Use Of Nanotechnology In Civil Engineering

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ABSTRACT

The recent researches on nanomaterials and nanotechnologies have highlighted the potential use of these materials in various fields such as medicine, construction, automobile industry, energy, telecommunications and informatics. This is due to the special characteristics of materials at the nano scale. Building materials domain can be one of the main beneficiaries of these researches, with applications that will improve the characteristics of concrete, steel, glass and insulating materials. Improving the materials resistances and the increasing of their durability will reduce environmental pollution by reducing the carbon footprint of the building. In general, the largest amount of pollutants is due to the production of various construction materials and to the energy required during their service. The use of nanomaterials in the composition of some materials, such as cement, will result in significant reductions of CO2 pollution and the use of performance thermal insulations will result in efficient use of energy for air conditioning. Moreover, nanomaterials applied to the surfaces of structural elements of the building can contribute to environmental cleaning by photocatalytic reactions.

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 nano meters, 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.

WHAT IS NANOTECHNOLOGY?

Nano, which comes from the Greek word for dwarf, indicates a billionth. One nanometer is a billionth of a meter. Definitions of 'nanotechnology' vary, but it generally refers to understanding and manipulation of matter on the nanoscale, say, from 0.1 run to 100 nm. The significance and importance of controlling matter at the nanoscale is that at this scale different laws of physics come into play (quantum physics).

There are two ways to approach the nanoscale: shrinking from the top down, or growing from the bottom up. The 'top down' approach entails reducing the size of the smallest structures towards the nanoscale by machining and etching techniques, whereas the 'bottom up' approach, often referred to as molecular nanotechnology, implies controlled or directed self-assembly of atoms and molecules to create structures.

A more accurate definition of nanotechnology was presented in 1981 by Drexler (Drexler 1981), such as the production with dimensions and precision between 0.1 and 100 nm. In medium terms, nanotechnology involves the study at microscopic scale (1 nm = 1 × 10 -9 m). As a comparison, one must realize that a strand of human hair has 80,000 nm thickness and that the DNA double helix has 2 nm diameter.

Between 1997 and 2003, the investment in nanotechnology increased at 40%, reaching up to 35,000 million Euro (Andersen et al., 2007). Some estimates predict that products and services related to nanotechnology could reach 1,000,000 million Euro per year beyond 2015 (NSF 2001). According to the report of RILEM TC 197-NCM, "Nanotechnology in construction materials" (Zhu et al., 2004), is the first document that synthesis in a clear manner the potential of nanotechnology in terms of the development of construction and building materials, namely:

- The use of nano-particles, carbon nano-tubes, and nano-fibers to ncrease the strength and durability of cementitious composites, as well as for pollution reduction.
- Production of cheap corrosion free steel.

- Production of thermal insulation materials with performance of 10 times the current commercial options.
- Production of coats and thin films with self-cleansing ability and self-colour change to minimize energy consumption.

SUSTAINABLE CONSTRUCTION:

At an annual production rate of 2.35 billion tons, the cement industry contributes about 5% to global anthropogenic CO_2 emissions. Additives such as belite, calcium sulfo-aluminate and calcium alumino-ferrite (BASF 2008) have been found to reduce the CO_2 emissions by nearly 25% in the production phase.

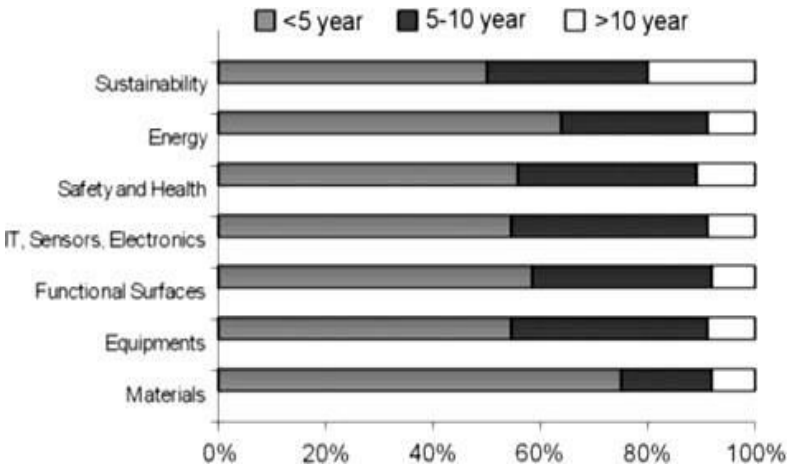
A wall made of nano-modified concrete during a cold weather season could potentially be used as a thermal insulator when the outside temperature falls or used as a conductor when the ambient temperature inside the building is low, thereby reducing the energy load required for conditioning the building interior.

With further development of LED & OLED technology and progress in the insulating materials and smart glazing, the vision for buildings to meet their own energy requirement will become a reality.

FUTURE PROJECTION OF NANOTECHNOLOGY IN CONSTRUCTION:

- There is substantial money flowing into nano-related research from ultinational 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 changing environment.



Future projection of nanotechnology

2.LITRATURE REVIEW

The recent researches on nanomaterials and nanotechnologies have highlighted the potential use of these materials in various fields such as medicine, construction, automobile industry, energy, telecommunications and informatics. This is due to the special characteristics of materials at the nano scale. Building materials domain can be one of the main beneficiaries of these researches, with applications that will improve the characteristics of concrete, steel, glass and insulating materials. Improving the materials resistances and the increasing of their durability will reduce environmental pollution by reducing the carbon footprint of the building. In general, the largest amount of pollutants is due to the production of various construction materials and to the energy required during their service.

The use of nanomaterials in the composition of some materials, such as cement, will result in significant reductions of CO2 pollution and the use of performance thermal insulations will result in efficient use of energy for air conditioning. Moreover, nanomaterials applied to the surfaces of structural elements of the building can contribute to environmental cleaning by photocatalytic reactions.

- "Gheorghe Asachi" Technical University of Iaşi, Faculty of Civil Engineering and Building Service: Nanomaterials and nanotechnologies have attracted considerable scientific interest due to the new potential uses of particles in nanometer scale and, consequently, large amount of funds and effort have been utilized. Even though

construction materials may constitute only a small part of this overall effort, it could pay enormous rewards in the areas of technological breakthroughs and economic benefits. Although today the total market share of nano products for construction is small and deemed to be applied in niche markets, this share is expected to grow in the near future, and nanoparticles to play an important role as a basis for the design, development and production of materials construction industry. In this paper, it can be concluded that the use of nanomaterials in construction is viable in four major directions of development: structural concrete; real time structural monitoring; coatings and paintings; thermal insulations.

- Ali Akbar Firoozi; Mohd Raihan Taha; Ali Asghar Firoozi University Kebangsan Malaysia, 43600 UKM Bangi Selangor Malaysia: According to this paper 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.

  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.

3. NANOMATERIALS USED IN CIVIL ENGINEERING

Nanotechnology requires advanced imaging techniques for studying and improving the material behavior and for designing and producing very fine powders, liquids or solids of materials with particle size between 1 and 100 nm, known as nanoparticles (Gogotsi, 2006). Currently, the use of nanomaterials in construction is reduced, mainly for the following reasons: the lack of knowledge concerning the suitable nanomaterials for construction and their behavior; the lack of specific standards for design and execution of the construction elements using nanomaterials; the reduced offer of nanoproducts; the lack of detailed information's regarding the nanoproducts content; high costs; the unknows of health risks associated with nanomaterials.

In order to be able to use in the construction industry the nanomaterials at wide scale it is necessary that the researches to be conducted following the next stages: the choice of nanomaterials with potential use in construction and the study of their characteristics; the behavior study of the building elements that contain nanomaterials under various loads; the

development of specific design and construction standards. This paper is part of the first stage of research and represents a synthesis of nanomaterials proper to be used in construction.

3.1 NANO MATERIALS FOR CONSTRUCTION

Studies in nano composites for improvement in cement performance are very important for construction industry. The materials such as Nano-Titania (TiO2), Carbon Nanotube, Nano Silica (SiO2) and Nano-Alumina (Al2O3) can be combined with cement. These materials are densifying the matrix which cause to increase in strength and speed chemical reactions e.g. hydration reaction. Due to effective filling pores with nanoparticles, strength and durability of the material will be improved. Therefore, nanoparticles can produce a new generation of cement composites with enhanced properties.

Most important nanomaterials with potential use in construction are Carbon Nanotube, TiO_2, SiO_2, ZnO, Ag, Al_2O_3, ZrO_2 and WO_3 nanoparticles/nano powder. These nano-materials can be used for different construction purposes as in the following list:

- Usage of Carbon nanotube instead of steel cables in bridges.
- Nano Silica for densifying cement composites.
- Addition of resistive Carbon Nano fibers in concrete roads especially for snowy regions.
- Titania nanomaterials for producing photo catalytic concrete.
- Nano Calcite particles for protection of sealants from aggression.
- Nano Clays to improve plastic and flow characteristics of cement.

3.2The Carbon Nanotubes: Carbon nanotubes are a form of carbon having a cylindrical shape, the name coming from their nanometer diameter. 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) (Lu et al., 2010). Nanotubes are members of the fullerene structural family and exhibit extraordinary strength and unique electrical properties, being efficient thermal conductors. For example, they have five times the Young’s modulus and eight times (theoretically 100 times) the strength of steel, whilst being 1/6th the density. Expected benefits of carbon nanotubes are: mechanical durability and crack prevention in concrete, enhanced mechanical and thermal properties in ceramics and real-time structural health monitoring capacity (Mann, 2006).

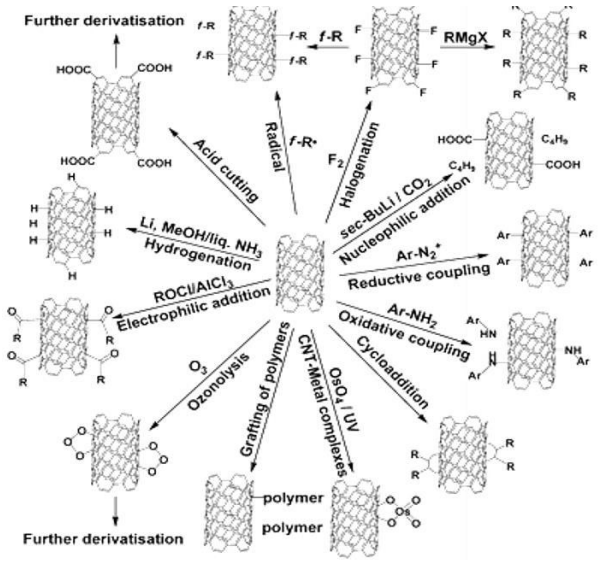


Fig.3.1. Functionalized carbon nanotube

3.3 Titanium Dioxide Nanoparticles (TiO2): The titanium dioxide nanoparticles are added to concrete to improve its properties. This white pigment is used as an excellent reflective coating. or added to paints, cements and windows for its sterilizing properties. The titanium dioxid breaks down organic pollutants, volatile organic compounds and bacterial membranes through powerful photocatalytic reactions, reducing air pollutants when it's applied to outdoor surfaces. Being hydrophilic gives self cleaning properties to surfaces to which it is applied, because the 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 surface has a white colour that retains its whiteness very effectively (Mann, 2006).

3.4 Silicon Dioxide Nanoparticles (SiO2): Nano-SiO2 could significantly increase the compressive strength of concretes containing large fly ash volume at early age, by filling the pores between large fly ash and cement particles. Nano-silica decreases the setting time of mortar when compared with silica fume (micro silica) and reduces bleeding water and segregation by the improvement of the cohesiveness (Sadrmomtazi & Barzegar, 2010).

3.5 Zinc Oxide Nanoparticles (ZnO): Zinc oxide is a unique material that exhibits semiconducting and piezoelectric dual properties. It is added into various materials and products, including plastics, ceramics, glass, cement, rubber, paints, adhesive, sealants, pigments, fire retardants. Used for concrete manufacturing, ZnO improves the processing time and the resistance of concrete against water (Broekhuizen & Broekhuizen, 2009).

3.6 Silver Nanoparticles (Ag): The nano-silver will affect, in contact with bacteria, viruses and fungi, the cellular metabolism and inhibit cells growth. The nano-silver inhibits multiplication and growth of bacteria and fungi, which causes infection, odour, itchiness and sores. The core technology of nano-silver is the ability to produce particles as small as possible and to distribute

these particles very uniformly. When the nanoparticles are coated on the surface of any material, the surface area is increasing several million times than the normal silver foil.

3.7 Aluminum Oxide Nanoparticles (Al2O3): Alumina (Al2O3) component reacts with calcium hydroxide produced from the hydration of calcium silicates. The rate of the pozzolanic reaction is proportional to the amount of surface area available for reaction. The addition of nano-Al2O3 of high purity improves the characteristics of concretes, in terms of higher split tensile and flexural strength. The cement could be advantageously replaced in the concrete mixture with nano-Al2O3 particles up to maximum limit of 2.0% with average particle sizes of 15 nm, the optimal level of nano- Al2O3 particles content being achieved with 1.0% replacement (Nazari et al., 2010).

3.8 Zirconium Oxide Nanoparticles (ZrO2): Zirconium oxide (or Zirconia) nano powder or nanoparticles are white high surface area particles with typical dimensions of 5…100 nanometers and specific surface area in the 25…50 m2 /g range. Nano zirconium shows good aesthetics (translucency), superior physical resistance (hardness, flexibility, durability), chemical resistance (practically inert) and is a very good insulator.

4 APPLICATIONS AND PRODUCTS

"Nano-products" in the construction industry are currently concentrated in four sectors:

- Cement-bound construction materials.
- Noise reduction and thermal insulation or temperature regulation.
- Surface coatings to improve the functionality of various materials.
- Fire protection

5. ADVANTAGES OF NANO-TECHNOLOGY:

Understanding, shaping and combining matter at the atomic and molecular scale is called nanotechnology. Nanotechnology encompasses science, medicine, engineering, computing and robotics at this scale, called the nanoscale. Nanotechnology offers the potential for new and faster kinds of computers, more efficient power sources and life-saving medical treatments. Potential disadvantages include economic disruption and possible threats to security, privacy, health and the environment.

let us first run through the good things this technology brings:

- Nanotechnology can actually revolutionize a lot of electronic products, procedures, and applications. The areas that benefit from the continued development of nanotechnology when it comes to electronic products include nano transistors, nano diodes, OLED, plasma displays, quantum computers, and many more.
- Nanotechnology can also benefit the energy sector. The development of more effective

energy-producing, energy-absorbing, and energy storage products in smaller and more efficient devices is possible with this technology. Such items like batteries, fuel cells, and solar cells can be built smaller but can be made to be more effective with this technology.

- Another industry that can benefit from nanotechnology is the manufacturing sector that will need materials like nanotubes, aerogels, nano particles, and other similar items to produce their products with. These materials are often stronger, more durable, and lighter than those that are not produced with the help of nanotechnology.
- In the medical world, nanotechnology is also seen as a boon since these can help with creating what is called smart drugs. These helps cure people faster and without the side effects that other traditional drugs have. You will also find that the research of nanotechnology in medicine is now focusing on areas like tissue regeneration, bone repair, immunity and even cures for such ailments like cancer, diabetes, and other life-threatening diseases.

DISADVANTAGES OF NANOTECHNOLOGY:

Nanotechnology has raised the standard of living but at the same time, it has increased the pollution, which includes water pollution, air pollution. The pollution caused by nanotechnology is known as nano pollution.

- The lack of employment in the fields of traditional farming and manufacturing and industrial sector because of the vast development in the nanotechnology.
- Nanotechnology raises the possibility of microscopic recording devices, which would be virtually undetectable. Atomic weapons would be easier to create and novel weapons might also be developed. One possibility is the so-called "smart bullet, Nanoparticles could potentially have a toxic effect.
- Mass production of nanotechnology material may or may not be possible.
- The potential for mass poisoning over a period of time. They may very well cause eventual health problems in the consumers that use them i.e. health effects could be at large scale. Inhaled nanoparticles may settle in the brain and lungs, which may led to significant increases in biomarkers for inflammation and stress response. For example: the so-called "gray goo" scenario, where self-replicating nanobots consume everything around them to make copies of themselves

- Lack of our own knowledge about nanotechnology makes it pretty difficult to manufacture.
- Nanotechnology is very expensive
- It is likely that nanotechnology, like other technologies before it, will cause major changes in many economic areas. Although products made possible by nanotechnology will initially be expensive luxury or specialist items, once availability increases, more and more markets will feel the impact. Some technologies and materials may become obsolete, leading to companies specializing in those areas going out of business. Changes in manufacturing processes brought about by nanotechnology may result in job losses

CONCLUSION

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. Recent years of R&D have shown massive investments Nano- construction. The activities in Nano related products for the construction industry are not well marketed and are difficult for industry experts to identify. A large-scale and visible initiative from nano-science and nanotechnology in the construction area could help seed construction related nano-technological development. Focused research into the timeous and directed research into nanotechnology for construction infrastructure should be pursued to ensure that the potential benefits of this technology can be harnessed to provide longer life and more economical infrastructure. This report concludes with a roadmap and strategic action plan on how nanotechnology can have its biggest impact on the field of civil engineering and on other engineering fields also.

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