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STUDY ON BEHAVIOUR OF NANO CONCRETE

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Abstract: ***Nanotechnology is one of most active research areas which have wide application in all construction fields. In this paper, a study is carried out about Nano materials used like nano silica, nanoTio$_2$, and carbon nanotubes which are less than 500 nano meter. Nano silica has heat transfer. Nano Tio2 also has heat transfer and UV absorption character. By the addition of nano silica, durability and strength performance is increased than conventional concrete.***

Keywords: Nano silica, Nano technology, concrete, durability, NanoTio$_2$

1. INTRODUCTION

Nanotechnology is one of the most active research areas which has wide application in almost all the fields. As concrete is most usable material in construction industry it's been required to improve its quality. Improving concrete properties by addition of Nano particles have shown significant improvement than conventional concrete.

Nano concrete is defined as a concrete made by filling the pores in traditional concrete using Nano particles of size <500 nano meters. There are some additions of Nano sized material. Some of the applications of nanotechnology are:

- Cuore concrete- Nano silica
- Titanium dioxide
- Carbon nanotubes
- Polycarboxylates

1.1 Nanosilica

Silicon dioxide nanoparticles, also known as silica nanoparticles or nano silica, in nature, silica makes up quartz and the sand. It is the first Nano product that replaced the micro silica. Advancement made by the study of concrete at Nano scale has proved Nano silica much better than silica used in conventional concrete.

Micro silica has been one of the world's most widely used additives in concrete for over 80 years. It properties allows high compressive strength, durability and impermeability, and they have been part of many important concrete structure. Its main disadvantages being its relatively high cost and contamination which adversely affects the environment and the health of the construction workers. Micro silica as a powder is one thousandth fold thinner than cigarette smoke. Hence, operators must take special precautions to avoid inhaling micro silica to prevent silicosis, a deadly disease of the lungs. In the middle of 2003, a product which could replace micro silica was developed having better characteristics incurring a lower cost and also fulfilling environment regulation of ISO-14001. Using tools of physics, chemistry and recent Nano technology revolutionary product cuore Nano silica was developed which had superior advantages in comparison with micro silica. A liter bottle of Nano silica was equivalent to a barrel full of micro silica, extra cement and super plasticizing admixtures. Compressive strengths of70 to 100 N/mm^2 have been reported at 28 days. . Nano-silica addition to cement based materials can also control the degradation of the fundamental C-S-H (calcium-silicate hydrate) reaction of concrete caused by calcium leaching in water as well as block water penetration and therefore lead to improvements in durability. High workability with reduced water/concrete levels, for example: 0.2.

1.2. Titanium dioxide

Nano titanium dioxide is divided into two crystal forms of rutile and anatase. It has high purity, an average particle size of less than 100nm, great transparency and excellent UV absorption. It also has high thermal and chemical stability.

The anatase crystal form is used for production of photo-catalysts. Under illumination, it can help break down hazardous gases and organic pollutants via photo-catalysis. The anatase form can also be used in the decomposition of automobile exhaust and sewage treatment.

The rutile crystal form excels at UV absorption, under the joint action of UV rays and oxygen, the Nano titanium dioxide has strong bactericidal powder. With its smaller particle size and high specific surface area, the rutile form provide a fine and smooth feel suitable for sunscreens and cosmetics. It is widely used in the production of cosmetics, sunscreen, and high-grade plastics.

1.3 Carbon Nanotubes

A carbon nanotube is a tube-shaped material, made of carbon, having a diameter measuring on the nano meter scale. A nano meter is one-billionth of a meter, or about 10,000 times smaller than a human hair. CNT are unique because the bonding between the atoms is very strong and the tubes can have extreme aspect ratios. Carbon nanotubes

are molecular-scale tubes of graphitic carbon with outstanding properties. They can be several millimeters in length and can have one "layer" or wall (single walled nanotube) or more than one wall (multi walled nanotube). Carbon nanotubes can be visualized as a modified form of graphite. Graphite is formed from many layers of carbon atoms that are bonded in a hexagonal pattern in fiat sheets, with weak bonds between the sheets and strong bonds within them. A CNT can be thought of as a sheet or sheets of graphite that have been rolled up into a tube structure. CNT can be single walled nanotubes (SWNT), as if a single sheet had been rolled up, or multiwall (MWNT), similar in appearance to a number of sheets rolled together.

1.4. Poly-carboxylates

Super plasticizer is also known as high rang water reducers, are chemical admixtures used where well dispersed particles suspension is required. The new generation of this kind of admixtures is represented by poly-carboxylate ether based super plasticizers (PCEs). With a relatively low dosage (0.15-0.30% by cement weight) they allow a water reduction up to 40%, due to their chemical structure which enables good particle dispersion.

2. Review of Literature

Pranay Lanjewar et al (2017) Nanotechnology is one of the most active research, Nano-Silica is used as a partial replacement for cement in the range of 1%, 1.5%, 2%, 3.5% and 4% for M_{25} mix. This study summarizes the influence of nano-silica on strength and durability of M_{25} grades of concrete with the used of nano-silica as a replacement of cement. The replacement of cement with nano-silica more than 3.5% results in the reduction of compressive strength of nano-concrete. From the experimental results, it can also be concluded that the permeability of concrete decreases with increase in the percentage of nano-silica up to 3.5 %.

Vasanthi et al (2017) have shown that concrete containing nano particles has demonstrated increased strength, durability and reduction of pores in the concrete due to the pore filling properties of the nano materials. The nano materials are useful to improve the life of the building. The use of large quantity of cement produces increasing CO2 emissions. Nano Silica produces high compressive strength concrete. It also provides high workability with reduced water cement ratio.

Sakthivel et al (2017) The influence of Nano-Silica on various properties of concrete is obtained by replacing the cement with various percentages of Nano-Silica and natural hybrid fibres. Nano-Silica is used as a partial replacement for cement in the range of 2%, 2.5%, 3%, 3.5%, 4% and hybrid fibre (coir fiber & human hair) of percentage 0.5%, 1%, 1.5%, 2% and 2.5% for M25 mix. Specimens are casted using Nano-Silica concrete. Laboratory tests were conducted to determine the strength of Nano-Silica concrete at the age of 28 days. The replacement of cement with Nano-Silica results in higher strength and reduction in the permeability than the controlled concrete. The replacement of cement with Nano-Silica more than 3% results in the reduction of various properties of Nano-Silica concrete.

Namdev BapuRajguru et al (2017) This paper shows the partial replacement of cement with the Nano silica with different dosses like 1%, 1.5%, and 2% by weight and increase the strength property of concrete and also shows that the comparative study between the concrete without addition of Nano silica and with addition of Nano silica. The result of this paper gives the increase in compressive strength of concrete by the application of Nano silica Average percentage increase in strength of concrete after 3 days, 7 days, and 28s days is 10.3%, 15%, and 19.43% with respect to dosses.

Rahini et al (2017) This study concern with the use of titanium dioxide(TiO_2) to increase the strength of concrete. An experimental investigation has been carried out by replacing the cement with titanium dioxide(TiO_2) of 0.5%, 1%, 1.5% by water ratio. This test conducted on it shows a considerable increase in early age compressive strength and also improves the overall compressive strength of concrete. The strength increase was observed with the increase in the percentage of nano silica.

Namdev Rajguru et al (2017) This paper shows that the partial replacement of cement by Nano silica powder (1%, 1.5%, 2%) by the weight of cement. After that replacement to do the comparative study of compressive strength of concrete with addition of Nano silica and without addition of Nano silica. Nano silica is suitable to reduce the environmental pollution by reduction of CO_2 emission in atmosphere. This paper also shows that improvement in permeability of concrete.

Ramachandran et al (2017) In this paper the behaviour of RC slab structures by using Natural hybrid Fibre (coir and hair) and Nano silica reinforced Concrete (NHFRC) was determined. The various percentages of fibres ranging from 0.5% to 2.5% by weight of cement were used in the investigations and the various percentages of Nano silica ranging from 0.2% to 4.5% by weight of cement were used in the investigations. The test results shown that use of NHFRC with Nano silica improves loading performance of slab under static loading. It was found that slab with 1.5% NHFRC with 3% Nano silica slab specimen shows an increase of 73.33% in ultimate load and 56.97% in deflection when compared to that of control slab.

Balasundaram et al (2016) The influence of Nano-Silica on various properties of concrete is obtained by replacing the cement with various percentages of Nano-Silica. Nano-Silica is used as a partial replacement for cement in the range of 2.5%, 3%, and 3.5% for M25 mix. Specimens are casted using Nano-Silica concrete. Laboratory tests were conducted to determine the compressive strength, split

tensile and flexural strength of Nano-Silica concrete at the age of 7 and 28 days. Results indicate that the concrete, by using Nano-Silica powder, was able to increase its compressive strength. That the compressive strength of concrete initially increased up to 3% of Nano-Silica and with further increase in the Nano-Silica content the compressive strength of concrete decreases.

Rajkumar et al (2016) In this paper an attempt has been made to improve the strength characteristics of concrete with the addition of Nano-silica which not only acts as a filter to improve the microstructure but also as an activator to promote pozzolanic reaction there by resulting in the enhancement of the mechanical properties of the concrete mix. The replacement of nano silica range 1.5%of cement. The results obtained from water absorption test suggest that nS concrete is more durable than conventional concrete. The percentage increase in strength of nano silica concrete after 28 days was found out to be 35 MPa for compression and 45 MPa for tensile strength for M20 mix

Umesh Pendharkar et al (2016) In this reviews of recent developments and present state of the application of nano alumina, nano titanium dioxide, nano zinc oxide and nano-silica for sustainable development of concrete industry The cement was replaced by Nano-materials at various percentages (2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18% and 20%) for M20, M30, M40 and M50 grades. The replacement of Nano particles more than 3.5% the result reduced.

Arun Nishchal Guleria et al (2016) studied the effect of MS and NS in the concrete properties with their different percentages in the different grades of concrete. The strength of concrete with the varying percentage ratio of nano silica at 0, 1, 1.5, 2 & 2.5 percent (%) with the partial replacement of cement. The max, Increase in compressive strength with nano silica was at 10% both on 7^{th} and 28^{th} days. On 7^{th} day at 10% the strength was 38.7 MPa and 28^{th} day it was 58.5 MPa.

Mohamed et al (2016) The presented research aims to study the bond performance of concrete containing relatively high volume nano silica (up to 4.5%) exposed to corrosive conditions. Adding 4.5% nano silica in concrete increased the residual bond strength to reach 79% instead of 27% only as compared to control mix (0%) before the subjection of the corrosive environment. From the conducted study we can conclude that the Nano silica proved to be a significant pore blocker material.

Renu Tiwaret al (2016) The research mainly focusing on the use of nanomaterials in concrete. Further researchers are continuing to improve the durability and sustainability of concrete and have realized significant increment in mechanical properties of concrete by incorporating nano-silica. The review paper summarizes the effect of nano-silica addition compressive strength on concrete 2% NS reduces initial and final setting time and compressive strength increases by 22% and 18% at 3 days and 7 days

Mohammad Reza et al (2016) In this study, the effect of combined nanosilica (nS) and microsilica (mS) on sulfate resistance of Portland cement (PC) mortars was evaluated against all cement control mortars and mixtures with equivalent contents of only one form of silica. Silica contained mortars had 6% cement replacement of either nS, mS, or 3% of each. The mortars in this study were subjected to a 1.5-year period of full submersion sulfate attack in a 5% sodium sulfate ($Na2SO_4$) solution. The results most of the beneficial contribution from the cement replacement with the combination mixtures could be attributed to the mS proportion given that the combination mixtures' expansion performance was comparable to that of the 3% mS only mortars

Mainak Ghosal et al (2015) This paper deals with the fact that nanomaterials (like nano-SiO_2 & nano-TiO_2) when added in optimized proportions to a standard M-40 Grade concrete improves its both fresh and hardened properties (both short term & long term). The results simply corroborated the fact that for nano concrete the workability increased by more than 90% with respect to controlled M-40 Grade concrete. The compressive strength of nano concrete with nano-SiO_2 gave a strength gain of more than 24% at 28 days and more than 18% at 90 days while that of & nano-TiO_2 gave a strength gain of more than 9% at 28 days and more than 6% at 90 days all under ordinary curing conditions. However, under exposure to $MgSO_4$ &$MgCl_2$ the standard concrete specimens gave a greater crushing strength when compared with both the nano concretes.

Malek Mohammad Ranjbar et al (2015) investigated the hardened properties of HPC incorporating nanoTiO_2 (NT) and Fly Ash (FA). TiO_2 nanoparticles at the rates of 1, 2 and 3% and low-calcium fly ash at the rate of 30% of the binder by weight were considered. The durability performance was assessed by means of water absorption by capillarity, ultrasonic pulse velocity, chloride diffusion and resistance to sulphuric acid attack. the results showed significant improvement in the properties of the samples incorporating the replacement of cement with a combination of 1% TiO_2 nanoparticles and 30% FA.

Haininet al (2014) reviewed the use and performance of nano silica in porous concrete pavement and previous laboratory study on porous concrete pavement. To improve the strength of the porous concrete, various additives have been studied as a part of porous concrete mix and yet, the optimum condition to produce good porous concrete has still not been established. using the standard Proctor hammer (2.5 kg) and pneumatic press (70 kPa compaction effort).

Arkadeep Mitra et al (2014) studied ground and unground micro-silica with concrete in 5, 10 and 15% as a partial substitute to cement and result were compared with conventional concrete. Concrete specimens were cast in the laboratory and tested for compressive and tensile strength

at different age of concrete. The morphology of the ground and unground micro-silica for different time duration were studied using scanning electron microscope, more irregular shapes were observed after 6 hrs of grinding. Result was observed that the specimens cast with micro silica with 6hrs grinding and 5% of replacement of cement showed improvement in strength of 30%. Resistance to permeability was also higher in concrete specimens.

Esmaeili et al (2013) studied the effects of adding nano-silica particles on the compressive strength and water permeability of concrete and its comparison with that of micro silica. The effect of combination of nano silica and micro silica were also studied in this work, which resulted in an increase in compressive strength of concrete in comparison with other concrete specimens tested in this study. The XRD analysis showed that the $Ca(OH)_2$ amount of such samples is considerably less than that of the control sample.

Iyer et al concluded that nano-scale silica or nano silica is a material at level of individual atoms and molecules in the range of 0.1 to 100 nano meter (10-6 mm). Adding nano-scale silica fume into concrete mixes improves durability of concrete structures. Understand in that takes place in the cement particle at a nano-scale level can lead to improved industry standard for mixing and curing concrete. Material of nanotechnology product enables self-consolidating concrete (SCC) achieve consolidation without the need for vibration and to saving up 50% labour costs. The construction sector can benefit from this new construction material with ultra-high strength, ductility, and high durability, such as concrete. The research showed that2.5% - 10% percentage weight nano silica to cement's as partial cement substitution increases the mechanics and physics properties of concrete.

Georgene Geary et al studied the effect of multi-wall carbon nanotube (CNT) on strength characteristics and durability of concrete. Sonication process is carried out by adding MWCNT with surfactants (super plasticizers – poly-carboxylate 8H), 0.25% by weight of cement and also with water. 36 Specimens with MWCNTs of 0.015%, 0.03% and 0.045% of cement (by weight) were tested after 28 days of curing. Results show an increase in compressive and splitting-tensile strengths of the 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.

Reshma et al (2013) studied the combination of partial replacement of fly ash and Nano Silica in concrete and determined the compressive strength, split tensile strength, flexural strength and young's modulus of elasticity of M20 grade concrete and compared with controlled concrete. Cement is replaced by 20% and 30% of fly ash and Nano silica 1.5%, 3% and 4.5% by weight. From the tests conducted, it has been concluded that concrete prepared with 20% Fly ash and 3% Nano silica combination possess improved properties compared to controlled concrete.

Vijaya Sekhar Reddy et al (2013) concluded that Pozzalonic materials are widely used in concrete and mortars for various reasons, particularly for reducing the amount of cement required for making concrete and mortar which lead to a reduction in construction cost. In the new millennium, concrete incorporating self-curing agents will represent a new trend in the concrete construction. Curing of concrete plays a major role in developing the concrete microstructure and pore structure, and hence improves its durability and performance. Due to the high alkalinity of concrete it has always been susceptible to acid attack. Hence, in this investigation an attempt was made in order to know the behaviour of standard concrete of M40 grade specimens curing with acids such as HCL, Alkaline such as NaOH and sulphate solution $MgSO_4$ and $Na2SO_4$. In the last decade the use of Supplementary Cementing Materials (SCMs) has become an integral part of high strength and high performance concrete mix design. The addition of SCM to concrete reduces the heat of hydration and extends the service life in structures by improving both long term durability and strength. Some of the commonly used SCMs are Fly ash, Silica fume and Metakaoline. This paper presents results of the durability characteristic properties of M40 grade of with and without SCMs.

Yuvaraj et al (2012) reviewed about to reduce the carbon emission due to the cement manufacturing the fly ash is partially replaced in ordinary Portland cement and termed as Portland pozzolana cement (PPC) it not only reduces the environmental impact, improves the workability, corrosion strength and long term strength of concrete but this replacement of fly ash in the ordinary Portland cement deviating its strength consequently. Hence here we added Nano silica as an additive to fill up the deviation, the range of nano silica 2.5 %Corrosion resistance property of the nS added concrete is comparatively higher than ordinary fly ash concrete. Finally, the compressive strength of 28 days cured Nano concrete possess an incremental strength by 23% than the ordinary fly ash replaced concrete.

Partha Ghosh et al (2012) appreciated the effect of Na_2O and SiO_2 on apparent porosity and sorptivity of fly ash based geopolymer mortar. The study revealed that the apparent porosity and sorptivity as well as microstructure depended basically on alkali content and silica content. Strong alkali solutions are needed to dissolve fly ash during the process of geopolymerisation. There is no direct relationship between compressive strength and sorptivity. However, generally there is decrease in water sorptivity and water absorption with increase in compressive strength and bulk density.

Rupasinghe et al (2010) concluded about the most interesting research fields of recent time i.e. the study of reaction mechanism of nano embedment in cement composites. Cement composites prepared with river sand as per Indian standards with and without Nanoparticles

showed an increase of 31% in compressive strength at 7 days & 32% at 28 days & 59% at 90 days respectively. Similarly, Nano Carbon tube embedment showed a decrease of 16% at 7 days, 37% increase at 28 days, 14% increase at 90 days & 3% increase at 180 days when compared to ordinary controlled cement composite after dispersion in Super.

Flores et al (2008) discussed about nano science and technology which is a new field of emergence in materials science and engineering, which forms the basis for evolution of novel technological materials. Nano technology finds application in various fields of science and technology. A critical review of the literature on the influence of nano silica in concrete and its application for the development of sustainable materials in the construction industry and to study the pour filling effect and its pozzolanic activity with cement towards improvement of mechanical properties and durability aspects. Thus, there is a scope for development of crack free concrete towards sustainable construction.

3. Conclusions

From above literature study carried out, the following points about nano concrete are observed:

- The above papers show partial replacement Nano materials like nano silica which improves the strength of concrete
- The tests conducted on cubes, cylinders and prism Which shows compressive, split tensile and flexural strength increased.
- The effects of different ratios of Nano-Silica to cement content were well investigated, and the optimum ratio of 3% was reported.
- Resistance to permeability was also higher in concrete. Corrosion resistance property of the nS added concrete is comparatively higher than ordinary fly ash concrete.
- Concrete mixtures including fly ash show a higher mass loss after sulphuric acid attack exposure
- Workability of concrete decreases with the increase in the percentage of silica fume.
- The durability of nano concrete is more than the conventional concrete.
- Tension cracks were formed in the NHFRC beams with NS under the loaded area.
- It can also be concluded that the permeability of concrete decreases with the increase in the percentage of Nano-Silica up to 3% due to the effect of Nano-Silica filling the voids in concrete.
- The results obtained from water absorption test suggest that nS concrete is more durable than conventional concrete.
- The effects of different ratios of Nano-Silica to cement content were well investigated, and the optimum ratio of 3% was reported
- The addition of nanosilica Resistance to permeability was also higher in concrete.
- The use of large quantity of cement produces increasing CO2 emissions.
- From the tests conducted, it has been concluded that concrete prepared with 20% Fly ash and 3% Nano silica combination possess improved properties compared to controlled concrete.
- Corrosion resistance property of the nS added concrete is comparatively higher than ordinary fly ash concrete.

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