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Nano Concrete: A Review

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Abstract: **This review paper deals with the infused nanoparticles within a concrete known as Nanoconcrete, has been an unidustrialized area of research that is yet to be commercialized. These exorbitant materials are still in progress of having their prices reduced through different sustainable production to get their way into the concrete industry as sustainable, durable and economical material. This paper summarized the literature survey including different nano particles like carbon nanotubes, nano silica, nanographene oxide, nano titanium oxide, etc. The microstructural and physical changes, enhance the properties of concrete. The future scope of nanoconcrete is on beneficial side, including improvement in infrastructure reliability and longevity, durability, improved safety against natural hazards and vibrations, reduced lifecycle cost in operating and managing infrastructures, and reduced burdens on resources, energy and environment.**

Keywords: **nanomaterials, nanosilica, carbon nanotubes, nanographene oxide, nano titanium oxide.**

I. INTRODUCTION

Nanotechnology is science and engineering at the scale of atoms and molecules. It is the manipulation and use of materials and devices so tiny that nothing can be built any smaller. Nanomaterials are typically between 0.1 and 100 nanometres (nm) in size – with 1 nm being equivalent to one billionth of a metre (10^{-9} m). this is the scale at which the basic functions of the biological world operate – and materials of this size display unusual physical and chemical properties. These profound different properties are due to an increase in surface area compared to volume as particles get smaller.

The concept of nanotechnology was originally introduced by the famous physicist Richard Feynman in 1959, through his talk "There' s Plenty of Room at the Bottom ", which he delivered to an American Physical Society meeting at the California Institute of Technology. In the lecture, he discussed the possibility of using atoms as building particles to create nano sized products. The ideas put forward by Feynman passed unnoticed until 1974 when Norio Taniguchi introduced the word "nanotechnology" at the International Conference on Production Engineering. Taniguchi described the processes of creating semiconductor structures using various methods with nanometer precision. He introduced the "top-down" approach, which refers to the successive cutting or slicing of a bulk material to create nano sized particles. In 1986 Kim Eric Drexler developed the idea of nanotechnology and published a book titled "Engines of Creation: The Coming Era of Nanotechnology". In the book, he proposed the idea of a nanoscale assembler, which would have the capacity and ability to build the copies of itself and other things of distinctive complexity, known as molecular nanotechnology (MNT). Today, nanotechnology offers potential opportunities to create better materials with enhanced properties for use in various application areas.

According to an economic assessment, nanotechnology has a significant impact in the construction sector several applications have been developed for this specific sector to improve the durability and enhanced performance of construction components, energy efficiency and safety of the buildings, facilitating the ease of maintenance and to prove increased living comfort.

Through self-cleansing features have been possible to attain using micron sized coatings and surface treatments e.g. Teflon, polysilazane based coatings, etc. now this feature has become a marketing tool / motto for nanotechnology applications, especially for consumer markets like construction, textile, etc.

Nanoconcrete is a form of concrete that contains Portland cement particles that are no greater than 100 micrometre and particles of silica no greater than 500 micrometre, which fill voids that would otherwise occur in normal concrete, thereby substantially increasing the material's strength. It is also a product of high-energy mixing (HEM) of conventional cement, sand and water which is a bottom-up approach of nanotechnology.

The incorporation of ultra-fine particles into a Portland-cement paste within a concrete mixture in accordance with top-down approach of nanotechnology alters the concrete's material properties and performance by reducing the void space between the cement and aggregate in the cured concrete. This improves strength, durability, shrinkage and bonding to steel reinforcing bars.

To ensure the mixing is thorough enough to create nanoconcrete, the mixer must apply a total mixing power to the mixture of 30-600 watts per kilogram of the mix. This mixing must continue long enough to yield a net specific energy expended upon the mix of atleast 5000 joules per kilogram of the mix, and may be increased to 30-80 KJ per kilogram. A superplasticizer is then added to the activated mixture which can later be mixed with aggregates in a conventional concrete mixer. In the HEM process, the intense mixing of cement and water with or without sand in conditions of queasy laminar flow, Reynolds number 20-800 provides dissipation and absorption of energy by the mixture and increases shear stresses on the surface of cement particles. As a result, the temperature of the mixture increases by 20-25 and more degree Celsius. This intense mixing serves to deepen hydration process inside the cement particles. The nano-sized colloid Calcium Silicate Hydrate (C-S-H) formation increased several times compared with conventional mixing. Thus, the ordinary concrete transforms to nanoconcrete. The initial process of cement hydration with formation of colloidal globules about 5nm in diameter spreads into the entire volume cement-water matrix as the energy expended upon the mix. The liquid activated mixture can be used by itself for casting small architectural details and decorative items, or expanded with gas-forming admixture for making aerated HEM Nanoconcrete hardens in low and subzero temperature conditions because the liquid phase inside the nano-pores of C-S-H gel doesn't freeze at temperature from -8 to -42 degree Celsius. The increased volume of gel reduces capillarity in solid and porous materials.

Nanoparticles such as nano silica, nano clays, nano titanium oxide (TiO_2), nano iron (Fe_2O_3), nano alumina (Al_2O_3), copper oxide (CuO), zinc peroxide (ZnO_2) and zirconium dioxide (ZrO_2) are considered for the improvement of concrete properties. Nano silica additives can improved durability, segregation resistance and self-compacting capability of concrete.

Applications of nanofibers or nanoparticles lead to high-performance (HPC), ultra-high-performance (UHPC), self-levelling (SLC), self-healing and self-compacting concrete (SCC). Furthermore, some nanotechnology applications during cement production lead to the improvement of sustainable construction as well. The cement production process is responsible for a considerable amount of CO_2 emission to the environment. Additives such as belite, calcium sulfo-aluminate, and calcium alumina-ferrite can reduce the CO_2 emission of the production process.

II. LITERATURE REVIEW

B.B.Das (2014)[5] has explained about all the types of nanomaterials used for construction purposes such as carbon nanotubes, nanoclays, nanoflex, nanowires, nanoceramic coating, nanosilica, nanocrystalline materials, etc. The properties and applications have been highlighted so that the readers can get the brief overview of the nanomaterials, considering the design of sustainable and durable structures.

Karla P. Bautisla-Gutierrez (2019)[6] highlighted the change in physical and chemical properties of concrete. Addition of nanomaterials in cement-based materials bring out microstructural development. Nano siloca, nano-ferric oxide, nano-titanium oxide, nano-alumina and grapheme- based nanomaterials are explained through SEM images. Incorporating variable percentages of different nano-materials, microstructural changes are shown precisely. Different tests such as compressive strength tests and flexural strength tests are shown using different percentage content of nanomaterials. Comparative bar graphs are also represented. Few challenges have been discussed with some approximate needful way of development.

N. Yazdani has been created a focus on the carbon nanofibers (CNF). The history of CNF and method of synthesizing is being tracked. The basic physical properties of CNF is tabulated. The utilization of CNF and its first usage in cement mortar was 0.2% by weight of cement.

V. Sai. Kiran (2016)[1] has shown experimental method and compares the mechanical properties of nano concrete to that of high strength of concrete. The compressive strength test, split tensile strength test and bond strength test have done to show the differences of the mechanical properties. It has been found that the performance of nano concrete is much better than control concrete.

VishutoshBajpai (2018)[2] shows the studt regarding the effect of nanosilica on the compressive strength, workability and the microstructure of the hardened cement concrete. Upto 3% nanosilica is replaced showing maximum result on 2.5% replacement in compressive strength test and tensile strength test. It has been concluded that even a small amount of nanosilica particles can increase the strength of concrete.

Dr. B. Vidivelli (2018)[3] discuss about the physical, mechanical, thermal, electrical and electronics properties of single-wall carbon nanotibes (SWCNT) and multi-wall carbon nanotubes (MWCNT). It has been concluded that addition of small amounts of CNT can improve the mechanical properties of samples consisting of the main Portland cement phase and water. Oxidized multi-walled carbon nanotubes show the best improvements both in compressive strength and flexural strength compared to the sample without reinforcement.

Syed Nooruddin[4] incorporated 1%, 2%, 3% and 3.5% of nanosilica by weight of cement. Throught experiment it has been observed that the compressive strength of concrete initially increased upto 3% nanosilica and with further increase in the nanosilica content the compressive strength of content decreases. The permeability of concrete decreases with the increase in percentage of nanosilicaupto 3% due to the effect of nanosilica filling the voids in concrete. Use of nanosilica in the concrete reduces the CO_2 emission.

Maheswaran S. (2013)[7] discussed about the influence of nanosilica along with cement, cement mortars, concretes and supplementary cementitious materials. The changes in the microstructure of cement by pore filling effect of nanosilica in the concrete. Different journals are analysed and influence of nanosilica with different dosages are studied. It has been concluded that enhancement of concrete is observed in delay of microcrack development ,pore filling effects, reduction of CH leaching, rheological behavior of cement paste, heat of hydration, the pozzolonic activity, workability, strength and durability.

Hardik Bhatia (2014)[8] discussed about the methods of synthesis of nanomaterials by grafting in C-S-H composites and sol gel process. Different nanomaterials with their applications and newly introduced properties such as electrical conductivity, temperature, moisture, stress-sensing abilities, etc. are explained briefly. Even the future developments such as mechano chemistry and nano-catalyst can change the face of modern cement industry. Nanomaterials coating on the concrete proves to be self-cleansing and self-healing. It has been concluded with the next level development of cementitious based materials through nano-engineering.

Mani. M(2017)[9] carried out a review about nanomaterials such as nanosilica, nanotitanium dioxide and carbon nanotubes. Analysis of different papers and conclusion drawn shows the factual features of nanoconcrete.

R. Mugilvani(2019)[10] shows an experimental result of nanoconcrete. Cement is partially replaced with 20%, 30% and 50% of nanosilica, silica fume and nano titanium dioxide. From the experiment investigation it has been concluded that nanoconcrete gives high homogeneity, light weight, good cohesion and complete protection to radiation effect.

Heba A. Gamal(2021)[11] analyse the efficiency of CNTs. They used 15% of nano clay and 0.01%, 0.02% and 0.04% of CNTs by weight with the mix. Different tests are carried out such as air content, workability, compressive strength test, tensile strength test, flexural strength test, sorptivity, water penetration test, chloride penetration test, corrosion resistance and scanning electron microscope (SEM). The test result are concluded that increase in bond strength, slight increment in sorptivity, increment trend in chloride penetration, hybrid nanoparticles improve the corrosion resistance and enhancing the durability properties.

ParamitaMondal(2010)[12] shows the nanoidentation experiment with data analysis. Silica fume is replaced by 6% and 18% by weight. From this experiment, unhydrated cement particles were found to have higher modulus than their products of hydration. Nanosilica increased the amount of high stiffness C-S-H gel significantly. Volume fraction of high stiffness C-S-H was high in 185 of nanosilica. Even it is more resistant to calcium leaching.

Abhinayaa (2014)[13] investigated and understood that the increasing the proportions of functionalized MWCNT into concrete increases the compressive strength. In fact the compressive strength of the concrete with a proportion of 0.045% of functionalized MWCNT increases by 26.69%. the split tensile strength increased by 66.3% for 0.045% of MWCNT. With increase in MWCNT, the rate of increase of the tensile strength is greater than that of the rate of increase of the compressive strength.

K. Habermehl C wirzen (2008)[14] found that the increase in the compressive strength is nearly 38% to 50% even with only a small addition of the MWCNTs, namely 0.045-0.15% of the cement weight. Highest increase in the compressive strength was nearly 50% in cement paste incorporating only 0.045% of the polyacrylic acid polymer-treated MWCNTs.

Rafat Siddique (2014) stated that the compressive strength of plain concrete and MWCNTs reinforced mortar increased as 150%, 170% and 120% respectively at 7, 14 and 28 days.

Li W(2013)[15] examined the properties of ultra-high-performance concrete, which is obtained with particles of nano-limestone and nano-silica. They used type I Portland cement and fly ash, and silica fume as binding agents. The compressive and tensile strength of concretes including nanomaterials were improved with respect to concretes without any additions. The microstructure with highest density values and mechanical strength was obtained with content levels of 1% nano-silica and 3% nano-limestone, respectively.

Lok Pratap Singh (2015)[16] investigated the influence of powdered and colloidal nano-silica (NS) on the mechanical properties of cement mortar. It has been concluded that non-agglomerated powdered-NS is effective in improving the properties. Powdered-NS due to higher pozzolanic reactivity reduced CH content upto 68% while colloidal-NS reduced to 57% at 28days of hydration. For durability assessment, chloride ingress was also monitored in cement mortar with powdered-NS, colloidal-NS and SF.

WijdanDeyaa (2017)[17] deals with the impact of Nano-concrete on contemporary architecture explaining about the nano-concrete mixes different from the ordinary mixes of concrete, the applications in the buildings and its effect.

SudiptaNaskar (2016)[18] has taken up an experimental program on low calcium fly-ash based M25 grade geopolymer concrete having 16 (M) concentration of activator liquid. Different percentage of nano materials viz. nano silica, carbon nanotube, titanium di-oxide were also used to investigate the effect of nano materials on geopolymer concrete. Geopolymer concrete with 1% of titanium di-oxide shows appreciable improvement in compressive strength. pH maintained almost same in all cases.

R. Vetrivel aims to highlight the most important and novel studies of the mechanical behavior and applications of carbon nanotubes reinforced composites. The carbon nanotubes play a vital role due to their better structural and functional properties and it has a broad range of applications when it is reinforced with metal and polymer matrix composites. It is used as a potential candidate to be incorporated into marine current turbines and it is also aims to act as a starting point to connect the research areas.

Coppola (2011)[19] investigated about cement pastes reinforced with MWNTs are smart materials with piezoresistivity properties. MWNTs were dispersed in a surfactant (Sodium Linear Alkyl Benzene Sulphonate – LAS), and then mixed with cement and a defoamer (tributyl phosphate) to decrease the air bubble in MWNT filled cement-based composites. These findings seems to indicate that self-sensing CNTs/cement composites can be produced. These smart materials (Concrete with CNT) have great potential and they could be used in the next future in concrete field for practical applications to monitor stress level of reinforced concrete elements subjected to static, dynamic and impact loads.

Su-Tae Kang investigated the effects of acid-treated MWCNTs on the workability, compressive and tensile strength, porosity and microstructure of CNT/cement composites. While workability decreased with acid treatment of CNTs, compressive and tensile strength improved significantly. Strength was also enhanced by using acid-treated CNTs alone, compared to using a surfactant with acid-treated CNTs. MIP analysis revealed that the porosity decreases from using acid-treated CNTs and that using acid-treated CNTs without a surfactant was more effective in reducing the size of micropores. A SEM analysis revealed improved CNT dispersion and dense hydration products in cement composites containing acid-treated CNTs.

TanzirManzur[20] has done a parametric experimental investigation to determine optimum mix dosage of CNT for cement mortar. Different dosage rates of surface treated MWCNTs, water-cement ratios and plasticizers amounts were investigated through compressive and flexural strength determination. A mixing technique was proposed to address the issues related to dispersion of nanotubes within cement matrix. Both enhances the strength compared to control samples with no MWCNTs.

III. SCOPE OF NANOCONCRETE

A. SCOPE

- If Portland cement can be formulated with nano-size cement particles, it will open up a large number of opportunities.
- A number of investigations have been carried out for developing smart concrete using carbon fibers.
- This will become a reality with nano-cement because nanocarbontubes are much more effective than carbon fibers. The thickness of the composite can be reduced to microns and hence flexibility and smart cement composite can be manufactured.

B. ADVANTAGE

- Low maintenance.
- Reduces the thermal transfer rate.
- Increasing the sound absorption of acoustic absorber.
- Improve segregation resistance.
- Fix micro- cracking.
- Cessation of contamination caused by micro silica solid particles.
- Concrete with good workability.
- Cessation of super plasticizing utilization.

C. DISADVANTAGE

- Required a lot of energy.
- Nanotubes might cause a lung problem.
- Research is in it's early stage yet.

IV. CONCLUSION

As in latest industrial development, nanotechnology infiltrating in the field of civil engineering provides impetus for developing high-performance and smart/multifunctional concrete. To restructure or modify material structure units in nano scale via interpreting material genetic code and drawing the blueprint of nano-scale properties provides new theory and method to develop high-performance, durable and environmental friendly concrete. The utilization of nanotechnology helps promote the understanding of concrete behavior, manipulate and design concrete performance, lower the concrete production and ecological cost, extend the service life of engineering infrastructures and reduce the relative demand of concrete. It is of profound significance to guide the sustainable development and application of concrete material and infrastructures.

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