Application of Nanotechnology in Concrete

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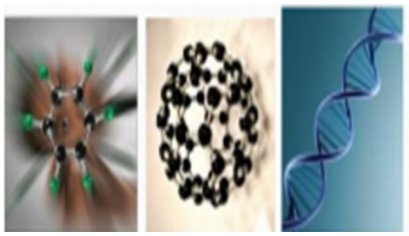
Abstract
In this article, use of nanotechnology in building materials on behalf of a range of civil engineering mechanism is discussed. In view of the fact that the use of nanotechnology controls the topic at the minute level, the properties of matter are sincerely affected. Strength, durability and other properties of materials are dramatically affected under a scale of nano meter(10-9m).This article as well reveals how the use of nano technology makes concrete more stronger, durable and more easily placed. Different types of nano materials used are discussed with its wide applications. The properties like self-sensing, self- rehabilitation, self-structural health monitoring, self-vibration damping, self-cleaning and self-healing are studied. Following this the analysis were carried out in ductile structural composites along with its improved properties, low repairs coatings, better properties of cementitious materials, reduction of the thermal transfer rate of fire retardant and insulation, various nanosensors, smart materials, intellectual construction technology.
Key words- civil engineering, Nanotechnology

1 INTRODUCTION

The American Physicist, Richards P.Feeynman 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, and the properties of material affects considerably. A billionth of a meter corresponds to a single nanometer. It concerns with particles ranging between 1 to 100 nanometer in size.

1 Nanometer (nm) = 1 X 10^{-9} 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.

2 NANO TECHNOLOGIES IN CIVIL ENGINEERING-

- To enhance properties of matters used in construction.
- To reduce cost of constructing structures.
- To reduce energy consumption for maintenance of structures.
- To satisfy the general aspect of people i.e. of quality, control and reliability.

2.1 Need of Nanotechnology In Construction

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 the vision of civil engineering. Many disciplines of 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, air cleaners, nano sized sensors, solar cells, ultra-thin strong-conductive wafers etc. this article introduces, in brief, the areas of application of this technology in civil engineering and the science & technology behind the improved performance.

2.2 Nano Materials Use in Practice

Carbon Nano Tubes (CNT)
Nano-silica(SiO2)

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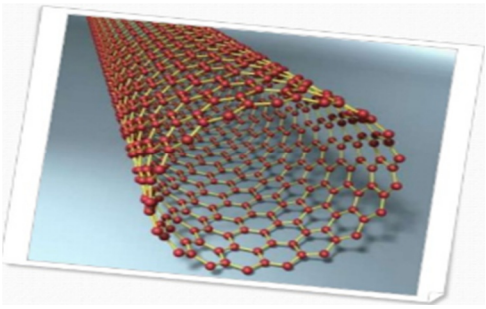

Titanium oxide(TiO2)
Vanadium Nano particles
Molybdenum Nano Particle
Copper Nano particle

Carbon nano tube(CNT)

They are cylindrical with nanometer diameter.
They can be several millimeters in length.
They have 5 times the young's modulus and 8 times (theoretically 100 times) the strength of steel whilst being 1/6th the density.

Thermal conduction is also very high along the tube axis.

Titanium dioxide (TiO2)

Titanium dioxide is a widely used white pigment.It can oxidize oxygen or organic materials, and so added to paints, cements, windows, tiles, or other products for sterilizing, deodorizing and anti-fouling properties.When incorporated into outdoor building materials can substantially reduce concentrations of airborne pollutants. Additionally, as TiO2 is exposed to UV light, it becomes increasingly hydrophilic, thus it can be used for anti-fogging coatings or self-cleaning windows.

Introduction

As people involved in construction, we are very familiar with the concept of getting raw materials, bringing them together in an organized way and then putting them together into a recognizable form. The finished product is a passive machine. It works and slowly decays as it is used and abused by the environment and the owners of the project. Construction then is definitely not a new science or technology and yet it has undergone great changes over its history.

In the same vein, nanotechnology is not a new science and it is not a new technology either. It is rather an extension of the sciences and technologies that have already been in development for many years. The size of the particles is the critical factor. At the nanoscale (anything from one hundred or more down to a few nanometres, or 10-9 m) material properties are altered from that of larger scales. Another important aspect is that, as particles become nano-sized, the proportion of atoms on the surface increases relative to those inside and this leads to novel properties. It is these "nano-effects", however, that ultimately determine all the properties that we are familiar with at our "macro-scale" and this is where the power of nanotechnology comes in – if we can manipulate elements at the nanoscale we can affect the macro-properties and produce significantly new materials and processes.

Benefits of Nanotechnology –

Materials & Properties

Strength and Durability, Wear and Tear Resistance,Corrosion Resistance, Fire Resistance and Retardants Aesthetics

Economical

Life-Cycle and Maintenance, Cost Labour, Pricing and Profit Customer Satisfaction, Market Value and Brand Image

Sustainability

Energy Efficiency,Material Consumption ,Social and Ethical Benefits ,Reduced levels of several environmental pollutants, Potential for numerous LEED point credits

Application of Nanotechnology in various construction material

Steel-

Steel is one of the most important building materials used today. The major problem of using steel however, is dealing with " exhaustion is one of the significant issues that can lead to the structural failure of steel subject to cyclic loading," fatigue can occur at stresses that are lower than the yield stress of the steel and leads to a shortening of the steel's life. The best way to reduce the fatigue is to add copper nano particles to the steel. The copper nano particles can help reduce the unevenness in the surface of the steel, which in turn reduces the amount of stress risers. Since the steel now has less stress risers, fatigue cracking is limited as well. "The new steel can also be developed with higher corrosion-resistance and weld ability". Another steel-related issue that is resolved by nanotechnology is in the area of welding. Welding strength is an extremely important issue. The area affected by heat in a weld can be brittle and fail without warning at times. The addition of nano particles such as magnesium and calcium can help solve this issue by making "the heat affected zone grains finer in plate steel". Which leads to strong welds. Improved fire resistance can also be achieved through nanotechnology. This is frequently done through a coating however, where the coating is "produced by a spray-on-cementations process".

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Nanotechnology in wood-

Wood is also composed of nanotubes or "nanofibrils", lignocelluloses are twice as strong as steel.Nanofibrils would lead to a new paradigm in sustainable construction.Functionality onto lignocelluloses surfaces at the nanoscale could open new opportunities for such things as self-sterilizing surfaces, internal self-repair, and electronic lignocelluloses devices. Currently, however, research in these areas appears limited. Researchers have developed a highly water repellent coating based on the actions of the lotus leaf as a result of the incorporation of silica and alumina Nanoparticle and hydrophobic polymers.

Nanotechnology In Glass-

Nanotechnology is used in Glass. Nano-Titanium dioxide is used to coat glass can give the glass a self-cleaning property. Titanium dioxide breaks down organic wastes and compounds, and because it also attracts water, the glass can attract rain water and use that to clean the dirt off of itself. Another use of nanotechnology in glass is to make it fire-protective. This can be done when a layer of silica nanoparticles is placed between glass panels. This layer turns into a fire-shield when heated. Pavement is yet one more area that can be improved by nanotechnology. Nano scale materials can be added to current roads to improve features such as the hardness of the road, the durability, and water and skid resistance. With the application of ZnO2, it is possible to make hydrophobic roads that cause quicker run-off and help prevent hydroplaning. Nanotechnology can even be used in water treatment. Some of the uses of nanotechnology in water treatment include " water purification separation and reactive media for water filtration," Nanotechnology also has the possibility to

help improve water quality, availability, and "viability of water resources, such as through the use of advanced filtration materials that enable greater water reuse, recycling, and desalinization" . Nanoparticles to "clean-up" contaminated areas, they can create new compounds that can have an impact on the environment.

Nanotechnology in Paint-

Nanotechnology is being applied to paints and insulating properties, produced by the addition of nano-sized cells, pores and particles, giving very limited paths for thermal conduction are currently available.

This type of paints is used, for corrosion protection under insulation since it is hydrophobic and repels water from the metal pipe and can also protest metal from salt water attack.

Nano Concrete

The most frequent and beneficial use of Nanotechnology in terms of civil engineering , is the use of it in concrete. Concrete " is a nano structured, multi phase, composite material that ages over time. It is composed of an amorphous phase, nanometer to micrometer size crystal and bound water." It is used in almost all construction from roads to bridges to buildings. Concrete can be modified in numerous ways;

One of which is to add mono particles to it. Most research done with mono particles is done with nano-silica, nano-titanium oxide and some studies involving nano-iron, nano-alumina and nano-clay. These " nano particles can act as nuclei for cement phases, further promoting cement hydration due to their high reactivity, as nanoreinforcement and as filler, densifying the micro structure and the ITZ thereby leading to reduced porosity." Each of the nano particle has a different on concrete. Nano-silica improve strength, resistance to water penetration, and helps control calcium leaching. Nano-titanium has been proven to assist in the " self cleaning of concrete and provides the additional benefit of helping to clean the environment ." nano-iron has shown to give concrete self-sensing capabilities and improve its " compressive and flexible strength ."

Concrete is one of the most common and widely used construction materials. Nanotechnology is widely used in studying its properties like hydration reaction, alkali silicate reaction (ASR) and fly ash reactivity Alkali silicate reaction is caused due to alkali content of cement and silica present in reactive aggregates like chert. The use of pozzolona in the concrete mix as a partial cement replacement can reduce the likelihood of ASR occurring as they reduce the alkalinity of a pore fluid. Fly ash not only improves concrete durability, strength and, importantly for sustainability, reduces the requirement for cement, however, the curing process of such concrete is slowed down due to the addition of fly ash and early stage strength is also low in comparison to normal concrete. Addition of Nano-silica leads to the densifying of the micro and nanostructure resulting in improved mechanical properties. With the addition of nano-SiO_2 part of the cement is replaced but the density and strength of the fly-ash concrete improves particularly in the early stages. For concrete containing large volume fly ash, at early age it can improve pore size distribution by filling the pores between large fly ash and cement particles at Nano scale. The dispersion/slurry of amorphous nano-SiO_2 is used to improve segregation resistance for self-compacting concrete . The addition of small amount of carbon nanotube (1%) by weight could increase both compressive and flexural strength . This can also improve the mechanical properties of

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samples consisting of the main portland cement phase and water. Oxidized multi-walled nanotubes (MWNT's) show the best improvements both in compressive strength (+ 25 N/mm^2) and flexural strength (+8 N/mm^2) compared to the reference samples without the reinforcement. Cracking is a major concern for many structures. University of Illinois Urbana-Champaign is working on healing polymers, which include a microencapsulated healing agent and a catalytic chemical trigger . When the microcapsules are broken by a crack, the healing agent is released into the crack and contact with the catalyst. The polymerization happens and bond the crack faces. The self-healing polymer could be especially applicable to fix the micro cracking in bridge piers and columns. But it requires costly epoxy injection. Research has shown that an anaerobic (one that does not require oxygen) microorganism incorporated into concrete mixing water results in a 25% increase in 28-day strength. The Shewanella microorganism was used at a concentration of 105 cells/ml and nanoscale observation revealed that there was a deposition of sand-cement matrix on its surface. This led to the growth of filler material within the pores of the cement sand matrix and resulted in increased strength. Finally, fibre wrapping of concrete is quite common today for increasing the strength of pre-existing concrete structural elements. An advancement in the procedure involves the use of a fibre sheet (matrix) containing nano-silica particles and hardeners. These nanoparticles penetrate and close small cracks on the concrete surface and, in strengthening applications, the matrices form a strong bond between the surface of the concrete and the fibre reinforcement.

It is evident from the Fig.1 that the SCCNFC (self consolidating concrete Nano fibre concrete) column failed at higher loads and with larger deflection than the SCRC (steel confined reinforced concrete) column. Additionally, the SCCNFC column was much stiffer than the SCRC column and exhibited higher energy dissipation. SCCNFC can also be used as a type of self- Structural Health Monitoring system.

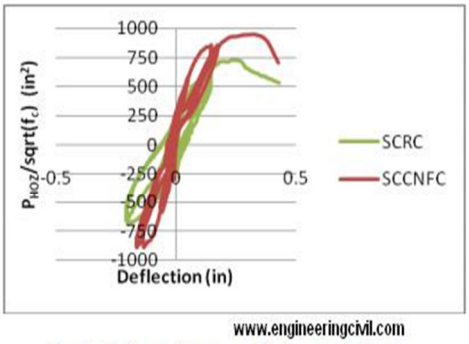


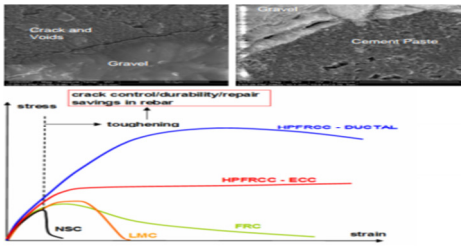
Fig. 1. Horizontal Force vs. Displacement Curves

Improved Performance

of Nano Concrete The given figures shows the nano concrete with less voids and cracks

Opportunities for Nano-concrete

Material (55% of Initial Cost)
Labour (45% of Initial Cost)
Decrease schedules by 20%



Properties

Tougher
Density (Weight!)
Low ductility, weak in tension
Durability (Cracking!)

Environmental load

CO 2 <10%
Smog eating, reduce pollution by 40%

Benefits of Nano Concrete-

Cessation of contamination caused by micro silica solid particles.
Lower cost per building site.
Concrete with high initial and final compressive and tensile strengths.
Concrete with good workability.
Cessation of super plasticizing utilization.
Cessation of silicosis risk.

Result-

Resistance to compression – 40 to 90MPa in 1 day.
Resistance to compression from 70 a 100 MPa (or more) in 28 days.
Produces high resistance even with low addition (1to 1.5% of the cements weights) and gives self compacting characteristics with higher proportions (2.5%).

3 FUTURE PROJECTION OF NANO TECHNOLOGY IN CONSTRUCTION

There is substantial money flowing into nano-related research from multinational corporations and venture capital investments . Many of the world's largest companies such as IBM, Intel, Motorola, Lucent, Boeing, Hitachi, etc. have all had significant Nano-related research projects going on, or launched their own nanotech initiatives. By 2015, the National Science Foundation estimates that nanotechnology will have a $1 trillion effect on the global economy. To achieve this market-sized prediction, industries will employ nearly two million workers towards advancements in many Nano materials, Nano structures, and Nano systems. The time needed for commercializing a product is long because industries may prefer monitoring development in research agencies and laboratories before making substantial investments. Furthermore, nanotechnology development, particularly in conjunction with biomimetic research will lead to truly revolutionary approaches to design and production of materials and structures with much improved efficiency, sustainability and adaptability to

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changingenvironment.

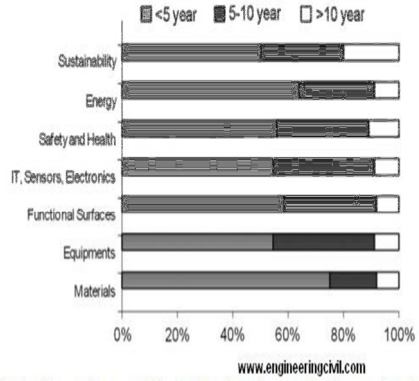

Fig. 4. Expected successful implementation of nanotechnology products in construction

4 CONCLUSION

Nanotechnology has the potential to be the key to a brand new world in the field of construction and building materials. Although replication of natural systems is one of the most promising areas of this technology, scientists are still trying to grasp their astonishing complexities. Nanotechnology can have a positive impact on our daily life and on the construction industry and provide better facilities that are essential for businesses and civilizations Furthermore, nanotechnology is a rapidly expanding area of research where novel properties of materials manufactured on nano-scale can be utilized for the benefit of construction infrastructure, and a number of promising developments exist that can potentially change the service life and life-cycle cost of construction infrastructure to make a new world in the future.

REFERENCES

Mann, S. (2006). "Nanotechnology and Construction," Nanoforum Report. www.nanoforum.org, May 30, 2008.
[2] Balaguru, P. N., "Nanotechnology and Concrete: Background, Opportunities and Challenges." Proceedings of the International Conference – Application of Technology in Concrete Design, Scotland, UK, p.113-122, 2005.
[3] ARI News (2005). "Nanotechnology in Construction – One of the Top Ten Answers to World's Biggest Problems." www.aggregateresearch.com/article.asp?id=6279, June 1, 2007.
[4] Goddard III, W.A., Brenner, D.W., Lyshevski, S.E. and Iafrate, G.J. "Properties of High-Volume Fly Ash Concrete Incorporating Nano-SiO_2." Cement and Concrete Research, vol.34, p.1043-1049, 2004.
[5] [8] Bigley C. and Greenwood P. "Using Silica to Control Bleed and Segregation in Self-Compacting Concrete." Concrete, vol. 37, no. 2, p.43-45, 2003.
[6] Tong, Z., Bischoff, M. and Nies, L. "Impact of Fullerene (C60) on a soil microbial community". B. Environ. Sci. Technol. 2007, 41, 2985-2991, 2007.
[7]MMFX Steel Corporation of America, http://www.~rarffxsteel.com/.
[8] NanoPore Incorporated, http://www.nanopore.com.
[9] Pilkington, http://www.activglass.com/.
[10] St. Gobain, http://www.saint-gobain.com/.
[11] BASF, http://www.basf.de.
[12] Castano, V.M. and Rodriguez, R, 'A nanotechnology approach to high performance anti-graffiti coatings'., London, Oct. 2003
[13] Baughman, R. H., Zakhidov, A. A., and de Heer W. (2002). "Carbon nanotubes— The route toward applications." Science, 297(5582), 787–792.
[14] BCC Research. (2008). "Nanotechnology reports and reviews." "http://www.bccresearch.com/nanotechnology/" (Mar. 5, 2008).
[15] Beatty, C. (2006). "Nanomodification of asphalt to lower construction temperatures." NSF Workshop on Nanotechnology, Material Science and Engineering, NationalScienceFoundation, Washington, DC.
[16] ASCE. (2005). "Report card for America's infrastructure. American society of civil engineers""http://www.asce.org"(Mar.8,2008).

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