

# Useable and Precautionary Aspects of Using Nanotechnology and Nano-materials in the Construction Industry

Azin Shakibabarough, Masoud Valinejadshoubi, Mojtaba Valinejadshoubi

**Abstract**—Nowadays, one of the most important research areas implemented in the construction industry is nanotechnology. Scientists have progressed a lot in their capability to produce substances from available materials. Nanotechnology could change the construction sector by creating new materials and providing new building technologies such as energy efficiency in the buildings and also a new technical tool which can modulate the climate changes and help us to mitigate the green house gases emissions in the future. It helps the construction sector to improve new products, and to significantly enhance the material quality. The field of building materials has had its most improvement in the characteristics of concrete, steel, glass and insulating material, including resistance, durability, reduction of pollution and etc. Generally the main causes of pollution produced in the construction field are related to the producing of different construction materials. So by using nanotechnology in materials and improving their performance, pollution in materials production will be mitigated. On the other hand, in recent years, in spite of many efforts in developing the technology by using these materials, few of them have dealt with the ecological cycle due to applying them. However, during utilizing a new technology, the negative aspects and consequences should also be considered to help us to seek ways to resolve the negative impacts. In this paper, a synopsis of the application of nanotechnology and nano-material in the construction industry and also the negative aspects and consequences of nano particles which may have on living organism have been investigated.

**Key Words**—Nano-materials, Nanotechnology, Nano particles, Construction industry, Construction materials

## I. INTRODUCTION

Nano-material is defined as a physical substance with one dimension at the lowest between 1...150 (NM) ( $1\text{nm}=10^{-9}\text{m}$ ). The characteristics of nano-material could be varied with the same material that has micro ( $10^{-6}\text{m}$ ) or macro ( $10^{-6}\dots 10^{-3}\text{m}$ ) scales. Nanotechnology is a domain that has many applications in the basics of physic and chemistry

*Azin Shakibabarough, Building, civil and environmental engineering department, Concordia University, Montreal, Canada,*

*Masoud Valinejadshoubi, Faculty of Art and Architecting, Central Azad University of Tehran, Tehran, Iran,*

*Mojtaba Valinejadshoubi, Building, civil and environmental engineering department, Concordia University, Montreal, Canada,*

researches. Using nanotechnology in construction has been ranked 8 of 10 applications that have a significant effect on the developing world [1]. The covering of nanotechnology has been in the design and construction of structures with at least one dimension that has been measured in nanometer scales [2]. Nanotechnology suggests many improvements in performance characteristics of adhesive, concrete, steel, coating, lighting equipment, plumbing fixtures and other construction products. The construction sector has had more improvement with sophisticated techniques and devices in the twentieth century. With the emergence of nanotechnology in construction, many outcomes have been achieved, which has resulted in cost effective, cleaner, and sustainable materials. Applications of nano-particles, nanotubes, and nano-fibers have resulted in novel construction materials, and new combinations of strength, durability, and toughness. For example bio-mimetic materials with self adjusting interfaces, shape memory, self repairing and strain harden materials [3].

In 1959, Richard Feynman published an article about the potential of nanotechnology in the future. Despite many situations and successes acquired by many scientists till that time, Richard Feynman has recognized as the founder of nanotechnology science [4].

The Construction Industry with the financial turnover of £ 1000 billion just in Europe (for example) and with more than 11 million people directly and 15 million people indirectly, involved in manufacturing and construction [5], has allocated an important part of the industry and manpower to itself that is the implication of the strong interaction with humans in this industry. Correspondingly small changes in this Industry will create lots of changes in this system. The early studies on the applications of nanotechnology in the Construction Industry go back to the 1990s. Maybe, the needs of human beings and/or other applied aspects can be considered as the significant factors for bringing the technology to the Construction Industry.

Through increasing in the population and development of construction, and due to limited resources and materials, demand for the use of new materials in the Construction Industry has been increasing. Trying to find ways to improve quality, increase materials efficiency and reduce the energy and materials consumption has led to increasing the use of nanotechnology in the Construction Industry. But what has been less investigated is looking at the impacts of these materials on living cells and the novelty of these materials. This may create new and unknown poisoning in humans.

These materials can easily become airborne and cause respiratory toxicity [6].

In this paper, some advantageous applications of nano-materials in construction and also the way of understanding the creating poisoning through toxic nano-materials in humans are investigated. Finally, some recommendations for avoiding toxicity in humans against nano-particles are taken into account.

## II. WHAT IS NANOTECHNOLOGY BASICS?

The nano is a Greek word and its meaning in the word is "Dwarf". It is the invention of materials by checking of matter at many levels: atoms, molecules, and sup molecular structures [7]. It is also defined as the application of very small particles of material to make new large scale of material [8]. Nanotechnology needs advanced techniques to improve the behavior of materials for creating very fine powders or particles between 1 to 100 nm [9]. A nanometer is one millionth of a meter that is eighty times thinner than a hair and its quantity is 5 to 10 atoms [10]. Nanotechnology has been applied in many fields such as electronics, biology, genetics, aviation, and etc. [10]. Application of nanotechnology in engineering, especially civil engineering needs the better understanding of characteristics at the Nano scale [11]. Nano particles have an impact on the behavior of materials at the macro - scale and if the elements of Nano scale are properly manipulated, it can lead to develop the new material on the macro-scale [12]. Figure 1 shows the uniform compositions of Nano-materials.

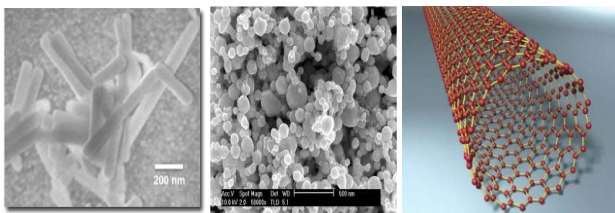


Figure1. Structure of Nanomaterials

## III. APPLICATION OF NANOTECHNOLOGY IN CONSTRUCTION

Construction is directly connected to construction materials, as famous construction materials could be specified such as: cement, concrete, and steel. In fact, Nanotechnology is the progression of materials with a considerable difference in the scale and characteristics compared to the classical macroscopic materials. Novel materials by using Nano particles have been progressed in construction building applications.

Nanotechnology could be applied in the construction process since it creates many products with many unique characteristics, including: lighter and stronger structural compounds, low maintenance coating, enhancing pipe joining materials, improvement properties of cementitious materials, decreasing the thermal rate of transfer, improvement of sound absorption, increasing the glass reflecting, and so on [13].

The applications of Nano material don't only focus on improving the properties of the material, but also can lead to

energy preservation (Berevoescu et al, 2009). Future building will be obligated to increase the capability of efficiency, security, and prevention of any energy loss by implementing new technologies and including healthier environment [10]. The buildings should be concentrated on reducing energy resource consumption. On the other hand thermal insulator can achieve high energy performance, and so make benefits of saving the energy [14].

The extraordinary chemical and physical characteristics of the material on Nano meter scale are capable of novel application ranging from improvement of structural strength and resource conservation to antimicrobial properties and self cleaning surfaces. There are different Nano-material (MNM<sub>s</sub>) and Nano composites implemented in various parts of the construction. At the Nano scale, these materials could not behave as same as a conventional scale counterpart, otherwise Nano scale creates the new products in a variety of constructions. The main Nano particles utilized in construction materials are: Nano Silica (SiO<sub>2</sub>), Titanium dioxide (TiO<sub>2</sub>), and Carbon nanotube (CNT).

Nano Silica (SiO<sub>2</sub>): the mixture of Nano silica with concrete could cause to improve the mechanical properties and reaction of concrete, control the degradation of C-S-H (calcium-silicate-hydrate), prevention of water penetration that lead to high durability, and strength of concrete. The structure of Nano porous silica is shown in Figure 2.

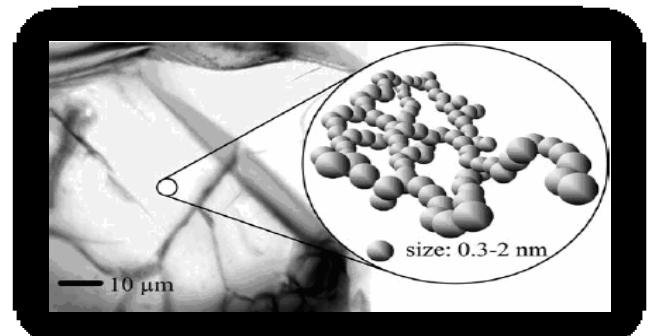


Figure2. Structure of Nano porous silica

Titanium dioxide (TiO<sub>2</sub>): the mixture of titanium dioxide Nano powder with concrete can cause the pollution to be broken down and washed off by rainwater. The color of TiO<sub>2</sub> is white and could be an excellent reflective coating and sun block. The mixture of TiO<sub>2</sub> with paint, cement, and windows for sterilizing properties, since TiO<sub>2</sub> can break down any pollution, such as organic pollutants, violate organic pollutants and bacterial membranes.

Carbon nanotubes (CNT): CNT could be mixed with the concrete that has many benefits such as improvement of strength and mechanical properties, compressive strength (+25 N/mm<sup>2</sup>) of concrete and also makes concrete flexural (+8 N/mm<sup>2</sup>).

### Concrete

Concrete is one of the widespread materials utilized in building construction and it is a macro level of material intensively affected by its Nano properties. Its characteristics have been researched at macro level without comprehending the characteristics of cementitious materials at the micro level. Investigation into the characteristics of cementitious materials at micro or Nano scale has been conducted by new experimental techniques. Research has been conducted into the hydration process, alkali silica reaction (ASR), and

reactivity of fly ash with using Nano technology [15]. The better comprehension of concrete structure in Nano or micro scale can assist to improve the properties of concrete and prevent its related diseases such as ASR [12]. The existence of Nano material into cement can improve its properties specially its performance. Nano Silica can enhance the compressive strength of concrete by filling the pores in concrete. The slurry of Nano silica can improve the segregation resistance for self-compacting of concrete (Bigley and Greenwood, 2003). Supplementing of a small amount of carbon nanotube (1%) by weight can enhance both compressive and flexural strength of concrete [5].

### Coating and painting

Coatings are anticipated to comprise the largest application of nano-material in construction. Major applications of coating in construction can be conducted in architectural paints, water sealers, and deck treatment. The coating combination with Nano particle or Nano tube have been progressing for many targets which involves one of the main application of Nanotechnology in building construction.  $\text{TiO}_2$  (dioxide, titanium) has the characteristics of sterilizing and antifouling, so it can be utilized to coat glazing.  $\text{TiO}_2$  will break down the organic dirt by the catalytic reaction. Moreover, it is hydrophilic, which induce water to move quickly over the surface and wash away organic dirt, broken down in the past, and the other exceptional coating which also have been used, including anti- Graffiti, energy saving, thermal control and anti-reflection coating [12]. Nanotechnology can be also used in the paints, due to providing the corrosion protection since it is hydrophobic and rejects water from the metal pipe and could protect the metal from attack of salt water. The coating has also self healing properties through a process of self-assembly and  $\text{TiO}_2$  Nano particles are being utilized as coating materials in the roadway tests around the world [5].

### Steel

Steel is another material used mainly in construction and applied in almost all structures. The significant properties of steel are strength and corrosion resistance. The new kind of steel through the integrating of copper Nano material, offers higher corrosion resistance and weld capability. Nano particles of vanadium and molybdenum can solve the fracture problems connected to the high strength bolt and reduction of hydrogen embrittlement [17]. Moreover, the nano particles of magnesium and calcium can cause enhancement in weld toughness. According to Mann [5], integration of carbon Nanotube with steel, has little application owing to its graphic nature. It can cause some problem to bind the bulk material in addition to high temperature included in the process of steel elements which increases the vibration of carbon atoms significantly ending up bond breaking and defects in the steel structure.

### Nano sensors

Nano sensors are any chemical, biological or surgical sensory points utilized to carry information related to Nano particles to the microscopic world. The monitoring and controlling of the condition of the environment and materials structure, performance in construction could be implemented by Nano and micro electrical mechanical system (MEMS) sensors. Dimension of Nano sensors is considered as one of these advantages. Nano sensors could be located in the building structure during the construction process. Moreover, early

age characteristics, monitoring of concrete such as temperature, humidity, moisture and strength could be carried out by Nano sensors such as: smart aggregate, low cost piezoceramic-based multi-functional device and etc. Nano sensors could also be used to monitor the corrosion and cracking of concrete and the smart aggregate is also implemented for monitoring the health of a structure. This sensor can indicate the internal stresses, cracks, and other physical forces in the structures during the whole life cycle of a structure. It has ability to show the structure of health before any failure occurs [12].

### Wood and glass

Wood is made up of nanotubes or Nano fibrils. The surface of lignocellulosic at the Nano scale can induce new chances for self sterilizing of surface, internal self-repairing devices of electronic lignocellulosic and preparing feedback for product performance and environmental conditions during the life [5]. Highly water resistant coating, integrated by silica and alumina Nano particle and polymer of hydrophobic are implemented for wood.

Self cleaning technology for glass is created by the integration of  $\text{TiO}_2$  Nano particles to glasses. Disintegration of bacterial membranes and any organic pollutants from glass could be implemented by the reaction of Nano particles photo catalytic. Previous disintegration (dirt particle) can be also washed off from glass by using  $\text{TiO}_2$  Nano particles being hydrophilic to glass. Moreover, using fumed silica ( $\text{SiO}_2$ ) Nano particles as an interlayer between two panels of glass can be changed from a rigid to opaque fire cover after warming known as fire-protective glass [16].

### Nano Insulators

One of the rapidest ways for increasing energy efficiency is improving the building insulation system. Nano technology can produce thermal insulators with greater functionality that is much lighter and thinner than traditional ones. Installing the new ones in the buildings is very comfortable than the traditional ones, for example, installing Nano insulator does not need to change the windows or other size of the component, but for traditional insulator it is needed [18]. Nano insulators in the structures are good thermal insulators against heat transferring such as radiation, conducting, and convection. Nano insulators have maximum heat-power and minimum thickness contrast to the traditional ones like polystyrene (thickness of Nano insulators is ten times lower than the other one and their service life is 30 to 50 years) [19].

Aerogel is one of the Nano-insulator which is similar to glass, but has a high melting point (1200 centigrade). If aerogel is used as a light-passing panel in the windows, it could cross the light fitting and also could perform as a great thermal and acoustic insulator. Aerogel has higher energy efficiency than conventional materials like polystyrene, cellulose, and rock wool (energy efficiency of aerogel is two or four times higher than the traditional ones) [14].

The new production of Nano-insulators is transparent foam which could be used in any internal surface. These materials indicate amazing characteristics with particles in molecular scale thinner than a color layer [20]. Therefore, building insulators can be applied as easily as painting in the near future.

### Nano technology for heat insulating coatings

“Thermo-s” is a good alternative for heat-insulating technology, and it is an atmospheric, resistant energy, efficient point, and coating including microscopically ceramic balls. “Thermo-s” could provide the ultimate economical effect while can solve any heat, noise and damp proof problem as well as corrosion and fire resistance. This product could also be fabricated on the fabric on a flexible roll or deposited on the plates of required thickness and quality. Figure 3 shows the process of heating, insulation using terms in the nanotechnology area.

The advantages of “Thermo-s” are as follows:

- The coating can be used on any surfaces such as: metal, plastic, concrete, brick, wood, and any brick building in dry weather.
- It can provide excellent protection against frost penetration.
- It protects the surface against condensate appearing.
- It characterizes the capability of excellent repair.
- It can make the operation life of pipelines much larger.
- It can keep ecologically safe.

Figure 3 shows the process of heating insulation using Thermo-s.

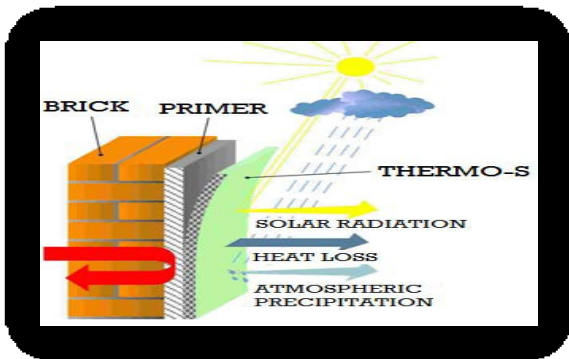


Figure3. The process of heating insulation using Thermo-s

#### IV. HARMFUL ASPECT OF USING NANOTECHNOLOGY: TOXICITY IN HUMANS

Poison is said to be a matter that after entering into the body causes disrupting the normal functioning of the body, or lead to tissue damage and probable death. The entrance of poisons to the body includes: digestion, breathing and contact. Figure 4 shows how the poisons in the forms of liquid or gas can enter the human’s body.

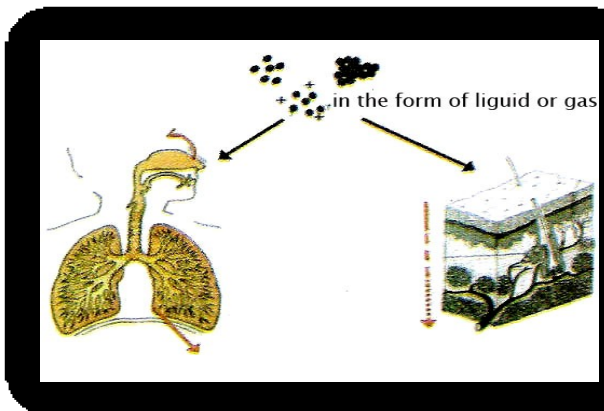


Figure 4: Entryways of poisons in the body

#### Digestive

Poisoning occurs when the toxin enters through the mouth and is absorbed through the digestive system, and then enters into the body cycle through the stomach. Workers exposed to nano material involuntarily put their hand contaminated with this particle into their mouth or swallow the cleared particles from the respiratory protection mask (respirators).

#### Respiratory

Poisoning happens when toxins enter through the mouth or nose and it is absorbed by the lining of the respiratory tract. Inhalation of fine fibers made of Nano Technology (Nano Fiber) can have similar effects of asbestos for human health. Some forms of fibers similar to asbestos fibers can cause lung cancer.

Donaldson [21], inhalation toxicology Professor at the University of Edinburgh, has concerned that creating new types of nano-fibers and Nanotechnologies in the industry due to the similar form of asbestos, can lead to health risks. In this investigation, silver nano fibers with different lengths were injected into the lungs of mice and it was recognized that the nano fibers longer than five micrometers caused inflammation in the lungs. But shorter and smaller nano fibers were removed from the lungs. Knowing that this short length of the fiber can cause disease is so significant, since it can be helpful in producing safe fiber in the future and also in identifying the current threats posed by asbestos and other fibers. Figure 5 indicates the structure of nano-fibers that have the similarities in the structure of asbestos. Due to these similarities, the negative impacts of using nano-fibers in the longtime may be the same as asbestos which must be controlled.

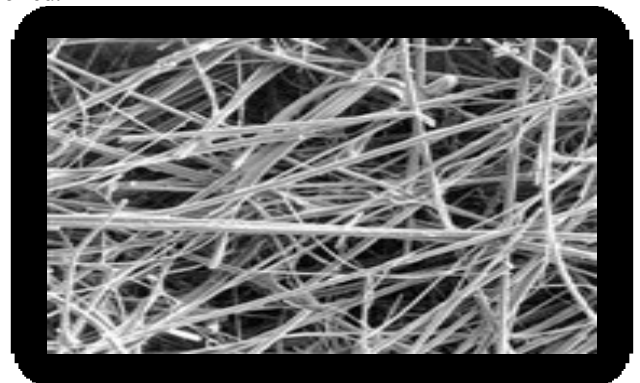
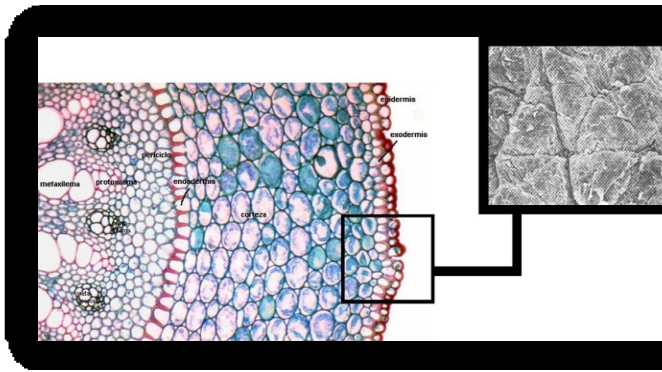


Figure 5: The structure of nanofibers

#### Contact

Poisoning occurs when the poison enters through contact with normal skin and spreads through the circulatory system. The skin immune system is always active and intelligent and through different way and positions controls viruses, bacteria and single-celled fungi. This system prevents microbes from entering through the skin and mucosal surfaces of the body like a computer input port. Microbes cannot be removed from the skin since the skin is the first immune barrier and is composed of layers of dead cells filled with a substance called keratin. Keratin cells known as keratinized cells physically prevent the bacteria from entry. Alongside the cells, there are some pores in which the sweat glands located and sweating action is done [22]. Figure 6 shows the layers of skin and the pores located on the keratin cells, which can be the ways of entering too small particles into the body.



**Figure 6:** The ways of entering small particles on the skin's surface

Absorption of various materials such as drug by keratin layer of the skin is poor, but the absorbing quality of skin will be good when the keratin layer is removed from the skin. Therefore, medication through the skin and even skin as a topical treatment is so difficult. But the absorption through the mucosa is relatively easy and many drugs use this way to penetrate generally or locally. Mucosal absorption rate of some substances is so high that their density in the blood goes up rapidly. The size of particles is effective in their distribution in the body. Particles larger than 100nm don't reach to the marrow and the particles larger than 3000nm don't exist in the blood. Surface load of particles is involved in their distribution in the body.

One nanometer (NM) is one billionth of a meter. The length of one pair DNA is close to nanometers and the other hand the smallest cellular bacteria are 200nm [29]. And it is shown that skin may prevent the bacteria and microbes against getting into the inner membrane, but a nano-scale particle with the scale of at least 200 times smaller than a bacterium can penetrate into the layers of the skin easier than topical medications.

## V. INCREASING INTEREST IN USING NANOTECHNOLOGY PRODUCTS

According to research conducted by the Center for Nanotechnology at Rice University [23], in collaboration with UCL and London Business School, American consumers, in spite of the potential risks related to the health and safety, like to use the products in which nanotechnology has been used. Because consumers believe that the potential benefits of nanotechnology is enormous. This study is considered as the largest study conducted for investigating the interest and willingness of consumers in using the products of nanotechnology.

According to Currell[23], responsible for research implementation, annually about \$ 30 billion are spent in producing a nanotechnology product. But the amount of these productions may be declined due to considerations of risks associated with them. He mentioned that informing people of the benefits and risks of nanotechnology transparently cause increased the use of nanotechnology products by consumers. Nanotechnology promises the new control of properties born of nano-scale particles. These properties caused that private companies, governments and investors, worldwide, invested in this technology up to \$10 billion in 2005. This trend remained constant at 2006.

## VI. WHY NANO PARTICLES CAN BE DANGEROUS

When materials are converted into nano-scale, some changes are made in their chemical and biological properties [24]. Therefore, the materials which are safe in bulk (mass) situation, when they are converted into Nano form, can be hazardous. In addition, the small size of nano-particles make these materials to overcome against immune dams. New research shows that increasing the nano particles in nature can result in concentration of them in the food chain. The study conducted by researchers at the University of Kentucky on Cadmium Selenide (CdSe) nano-particles [25] shows that these nano-particles are transmitted from the lower parts of the food chain to the top of the chain segments. This type of pollution at lower levels of the food chain, including plants and bacteria is being increased.

The most controversial properties of nano-particles include:

- A large surface area which will lead to increasing the chemical and biological activities [24].
- New features such as more solubility and activity, chemical shape and surface
- Very high mobility in the human body
- Ability to penetrate into the cell membrane

## VII. APPLICATION OF NANO PARTICLES AND THEIR SOME NEGATIVE IMPACTS IN THE CONSTRUCTION INDUSTRY

As mentioned earlier, nanotechnology has also important roles in the Construction Industry. In this regard, steel, glass and concrete are most significant. Applications of nano-particles used in the Construction Industry that are most critical, are carbon nanotubes and titanium dioxide, generally leads to enhanced mechanical properties of the samples in the main structure, and also in the joinery part of the building, application of nano coatings on the building interior and external view is also important. Building nano coatings lead to water repelling and make the dirt absorption minimized. These nano-coatings are used on the surfaces such as concrete, brick, stone, tile, marble, wood, ceramic, glass and steel. Producing reinforced, self-repair and self-cleaning concrete, and self-cleaning, fire resistance and energy controller glasses using nanotechnology can help in saving the building energy consumption. Using building colors produced by nano science caused bacteria not to penetrate to office and residential buildings, hospitals and etc. and gives them long life, bacteria-free environment and non-dirty nature.

Below, application of some nano particles in construction and their negative consequences which may affect living tissues is addressed.

### Ultra-fine particles of silica: $\text{SiO}_2$

By using silica particles, the amount of particle density of concrete can be increased which leads to increasing the density of concrete. Addition of silica nano-particles of the cementitious materials causes the controlling of chemical analysis and also preventing water penetration which both of these items will increase the durability of concrete. But along the positive characteristics of nano particles, they can also negative effects of living tissue. These substances are known to cause cancer in humans. If pitted cells are exposed to silica nano particles, it causes cell toxicity and leads to death of

genes in endocrine. These materials in faced with ultraviolet radiation produce ROS that has a mild toxicity [26].

### Carbon nanotube (CNT)

Superior strength, lightness and being conductive, are ideal features which have proposed carbon nanotubes as a significant future feedstock. Nanotubes are always used in the form of mixed with other materials or to be used on exterior surfaces such as combining with the plastics which use nanotubes to improve their mechanical properties. Although their density is six times smaller than steel, but their young's modulus and strength are five and eight times of steel respectively. But on the other hand, carbon nanotubes can cause pulmonary toxicity to mammals. They also due to direct physical interaction, or by making oxidative stress could damage cell walls and so damage DNA [27].

### Titanium dioxide nano-particles (TiO<sub>2</sub>)

Titanium dioxide nano particles are used as reflecting coating to improve the properties of concrete in the building view. These nano-particles are able to break down the organic pollutants and bacterial membranes through Photocatalyst reaction. And due to that it should be added to color, cement and glass for making disinfecting properties. On the other hand, titanium dioxide or titania is a light-sensitive nano material lead to fires, cellular toxicity, severe morbidity, photosynthetic activity prevention, oxidative damage in the presence of ultraviolet light radiation that as the result ROS is produced. However, these effects are seen only in the organisms such as bacteria, marine algae, small fish and crabs [26].

### Quantum Dots (QD)

Fluorescent nano-particles contain heavy metals such as cadmium, lead and zinc in their membrane structure. These materials have maintained their stability with the covers made with natural ingredients and became applicable in specified applications. Contamination and toxicity due to bursting and releasing of these materials' metal core can attack bacteria and mammalian cell biology. When the used surface coatings cannot prevent the core disintegration and the mentioned heavy metals are released, then these natural coating materials are also poisoned and can be harmful [27].

## VIII. CONCLUSION AND RECOMMENDATIONS

Nanotechnology could have a great impact on various industries, specifically in the Construction Industry. It provides many benefits in design and the process of construction, and due to that many scientists are doing various related researches with a large amount of funding. In spite of this fact, due to high initial cost, a total demand of nano materials for the construction process toward market share is low [28]. Implementing the nano technology in coating, glasses, nano-structured insulators, nano concrete and steel increases the functionality of materials as a perfecting system for producing long life which can lead to reducing in the maintenance cost. On the other hand, despite all advantageous impacts of these materials, they also have negative and dangerous impacts on living organisms that must be identified, and should be prevented and controlled by establishing some effective remedies.

The following recommendations can be applied as the remedies to mitigate the negative impacts of nano particles in the Construction Industry:

1. A coating on the nano-particles reduced the formation of free radicals, causing the particles to be more secure. However, there should be a reasonable balance between safety and performance of the material. A nano particle can be designed to be completely safe for the environment which does not have any value of business aspect, or the nano particles can be so prepared which lead to producing very unique products, but very toxic and dangerous that is irrational for the environment.
2. Passing the essential rules and regulations by which the environment and people are protected from possible risks. These laws should be predicted and enacted accurately to be used if necessary.
3. Some natural organic soluble materials can be used to mitigate the toxicity of some nano-materials. Because these materials on the nano-particles form a coating and keep them from active materials and prevent them from spreading.
4. Offering a software prior to the use of nano-materials in the desired location to investigate the various potentials of there and obtains its risk coefficient.
5. About the concrete products that use nano-particles, the necessary safety care should be taken into account in the construction and demolition stages.
6. In the demolition of concrete buildings which have used nano-particles, demolition heavy machinery and dynamite should not be used due to the releasing of the particles into the atmosphere.
7. If engineering and administrative control cannot control the exposure of a worker to nano-particles, appropriate respirators must be used. The decision about using respirators must be chosen based on expert opinion and evaluation of employee exposure and health risks to workers.
8. Using the ventilation system for pollutant emission that uses the filters for absorbing the particles in the air.
9. Applied training regarding how to deal with the risks of nano-particles.
10. Disposal and transporting of nano-particles wastes according to the principles of hazardous chemical waste.

Finally, it could be concluded that in spite of the high level of initial cost and some negative impacts, by controlling and mitigating these negative impacts, using nano particles in construction is viable, especially to improve the performance of structure and reduce the life cycle cost in the operation stage.

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**Azin Shakiba Barough** was born in Iran in 1984. He graduated at B.S. degree in Civil Engineering at University of Mazandaran, Iran in 2008. After receiving bachelor, she worked about 2.5 years as a civil engineer, project estimator and analyzer in CHAPAR building company. She received her master degree in the field of construction management from University Technology Malaysia in 2013. She is now a member of Iranian Organization For Engineering Order Of Building and also Iranian Young Researchers & Elite Club. Her research interests include Structural Health Monitoring, construction materials, sustainable and green building project management, and safety in construction.



**Masoud Valinejad Shoubi** was born in Iran in 1989. He graduated at B.S. Degree in Architectural Engineering at University of Tabari, Iran. He is currently a master student at Central Azad University of Tehran, Iran. He is the author of 3 international Journals and two national conferences. His research interests are sustainability in buildings, green building design and energy efficiency in buildings.



**Mojtaba Valinejad Shoubi** was born in 1985 in Iran. He graduated at B.S. Degree in Civil Engineering at Ghaemshahr Azad University, Iran in 2008. After receiving bachelor, he worked about 2 years as concrete building designer, project manager and site engineer. He received his master degree in the field of construction management from University Technology Malaysia in 2013. After coming back to Iran, he has been working in one of the government rubber dam project as project manager and site supervisor. He is now a member of Iranian Organization For Engineering Order Of Building and also Iranian Young Researchers & Elite Club. He has the Award of Excellence Certificate from Faculty of Civil Engineering at Universiti Teknologi Malaysia and four conference oral presentation certificates. His research interests include structural health monitoring, construction materials, Building Information Modeling (BIM), sustainable and green building, project management, and safety in construction. He is the author of twelve international publications till now, including six international conferences and six international Journals.