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Nanotechnology in Construction & Civil Engineering

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Abstract
This paper introduces relevant nanotechnology developments to convey the new and inspire creativity in civil engineering. The recent researches on nano materials and nanotechnologies have highlighted the potential use of these materials in various fields such as medicine, construction, automobile industry, energy, telecommunications and informatics. It has been observed that the inclusion of nano particles would improve the toughness, shear, tensile and flexural strength of cement based materials. Further, it is observed that the better understanding and engineering of complex structure of cement-based material at nano level will definitely result in a new generation of construction materials with enhanced properties, viz., strength and durability.
In today's life, though utilization of cement based materials plays a vital role in the infrastructure development, it is polluting the environment by emitting CO_2. Based on this view, researchers have been pursuing to evolve new or alternate material towards a green and sustainable solution. This paper presents the possible role of nanotechnology for the construction applications.
Keywords— *Civil Engineering, Construction, Nanomaterials, Sustainability.*

INTRODUCTION

The construction industry we see today is the result of a long progression in science, technology, process and business. As the human being involved in construction science, we became very familiar with the concept of getting raw materials, bringing them together in a well defined and organized way and then putting them together into a recognizable form. The finished product is a passive machine that does not change or adapt to surrounding or environment. After construction it works and slowly disintegrates as it gets wear and tear during its use by the owner and also abused by the environment. It undergoes regular maintenance until it becomes obsolete or loses its durability. After this it is dismantled to make way for something new. This is the role of an engineer in the society for hundreds and thousands of years. Hence the construction is not a new science and yet it has undergone great changes over its history.

Similarly the nanotechnology also is not a new science or new technology. It is rather an extension of technology that has already been in development for many years. It was believed first introduced by 'Richard P. Feynman' in his lecture at the California Institute of Technology in 1959. However, the research on this topic has been very active only in recent two decades. This is because the development and application of nanotechnology are relying on the development of other related science and technology such as physics and chemistry that are commonly new to break through at that time.

A. Nanotechnology Basics

Nanotechnology is the use of very small particles of material either by themselves or by their manipulation to create new large scale materials. Nanotechnology is the re-engineering of materials by controlling the matter at the atomic level. The key in nanotechnology is the size of particles because the properties of materials are dramatically affected under a scale of nano meter [10^{-9} meter]. Further, as particles become nano-sized the proportion of atoms on the surface increases relative to those inside and this leads to novel properties.

'Nano', which comes from the Greek word ''For Dwarf'' indicates a billionth. One nanometer is a billionth of a meter. At this scale the laws of physics are slightly different e.g. gravity becomes unimportant, electrostatic forces take over and quantum effects get in. All these nano-properties actually affect the materials behavior at macro-scale and, from this point; the power of nanotechnology is emphasized: if the elements are proper manipulated at the nanoscale, the macro-properties are affected and new materials and processes can be developed Hence nanotechnology can be defined as –

"Nanotechnology is an enabling technology that allows us to develop materials with improved or totally new properties."

B. Importance of Nanotechnology in Construction

The construction business will inevitably be a beneficiary of the nanotechnology. Traditionally, nanotechnology has been concerned with developments in the fields of microelectronics, medicine and materials sciences. However, the potential for application of many of the developments in the nanotechnology field, in the area of construction engineering is growing. Nanotechnology can be used for design and construction processes in many areas since nanotechnology generated products having many unique characteristics. Following disciplines can be benefited from nanotechnology. For example-

1.Lighter structure;
2.Stronger structural composites eg. for bridges etc ;
3.Low maintenance coating;
4.Improving pipe joining materials and techniques;
5.Better properties of cementitious materials;
6.Reducing the thermal transfer rate of fire retardant and insulation;
7.Increasing the sound absorption of acoustic absorber;
8.Increasing the reflectivity of glass;
9.nono sized sensors;
10.water repellents etc.

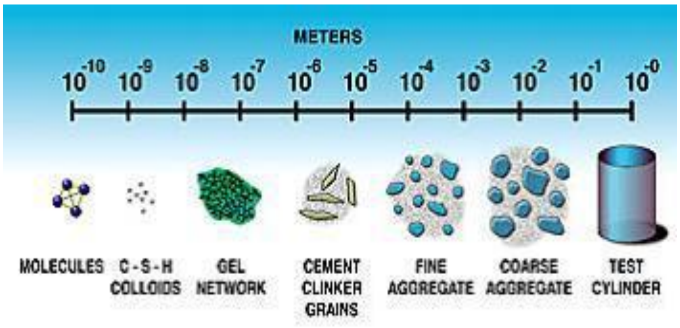
"Widespread use (of nanotechnology in construction) might be of course hindered (for) economic reasons but, in my opinion, currently, it is lack of knowledge which does not allow for the many small but possibly extremely useful improvements that nanotech might bring about."

APPLICATION OF NANOTECHNOLOGY IN CIVIL ENGINEERING

As described above the nanotechnology is of great importance in the construction and civil engineering point of view. Many disciplines of civil engineering including design and construction processes can be benefited from nanotechnology. There are large numbers of applications of nanotechnology in construction engineering / industry. Some of these applications are examined in detail below-

A. Nanotechnology in Concrete

Concrete utilizes nanotechnology because it contains Nano-particles as ingredients including Nano-water particles and Nano-air voids. However, to claim the use of nanotechnology, we should be able to control the amount and the locations of these Nano- ingredients inside the final products. The scales of various constituent materials of concrete are shown in Figure. If we can create chemical or mechanical tools to control Nano-scale pores and the placement of calcium-silicate hydration products then concrete becomes a product of nanotechnology.



Need of Nanotechnology in Concrete

The mechanical behavior of concrete materials depends on structural elements and phenomena that occur on a micro and a Nano scale. As a result, nanotechnology can modify the molecular structure of concrete material to improve the material's bulk properties; improve significantly the mechanical performance, volume stability, durability, and sustainability of concrete; and have revolutionary effects, allowing the development of cost-effective, high-performance, and long- lasting products and processes for cement and concrete, within the ideals of sustainable development. In addition, Nano-engineering and the modification of concrete materials can lead to unprecedented uses of concrete materials, as well as new classifications of concrete, with extensive applications for the concrete infrastructure of transportation.

Concrete is one of the most common and widely used construction materials. Its properties have been well studied at macro or structural level without fully understanding the properties of the cementitious materials at the micro level. The rapid development of new experimental techniques makes it possible to study the properties of cementitious materials at micro/nano-scale. Research has been conducted to study the hydration process, alkali-silicate reaction (ASR), and fly ash reactivity using nanotechnology (Balaguru, 2005). The better understanding of the structure and behavior of concrete at micro/nano-scale could help to improve concrete properties and prevent the illness, such as ASR.

1. 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.

2. Silica (SiO2) is present in conventional concrete as part of the normal mix. However, one of the advancements made by the study of concrete at the nanoscale is that particle packing in concrete can be improved by using nano-silica which leads to a densifying of the micro and nanostructure resulting in improved mechanical properties. *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. Related to improved particle packing, high energy milling of ordinary portland cement (OPC) clinker and standard sand, produces a greater particle size diminution with respect to conventional OPC and, as a result, the compressive strength of the refined material is also 3 to 6 times higher (at different ages). The dispersion / slurry of amorphous nanosilica is used to improve segregation resistance for self-compacting concrete.

3. Another type of nano particle added to concrete to improve its properties is *Titanium Di Oxide (TiO_2).* TiO_2 is a white pigment and can be used as an excellent reflective coating. It is incorporated, as nano particles and it is added to paints, cements and windows for its sterilizing properties since TiO_2 breaks down organic pollutants, volatile organic compounds and bacterial membranes through powerful catalytic reactions. It can therefore reduce airborne pollutants when applied to outdoor surfaces. Additionally, it is hydrophilic and therefore gives self cleaning properties to surfaces to which it is applied. The process by which this occurs is that rain water is attracted to the surface and forms sheets which collect the pollutants and dirt particles previously broken down and washes them off. The resulting concrete, already used in projects around the world, has a white color that retains its whiteness very effectively unlike the stained buildings of the material's pioneering past.

4. Fiber wrapping of concrete is quite common today for increasing the strength of pre- existing concrete structural elements. Advancement in the procedure involves the use of *a fiber 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 fiber reinforcement. In the strengthening process pre-cut carbon tows (fibers) and sheets impregnated with the matrix are placed on the prepared concrete surface and bonded using grooved rollers. The ability of the samples to sustain load after cracking is greatly improved by the carbon tows and both the matrix and the interface are durable under wetting and drying and scaling (scraping) conditions. Additionally, there is no decrease in the maximum load capacity after repeated cycles of wetting and drying or scaling.

5. A further type of nanoparticle, which has remarkable properties, is the *Carbon Nano Tube (CNT)* and current research is being carried out to investigate the benefits of adding CNT's to concrete. The addition of small amounts (1% wt) of CNT's can improve the mechanical properties of 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. It is theorized the high defect concentration on the surface of the oxidized MWNTs could lead to a better linkage between the nanostructures and the binder thus improving the mechanical properties of the composite rather like the deformations on reinforcing bars.

However, two problems with the addition of carbon nanotubes to any material are the clumping together of the tubes and the lack of cohesion between them and the matrix bulk material. Due to the interaction between the graphene sheets of nanotubes, the tubes tend to aggregate to form bundles or "ropes" and the ropes can even be entangled with one another. To achieve uniform dispersion they must be disentangled. Furthermore, due to their graphitic nature, there is not a proper adhesion between the nanotube and the matrix causing what it is called sliding. However, when pre-dispersing the nanotubes with gum arabic an increase in the mechanical properties is achieved, above all in the case of single walled nanotubes (SWNT's). Additional work is needed in order to establish the optimum values of carbon nanotubes and dispersing agents in the mix design parameters.

6. 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* (Kuennen, 2004). 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.

Thus all the above nanomaterials can be used for improved and good quality of concrete.

B. *Nanotechnology in Structural Composites*

Steel has been widely available since the second industrial revolution in the late part of the 19th and early part of the 20th Century and has played a major part in the construction industry since that time. Its properties, such as strength, corrosion resistance, and weld ability, are very important for the design and construction. The construction industry can benefit from the application of nanotechnology to steel and some of the promising areas currently under investigation or even available today are explored in the following paragraphs.

1. Fatigue is a significant issue that can lead to the structural failure of steel subject to cyclic loading, such as in bridges or towers. This can happen at stresses significantly lower than the yield stress of the material and lead to a significant shortening of useful life of the structure. The current design philosophy entails one or more of three limiting measures: a design based on a dramatic reduction in the allowable stress, a shortened

allowable service life or the need for a regular inspection regime. This has a significant impact on the life-cycle costs of structures and limits the effective use of resources and it is therefore sustainability as well as a safety issue. Stress risers are responsible for initiating cracks from which fatigue failure results and research has shown that the addition of *copper nanoparticles* reduces the surface unevenness of steel which then limits the number of stress risers and hence fatigue cracking. Advancements in this technology would lead to increased safety, less need for monitoring and more efficient materials use in construction prone to fatigue issues.

2. Two relatively new products that are available today are Sandvik Nanoflex (produced by Sandvik Materials Technology) and MMFX2 steel (produced by MMFX Steel Corp). Both are corrosion resistant, but have different mechanical properties and are the result of different applications of nanotechnology.

(1) Sandvik Nanoflex^{TM} is new stainless steel with ultra-high strength, good formability, and a good surface finish developed by Sandvik Nanoflex Materials Technology. Due to its high performance, Sandvik Nanoflex^{TM} is suitable for application where requires lightweight and rigid designs. For certain applications, the components could be even thinner and lighter than that made from aluminum and titanium due to its ultra-high strength and modulus of elasticity. Its good corrosion and wear resistance can keep life-cycle costs low. Attractive or wear resistant surfaces can be achieved by various treatments (Sandvik Nanoflex Materials Technology).

Hence Sandvik Nanoflex has both the desirable qualities of a high Young's Modulus and high strength and it is also resistant to corrosion due to the presence of very hard nanometre-sized particles in the steel matrix.

(2) MMFX2 is nanostructure-modified steel, produced by MMFX Steel Corp. Compared with the conventional steel; it has a fundamentally different microstructure- a laminated lath structure resembling "plywood". This unique structure provides MMFX2 steel with amazing strength (three times stronger), ductility, toughness, and corrosion resistance. Due to the high cost, the stainless steel reinforcement in concrete structure is limited in high risk environments. The MMFX2 steel could be an alternative because it has the similar corrosion resistance to that of stainless steel, but at a much lower cost (MMFX Steel Corp.)

3. Carbon nano tubes are over 100 times stronger than steel and only one-sixth of the weight in addition to its high thermal and electrical conductivities. A CNT composite has recently been reported to be six times stronger than conventional carbon fiber composites. Additionally, unlike carbon fibers which fracture easily under compression, the nano tubes are much more flexible and can be compressed without fracturing. CNT composite reinforced structures have a 50-to150-fold increase in tensile strength, compared with conventional steel-reinforced structures.

C. Nanotechnology in Coatings

Coatings are routinely used as protective barriers against abrasion, chemical attack, hydro-thermal variations and to improve aesthetics. Currently, most of these coatings are in the micrometer range. New materials and techniques are being developed to develop nano-meter thick coatings that are durable and generate less heat due to reduced friction. Coatings could be self-cleaning and self-healing.

The coatings incorporating certain nano particles or nanolayers have been developed for certain purpose. It is one of the major applications of nanotechnology in construction. For example, TiO_2 is used to coat glazing because of its sterilizing and anti fouling properties. The TiO_2 will break down and disintegrate organic dirt through powerful catalytic reaction. Furthermore, it is hydrophilic, which allow the water to spread evenly over the surface and wash away dirt previously broken down. Other special coatings also have been developed, such as anti-graffiti, thermal control, energy sawing, and anti-reflection coating.

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 (R values are double those for insulating foam), are currently available. This type of paint is used, at present, for corrosion protection under insulation since it is hydrophobic and repels water from the metal pipe and can also protect metal from salt water attack.

Furthermore nano structured coatings can be used to selectively reflect and transmit light in different wavebands. Research is focusing on smart and responsive materials able to sense and adapt to surroundings and change their appearance, such as whose color changes as a function of temperature, and cladding which responds to heat and light to minimize energy use in buildings.

D. Nanotechnology in Wood

Carbon nano tubes (CNT's) are a new discovery, whereas wood is an ancient material which has been used since the dawn of civilization. However, perhaps not surprisingly given nature's evolutionary process, wood is also composed of nano tubes or "nano fibrils"; namely, lignocellulosic (woody tissue) elements which are twice as strong as nano fibrils would lead to a new paradigm in sustainable construction as both the production and use would be part of a renewable cycle. Some developers have speculated that building functionality onto lignocellulosic surfaces at the nano scale could open new opportunities for such things as self-sterilizing surfaces, internal self-repair, and electronic lignocellulosic devices. Due to its natural origins, wood is leading the way in cross-disciplinary research and modeling techniques. Firstly, BASF 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 nano particles and hydrophobic polymers. And, secondly, mechanical studies of bones have been adapted to model wood, for instance in the drying process.

In the broader sense, nanotechnology represents a major opportunity for the wood industry to develop new products, substantially reduce processing costs, and open new markets for bio-based materials.

E. Nanotechnology in Sensors-

Nanotechnology enabled sensors/devices also offer great potential for developing smart materials and structures which have 'self-sensing' and 'self-actuating' capability. The device used for air bags in cars is such an example. Nano and Micro electrical mechanical systems (NEMS & MEMS) sensors have been developed and used in construction to monitor and/or control the environment conditions (e.g. Temperature, moisture,smoke, noise, etc.) and the materials/structure performance (e.g. stress, strain, vibration, cracking, corrosion, etc) during the structure's life. Nano sensor ranges from 10 - 9m to 10 - 5 m which could be embedded into the structure during the construction process.Cyrano Sciences has developed electronic noses based on an array of different polymer nanometre-thin film sensors. Siemens and Yorkshire Water are developing autonomous, disposable chips with built-in chemical sensors to monitor water quality and send pollution alerts by radio. Smart aggregate, a low cost piezoceramic-based multi-functional device, has been applied to monitor early age concrete properties such as moisture, temperature, relative humidity and early age strength development. Also it can provide an early indication before a failure of the structure occurs.Nano-sensors have a great potential to be used in concrete structures for quality control and durability monitoring. for example-

To measure concrete density and viscosity,

To monitor concrete curing and

To measure shrinkage or temperature, moisture, chlorine concentration, pH, carbon dioxide, stresses, reinforcement corrosion or vibration).

F. Nanotechnology in Glass

The use of TiO_2 nano particles to glasses leads to so-called self cleaning technology. Due to the nano particles photo catalytic reactions, the organic pollutants, volatile organic compounds and bacterial membranes are decomposed. As well, TiO_2 being hydrophilic, his attraction to water forms drops which then wash off the dirt particles decomposed in the previous process. Nano-TiO_2 coatings can also be applied to building exteriors to prevent sticking of pollutants, and thus reduce a facility's maintenance costs.

Fire-protective glass is obtained using fumed silica (SiO_2) nano particles as a clear interlayer sandwiched between two glass panels which turns into a rigid and opaque fire shield when is heated.

G. Nanotechnology in Fire protection

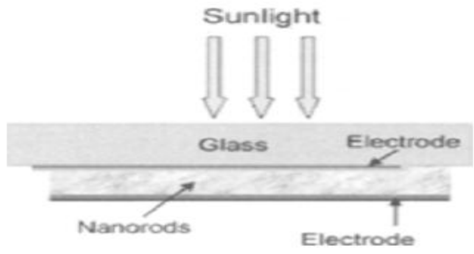
Fire resistance of steel structures is often provided by a coating produced by a spray-on cementitious process. Nano-cement (made of nano-sized particles) has the potential to create tough, durable, high temperature coatings. This is achieved by the mixing of carbon nano tubes with the cementious material to fabricate fiber composites that can inherit some of the outstanding properties of the nano tubes.

Polypropylene fibers also are being considered as a method of increasing fire resistance and this is a cheaper option than conventional insulation.

The use of processors in fire detection systems which are built into each detector head is fairly well established today. These improve reliability allowing better addressability and the ability to identify false alarms. The use of nanotechnology in the future through the development of nano-electromechanical systems (NEMS) could see whole buildings become networked detectors; as such devices are embedded either into elements or surfaces.

H. Nanotechnology in Solar Energy

The most promising application in the areas of energy and environment leading to the sustainable building is the development of fuel cells and photovoltaic. In the last few years, considerable efforts have been made to develop plastic solar cells in much simpler and cheaper to produce than that of conventional silicon semiconductor solar cells. Replacing conventional lamps with LEDs in the United States alone could generate energy savings of up to $100 billion by 2025 and reduce carbon emissions by 200 million tons per year.



NANOTECHNOLOGY IN SUSTAINABILITY AND THE ENVIRONMENT

Sustainability is defined as "the ability to provide for the needs of the world's current population without damaging the ability of future generations to provide for themselves". A key aspect of sustainability is conservation through the efficient use of the resources that are tied up in the already built environment.

Sustainability in the construction sector is mainly focused on the reduction of emissions, construction of energy efficient houses, etc. which could result in an increase in the use of nanotechnology driven innovations in this sector. Another key aspect of sustainability is the efficient use of energy. In the EU, over 40% of total energy produced is consumed by buildings. Insulation is an obvious solution to reduce some of this energy use; however, limited space for installation is a major problem for building renovation. Micro and nano porous aero gel materials are very good candidates for being core materials of vacuum insulation panels but they are sensitive to moisture. This risk is not acceptable for high performance thermal insulation and the next challenge is to develop a totally airtight wrapping, taking into account the foil and the welding. As a possible remedy, work by Aspen Aero gels has produced an ultra-thin wall insulation which uses a nanoporous aerogel structure which is hydrophobic and repels water so it is mould free. Another intriguing application of aerogels is silica based products for transparent insulation, which leads to the possibility of super-insulating windows. Micro or Nano Electomechanical Systems (MEMS or NEMS) also offer the possibility of monitoring and controlling the internal environment of buildings (through a potentially integrated network).

This could lead to energy savings much in the way that current motion detectors switch on light only when needed.

Sustainability and environmental concerns are closely linked and clean water is a key sustainable resource. Clean water has been one of the great leaps forward in public health provided by civil engineering and nanotechnology is being used to further this advance. In particular, iron nanoparticles, which have a high surface area and high reactivity, are being used to transform and detoxify chlorinated hydrocarbons (some of which are carcinogens) in groundwater. These nano-materials also have the potential to transform heavy metals such as soluble lead and mercury to insoluble forms, thus limiting their transport and contamination. In addition, dendrimers (a regularly branched molecule which resembles a nano "sponge") are capable of enhancing environmental clean-up as they can trap metal ions in their "pores", which can be subsequently filtered out of the water by ultra-filtration. In addition, nano-sized filters for water treatment have been produced which could possibly be applied to geo-environmental remediation though barriers and cut-off walls. These filters can work on both metallic and organic contaminant ions because they have a charged membrane and both the Steric (physical filtration based on its size of openings) and Donnan (filtration based on electrical charge) effects are exploited to filter and collect unwanted contaminants from the system.

Environment

A nanomaterial life cycle assessment—including manufacturing, transport, product use, recycling, and

disposal into the waste stream—is necessary to understand how various statutory systems apply and where regulatory gaps exist. Full lifecycle environmental, health and safety effects must be assessed prior to commercialization.

Once loose in nature, manufactured nanomaterials represent an unprecedented class of manufactured pollutants. Potentially damaging environmental impacts can be expected to stem from the novel nature of manufactured nanomaterials, including mobility and persistence in soil, water and air, bioaccumulation, and unanticipated interactions with chemical and biological materials. The limited number of existing studies has raised red flags, such as exposure to high levels of nanoscale aluminum stunting root growth in five commercial crop species, byproducts associated with the manufacture of single-walled carbon nanotubes causing increased mortality and delayed development of a small estuarine crustacean, and damage to beneficial microorganisms from nanosilver. The U.K. Royal Society has recommended that, "the release of nanoparticles and nanotubes in the environment be avoided as far as possible" and that, "factories and research laboratories treat manufactured nanoparticles and nanotubes as hazardous, and seek to reduce or remove them from waste streams." Potential environmental risks remain unidentified due to the failure to prioritize environmental impact research and the paucity of funding currently allocated for risk-relevant research Government funding of environmental, health and safety research must be increased dramatically and a strategic risk research plan delineated.

Nanomaterials create immense difficulties for the application of existing environmental protection regimes. Agencies lack cost-effective tools and mechanisms to detect, monitor, measure, and control manufactured nanomaterials, let alone the means to remove them from the environment. Industry shields even the scant data provided to government from public view by claims of confidential business information. The risk assessments, oversight triggers, toxicity parameters, and threshold minimums used by environmental laws in many countries, including the U.S. and E.U., are designed for bulk (non-nano) material toxicity parameters. The metrics used in existing laws, such as a relationship between mass and exposure, are insufficient for nanomaterials. Existing laws lack lifecycle analyses and fail to address existing regulatory gaps. Environmentally sustainable management of nanomaterials must address and remedy these failings.

1. Commitment to a continual improvement process in environmental management.
2. Selective raw material supply.
3. Evaluation of environmental impacts of Nano products, operations and facilities, with a commitment to minimize impacts and restore properties affected by our operations.
4. Improvement of employee environmental performance through detailed policies and procedures, training, and recognition of excellence.
5. Efficient use of natural resources to minimize waste generation through efforts that include recycling, innovation, and prevention of pollution.
6. Measurement of environmental performance through auditing with employee accountability and reporting to senior management.
7. Integration of environmental responsibilities and considerations into daily operations and business decision-making processes.
8. Commitment to emergency preparedness and response in order to minimize any potential environmental impacts resulting from day-to-day operations.

DRIVERS AND BARRIERS TO INNOVATION IN THE CONSTRUCTION SECTOR

The construction sector is one of the most traditional and cost oriented industries which make uptake of innovation and therefore making investments for novelties very difficult. As long as there are not clear / distinct benefits of new materials at a reasonable cost stakeholders of construction industry are reluctant to change the materials and the way they are working. Even though they do bring new features to the products at the present use of nano enhanced materials do not lead to a significant change in the constructions for constructors to uptake these new materials. Accordingly, penetration of nanotechnology applications to construction sector has been very small. However, construction sector has to adopt technological novelties and accordingly meet the needs of changing lifestyles, environment and socio-economic needs like global warming, energy resources' scarcity and increased cost, ageing population, migration, increase in population density, change in working habits, demand for more functional and comfortable living spaces, etc.

Drivers-

Emphasizing the need on innovation in the construction sector Regulatory bodies are taking measures to change the present focus of constructors from 'cost' to sustainability. The main drivers for innovation in construction sector are:

1. Regulations.
2. Sustainability.
3. Cleaner processing technologies.
4. Longer service life and reduced maintenance expenditure.
5. Use of less type and amount of material for the same functionality.
6. Ease of maintenance of construction components and therefore constructions.
7. Easier handling of construction materials at the construction site due to lightening of materials. 8. Easier transportation of construction materials leading to less consumption of resources and therefore, final cost.
9. Replacement of existing materials with new materials.
10. Changing life styles.
11. Multi-functionality.
12. Having more reliable and sensitive testing tools which would help engineers detect the failures of construction components earlier and predict the lifetime of structures more precisely is an important driver for investing in nanotechnology to ensure the safety of construction components.

Barriers-

In construction sector one of the main inconveniences for the implementation of technological novelties including nanotechnology applications is cost. Construction is a cost driven sector and despite the long-term benefits that could be obtained from the use of products including nanotechnology, the initial investment (higher than it is at the moment) remains a major issue for constructors. In some cases big construction companies could afford the high prices for investments, however this is not the case for small companies which are reluctant to change the way they are used to work.

Another important barrier, for now, is the lack of availability of good quality nano materials in large volumes. Moreover, uncertainty about long-term reliability of new nano enhanced functionalities andproperties of these new construction materials, is a barrier discouraging investment.

Apart from abovementioned barriers, scepticism of consumers / end-users about benefits of nanotechnology and also safety issues are other factors which slow down the adoption of nano materials in the sector. Surveys conducted have shown that end-users have concerns about safety issues and real benefits of "nano" products". To overcome this scepticism large companies supplying materials for the construction sector (cement, glass, paint, etc.) are carrying marketing campaigns promoting the use of these "new" materials with improved properties.

In addition to end-user scepticism, lack of awareness of architects about new materials is another barrier to overcome for widespread use of new materials in the construction sector. This study also showed that fragmentation of the construction industry and the corresponding slow pace of the information flow continues to be a big barrier for market entry of all new products and technologies.

FUTURE CHALLENGE AND DIRECTION

The application of nanotechnology in construction presents a myriad of opportunities and challenges. The use of micro nano materials (MNMs) in the construction industry should be considered not only for enhancing material properties and functions but also in the context of energy conservation. It is important to be realistic and identify and plan for the limitations and challenges inherent in this process. In this section a short summary of selected challenges and limitations affecting application of nanotechnology in construction engineering are provided. The following main challenges and limitations can be defined:

A. Cost

The costs of most nanotechnology materials and equipment are relatively high. This is due to the novelty of the technology and the complexity of the equipment used for preparation and characterization of the materials. However, costs have been shown to decrease over time and the expectations are that, as manufacturing technologies improve, these costs may further decrease. Whether the expected decreases will render the materials as run-of-the-mill construction engineering materials will have to be seen, and depends largely on the benefits rendered through the application of these materials. Current opinion is that in special cases, the materials will enable unique solutions to complicated problems that cause them to be cost effective, which will lead to large scale application of these specific technologies. In other cases the traditional methods for treating the problem may still remain the most cost effective. It is the challenge to the construction engineer to solve real world transportation infrastructure problems and provide a facility to the general public at a reasonable cost.

B. Health

Nanotechnology based construction products might be harmful to health. For example, the nanotubes might cause a lung problem to construction workers. In other words, it creates an environmental challenge to the construction industry as well.

C. Fabrication

Current efforts in the field of nanotechnology are focused on the fabrication, characterization and use of these materials on a nano scale domain. This leads to most of the development work focusing on very small quantities of material that is typically far removed from the type of quantities required for typical construction infrastructure. One of the potential solutions to this is to focus on the nano materials to act as catalyst, thereby reducing the amount of nano material required substantially. Another viewpoint is that for many applications, the material does not necessarily have to be used on a nano scale to obtain a major improvement in benefits. This would be the case with reduction of the dimensions of cement, where a substantial improvement in strength can already be obtained through the large scale milling of the cement to a finer form than the traditional form. Although the cement may not be purely a nano material as yet, the benefits obtained would already be substantial.

D. Environment

The effect of various nanomaterials on the natural environment is hotly debated in nanotechnology and environmental research. Various ongoing investigations focus on the uncertainty regarding the potential effects of materials that exist on the nanoscale with properties that are different than when using the material on a micro or macro scale. Some work in this regard shows that the potential effects may be minimal. As constructed infrastructure are provided in the natural environment, all materials used in the construction and maintenance of these facilities need to be compatible to the natural environment and their effects on the natural environment should not be negative. Typical potential problems in this regard include leaching of materials into groundwater, release of materials into airways through the generation of dust and exposure to potentially harmful materials during construction and maintenance operations. The nanotechnolgy becomes a double-edge sword to the construction industry. More research and practice efforts are needed with smart design and planning, construction projects can be made sustainable and therefore save energy, reduce resource usage, and avoid damages to environment.

CONCLUSIONS

Nanotechnology is disruptive and offers the possibility of great advances whereas conventional approaches, at best, offer only incremental improvements. Nanotechnology is not exactly a new technology, rather it is an extrapolation of current ones to a new scale and at that scale the conventional tools and rules no longer apply. Nanotechnology is therefore the opposite of the traditional top-down process of construction, or indeed any production technique, and it offers the ability to work from the "bottom" of materials design to the "top" of the built environment. There are three main issues that might prevent the widespread use of the nanotechnology

(1) Lack of vision to identify those aspects that could be changed through its use,
(2) Lack of skilled personnel and
(3) Level of investment"

Research in nanotechnology that is related to construction is still in its infancy; however, this paper has demonstrated the main benefits and barriers that allow the effect of nanotechnology on construction to be defined.

REFERENCES

1. 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.
2. Chong, K.P. "Nanoscience and Engineering in Mechanics and Materials", J. of Physics & Chemistry of Solids, 65, 2004, 1501-1506.
3. Chong, K.P. "Research and Challenges in Nanomechanics" 90- minute Nanotechnology Webcast, ASME, 2002; archived in www.asme.org/nanowebcast
4. ARI News (2005). "Nanotechnology in Construction – One of the Top Ten Answers to World's Biggest Problems. www.aggregateresearch.com/article.asp?id= 62 79

5. Mann, S. (2006). “Nanotechnology and Construction, Nanoforum Report. www.nanoforum.org.
6. Li, G., “Properties of High-Volume Fly Ash Concrete Incorporating Nano-SiO2.”Cement and Concrete Research, vol.34, p.1043-1049, 2004.
7. M. Aui, and C.P. Huang, the Chemistry and Physics of Nano-Cement. Report submitted to NSF-REU, University of Delaware, 2006.
8. Sandvik Nanoflex Materials Technology. http://www.smt.sandvik.com/nanoflex
9. MMFX Steel Corp. http://www.mmfx.com/products .shtml
10. Song, Gl, Gu, H. and Mo, Y. “Smart Aggregates: Multi-Functional Sensors for Concrete Structures-a Tutorial and a review.” Smart Mater. Struct. vol.17, 2008.
11. Dhir, R. K., Newlands, M. D., and Csetenyi, L. J. “Introduction.” Proceedings of the International Conference – Application of Technology in Concrete Design, p. IV, 2005, Scotland, UK.
12. BCC Research. (2008). ―Nanotechnology reports and reviews.‖ http://www.bccresearch.com/nanotechnology/