2$ the reason of inhibition. M. R. Arefi et al (2010) : In this study mechanical properties (flexural and split tensile) of self-compacting concrete has been investigated using 30 nm nano zinc oxide particles, investigation are done with Scanning electron microscope (SEM) and X-ray diffraction analysis. The strength was measured after 7, 14, 21, 28 days curing and with varying percentage (0.05, 0.1, 0.2, 0.5, and 1.0 %) of nano zinc oxide particles. It was found that by adding 0.5 % nano additive can improve the flexural and split tensile strength of the self-compacting concrete, pore structure is also improved, so that density increased, and porosity reduced.

C. Addition of nano Titania in cement mortar

Use of nano TiO_2 can improve chloride penetration and abrasion resistance. TiO_2 have shown ability of removing organic pollutants, building facades exposed to UV radiation. Influence on these factors after adding nano Titanium oxide has been studied.

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Different researchers having different views over the impact of these materials. Some of them think that only SiO_2 having pozzolanic activity while other nano material not. A. Nazari et al (2016):In this paper concrete is tested with nano phase TiO_2 by fraction of 0.5, 1.0, 1.5 and 2 %.and found that split tensile, flexural strength increases, and maximum results found at 1 % replacement. The diameter of nano particle was 15 nm. Setting time decreases by use of nano TiO_2. In this study workability and compressive strength determined by partial replacement of Titanium dioxide nano particles, found that workability decreases, and compressive strength increases up to 2 % use and maximum improvement is found at 1.0 %.

D. Addition of nano Silica in cement mortar

many researchers found the effect of nano silica particles for high mechanical properties different size of particles affect the properties differently. Silica fume, nano silica with superplasticizer is used. It is found that flowability of cement paste decreases with use of nano silica. Compressive strength and abrasion resistance increase by incorporating nano alumina particles**.**

M. Golestaneh, et al (2016): In this paper waste silica powder is used as filler in polymer concrete, the percentage of resin is taken 10, 15, 20% of cement and silica powder is taken as 100, 150, and 200 %. The result shown in this experiment that combination of polymer and silica filler improved the strength up to four-fold. Best compressive, and flexural strength is found at 15 % resin and 200 % filler, while tensile strength is best found at 20% resin and 200% filler. The maximum strength values are found compressive, flexural and tensile is 129, 22, 16 MPa. Silica powder used was mixture of fine, medium, and coarse silica powder in proportion of 15, 25 and 60%.

F. Soleymani (2015): In this study abrasion resistance and compressive strength of concrete is determined with different curing media and with nano silica powder. Result found that when saturated lime water is used as curing medium the abrasion resistance increases. Similar trend is found when nano silica powder is used up to 2%.it was also shown that abrasion resistance in not only dependent on compressive strength.

A. Boshehrian et al (2011): Here the compressive strength, flexural strength of ferrocement mixed with silica is studied. Scanning electron microscopy and atomic force microscopy test (SEM, AFMT) are also performed to understand microscopic properties. Cement sand ratio 1:2 and 1:2.5, water cement ratio taken 0.35, 0.4, 0.5, and nano silica taken at the 1%, 2%, 3%. The results indicate that in comparison to normal OPC, silica concrete has higher strength and low water absorption and denser interfacial transition zone. It is also found that increasing water cement ratio and sand cement ratio strength decreases. Up to 3% use of nano silica improves the strength and durability. Prevents the harmful Ca $(OH)_2$ crystal growth and produces more C-S-H gel, micro, and nano filling effect and helps in hydration reaction

H. Yang (2013): In this experimental study nano silica powder is used in cement concrete by 0.5, 0.75, 1.0% of cement and 28 days strength determined. The results showed that tensile strength increased by 3.2, 7.5 and 4. 5%. Shrinkage increased by 75.5, 127.1, and 163 %. This significant increase in shrinkage cause shrinkage cracks in cement concrete.

M. Khanzadi et al, (2012): Nano silica concrete is tested for capillary absorption, chloride-ion distribution, and for water absorption and found that this concrete is better in permeability resistance and better microstructure and dense concrete. SEM also showing the same conclusion. Both silica fume and nano silica tested and compared, it is found that in early stages nano silica gives better strength while silica fume gives less strength hence pozzolanic activity of nano silica is better than silica fume, nano silica reduces the calcium hydroxide.

III. EXPERIMENTAL WORK

Materials and methods

For comparative study of effect of nano oxides in cement mortar, mortar mix is prepared with proportion of 1:3 by weight. The cement used in this work was 43 grade OPC confirming to IS 8112. The fine river sand was used with 1.18 mm sieved passed. The fineness of cement by sieve analysis is found 2 % retained on 90 No. sieve hence fineness within the specified limit as per IS specifications. The specific gravity of cement and 3.1 and specific gravity of sand was 2.85. Initial setting time of cement was found 43 minutes. Three mould were prepared for each test and average result is taken. Samples are prepared by taking cement and sand in 1:3 ratio by weight and water cement ratio was 0.5, nano material taken by 0.5%, 1.0%, 1.5 %, 2.0%. of weight. All ingredients are mixed in mixer for one minute. Cubes of 50mmX50mmX50mm filled with mortar, and moulds removed after 24 hours. Then moulds are kept in water for curing tank for 3, 7, 14, 28 days. Three specimens are tested for each curing time and result is averaged.

Table 1 strength after 3 days curing

	SiO2	Al2O3	ZnO
0.50%	30	26.44	24.07
1.00%	37.34	29.42	10.3
1.50%	36	22.06	7.35
2.00%	27.34	21.06	2.33

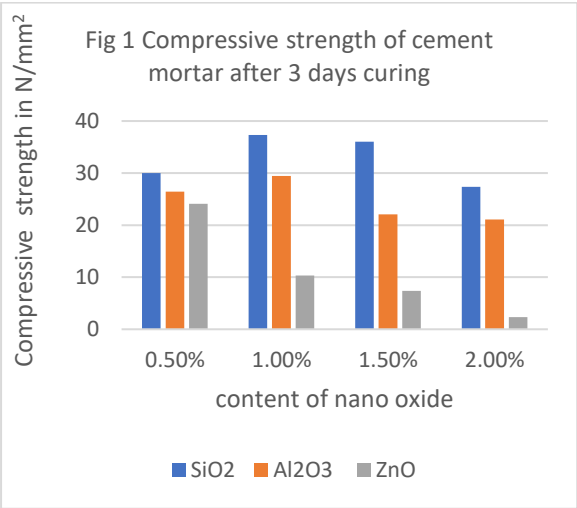

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Table 2 Strength after 7 days curing			
	SiO2	Al2O3	ZnO
0.50%	36.68	28.75	23.73
1.00%	40	30.4	23.41
1.50%	44	27.41	4.01
2.00%	35.34	20.72	3.33

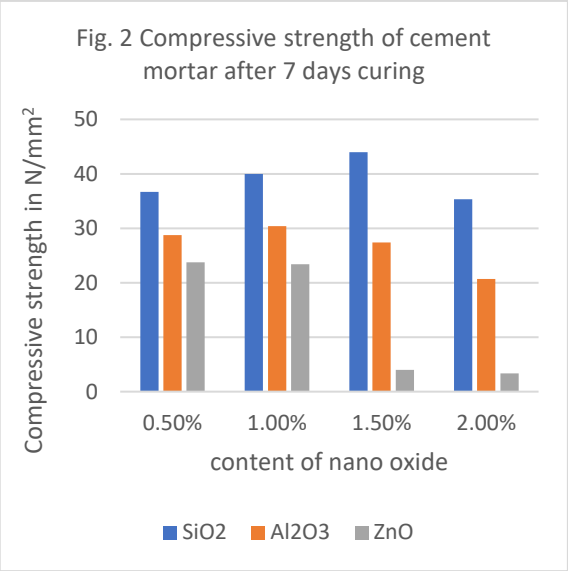


Table No.3 strength after 14 days curing			
	SiO2	Al2O3	ZnO
0.50%	36	28.75	24.07
1.00%	33.34	30.4	24.4
1.50%	23.34	27.41	4.01
2.00%	29.34	29.09	4.67

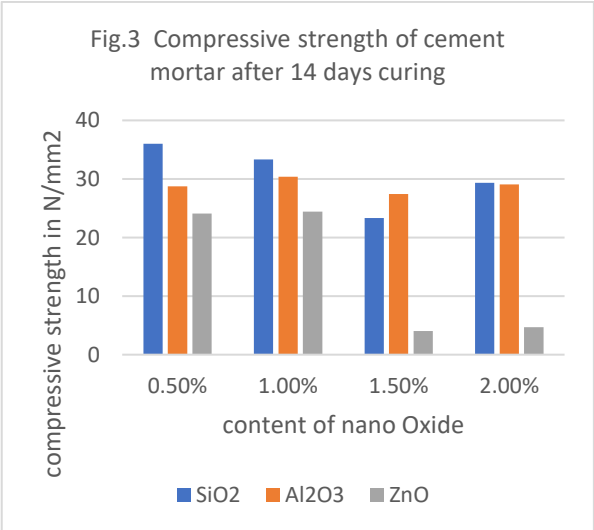
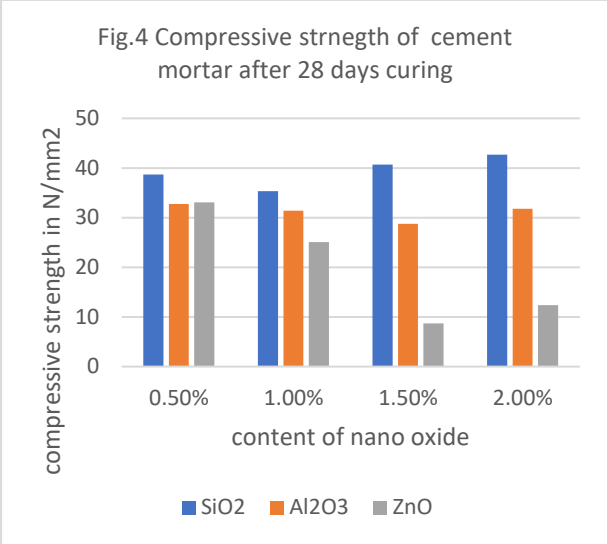


Table No.4, 28 days curing strength			
	SiO2	Al2O3	ZnO
0.50%	38.67	32.76	33.1
1.00%	35.34	31.43	25.07
1.50%	40.67	28.75	8.69
2.00%	42.67	31.76	12.37



IV. RESULT AND DISCUSSION

Results of compressive strength after 3days, 7days, 14 days, 28 days, are shown in table. The results shows that compressive strength increases as nano particle content increases form 0.5% to 1.5 % but at higher percentage (2%) results are less. ZnO gives best results at 0.5%, and then the strength decreases. This may be due to that ZnO makes amorphous layer of Zn $(OH)_2$ is formed or crystalline $CaZn_2(OH)_2.2H_2O$ is formed around anhydrous cement grain. Some researchers showed by XRD analysis that Calcium zinc hydrate is formed with nano zinc oxide $(Ca[Zn(OH)H_2O]_2)$ is formed which obstructed hydration process and less hydrate are formed. Therefore, less compressive strength is found. Nano Silica gives better results than ZnO and Al_2O_3. At 3 days curing nano silica compressive strength was found to be best at 1 % content, the strength was found 37.34 N/mm^2 . For 7 days curing the best strength found in silica than alumina and ZnO. 7 days strength was 44, 30.4 and 23.73 N/mm^2 for silica (1.5%). Alumina (1.0%) and ZnO (0.5%. After 14 days curing the best strength was in silica alumina and Zinc oxide 36, 30.4and 24.07 N/mm^2, while their percentage content was 0.5, 1.0 and 0.5 %. After 28 days curing the compressive strength was 42.67, 32.76, and 33.1 for silica, alumina and Zinc Oxide at their % content was 2.0, 0.5, 0.5%. The test result shows that overall silica oxide gives best results and alumina medium and zinc oxide lowest compressive strength. The Results also indicate that nano materials can be best use in cement mortar between 0.5% to 1.5%. nano silica giving highest strength at 7 days curing and 1.5% content then decreases. Alumina giving best results at 0.5% content and at 28 days curing.

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Zinc oxide gives best results at 0.5 % content in all types of curing time and best result is at 28 days curing, which shows that initially it retards the hydration and at 28 days it gains strength.

V. CONCLUSION

Cement mortar compressive strength has been found by nano oxides as admixture. In this Experimental work nano Zinc Oxide, nano Aluminum Oxide, and nano Silica Oxide has been used. Nano oxides 0.5 %, 1.0%, 1.5%, and 2.0 % of cement is used. The curing time kept 3 days, 7 days, 14 days, and 28 days. Compressive strength after 3 days curing results shows that at 1% nano silica gives maximum strength of 37.34 N/mm^2. Aluminum oxide and Zinc Oxides gives results in decreasing order. Result also showed that at higher percentage content of nano oxide the compressive strength result declines. Best results are found between 0.5% to 1.5 %. At 7 days strength maximum strength is found 44 N/mm^2, at 1.5 % of nano Silica oxide, 7days strength of 1%alumina was 30.4 N/mm^{2}and nano zinc 23.0 N/mm^2 and 0.5 % content was less than silica oxide. 14 days curing strength was less than the other strength. In all oxides nano silica oxide gives better results than alumina and Zinc oxide. Nano Zinc Oxide give the least results and nano ZnO given best result at the 0.5 %. Experiment concludes that addition of nano material is best suitable between 0.5% to 1.5%. This may be due to either pore space available at nano level.

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