Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 4, Issue 2; April-June, 2017, pp. 148-150

http://www.krishisanskriti.org/Publication.html

# A Paradigm Shift in Civil Engineering: Nanotechnology

**Kamaldeep Kaur[1], Jaspal Singh[2] and Manpreet Kaur[3]**

*[1]M.Tech. Student, Department of Civil Engineering, Punjab Agricultural University, Ludhiana*
*[2,3]Department of Civil Engineering, Punjab Agricultural University, Ludhiana*
*E-mail: [1]kamalbrar45@gmail.com, [2]jaspalsingh@pau.edu, [3]manpreetkharay@pau.edu*

**Abstract—***The advanced research on nanomaterials and nanotechnologies has highlighted the potential use of these materials in medical, automobile industry, energy, electronic and material science and also in civil engineering. Nanotechnology is the understanding, control and re-engineering of matter on the order of nanometers (≤ 100 nm) to create materials with new fundamental properties and functions. Matter controlled at the nano scale provides an exceptional surface area-to-volume ratio, change in the surface energy, surface chemistry, surface morphology and basic properties of the particles such as mechanical, thermal, electrical, magnetic and chemical reactivity. The special characteristics of nanomaterials improve the properties of concrete, steel, glass, wood, light equipment, plumbing works and insulating materials. The application of nanotechnology in civil engineering results in lighter and stronger structural composites, low maintenance coating and better properties of cementitious materials. The objective of this paper is to review the role of nanotechnology in civil engineering and its effects on various constructional materials such as concrete, steel, glass, wood and paints. It also elaborates the limitation to application of nanotechnology in construction industry.*

**Keywords***: Concrete, Nanomaterials, Paints, Steel, Glass.*

## 1. INTRODUCTION

Nowadays, world of science has started to develop new materials and to evaluate their characteristics with nanotechnology. The nanotechnology is neither new science, nor technology but it is an advancement of existing science and technology which deals with particle at nano scale (≤100nm) to create materials with fresh fundamental properties and functions [1]. At the nanoscale properties of material are different from larger scales such as an exceptional surface area-to-volume ratio, change in the surface energy, surface chemistry, surface morphology and basic properties of the particles such as mechanical, thermal, electrical, magnetic and chemical reactivity [2].

The speech of the physicist Richard Feynman, entitled ‘‘There’s plenty of room at the bottom”, that took place in 1959 at the California Institute of Technology, in a meeting of the American Physical Society is considered the beginning of the nanotechnology. The terminology popularly referred to as nanotechnology itself coined by Prof. Nario Tanguchi in 1974 [3].

The word nano which was derived from Greek word dwarf, indicates a billionth. One nanometer is a billionth of a meter. There are two main approaches to reach nano scale “top-down” and “bottom-up”. The top-down approach encompasses reducing the larger structures towards nano scale by machining and etching techniques where as bottom up approach referred to ‘‘molecular nanotechnology” or ‘‘molecular manufacturing,” in which materials are engineered from atomic and molecular level by a process of assembly or self-assembly [4].

## 2. APPLICATION OF NANOTECHNOLOGY IN CIVIL ENGINEERING

As the potential for application of nanotechnology in the area of civil engineering is growing, various sector of civil engineering in conjunction with design and construction processes can be benefited from nanotechnology and creates new products with many unique characteristics. For example lighter and stronger structural composites, low maintenance coatings, better cementitious materials, less thermal transformation and insulation, better sound absorption of acoustic absorbers and better reflectivity of glass [5].

### Concrete

Compared to other forms material used in construction concrete is ubiquitary and predominately used material in the world. Concrete is multi-phase, nano structured, composite material used in all construction activities. The understanding of structure and behavior of concrete at nano scale, yields a new avenues for improvement of mechanical properties and microscopic structure of concrete. The annexation of nanomaterials such as nano silica ($SiO_2$), nano clays, nano titanium Oxide ($TiO_2$), Nano Iron ($Fe_2O_3$), Nano alumina ($Al_2O_3$), Cuo, ZnO and $ZrO_2$ is best way to enhance the properties of concrete.

The addition of nano $SiO_2$ significantly improves the properties of concrete and cement. Nano $SiO_2$ is about 100 times smaller than cement. It can fill the voids in fresh and partially hardened cement paste finally densifying the micro and nanostructure which results in improved mechanical properties. Also, addition of nano-silica also control the degradation of the fundamental C-S-H (Calcium-Silicate-

Hydrate) reaction of concrete and block water penetration and therefore, it lead to improvements in durability [5].

Another nanomaterial is used to improve the properties of concrete is $TiO_2$ which is a white pigment. The small amount of nano-$TiO_2$ can accelerate the hydration of cement [6]. It has sterilizing and anti-fouling properties. These particles break down organic pollutants, volatile organic compounds and bacterial membranes by catalytic reaction. Furthermore, $TiO_2$ is hydrophilic and attracts the rain water to surface and forms sheets which collect the pollutants and dirt which then wash off [7].

Nano-$Al_2O_3$ has shown considerably increase in modulus of elasticity upto 143% at the dosage of 5% but there are limited effect on compressive strength [4]. The cement could be replaced in the concrete by nano-$Al_2O_3$ particles up to maximum limit of 2.0, the optimum content for replacement with nano- $Al_2O_3$ particles at 1.0%

The addition of Nano $CaCO_3$ in concrete activates the cement hydration and reduces the setting time. The flowability of concrete increase with the content of Nano $CaCO_3$. The flexural and compressive strength increase with the addition of Nano $CaCO_3$ at the age of 7days and 28days. The optimum content of Nano-$CaCO_3$ was 1% [8].

Zinc oxide is a unique material that exhibits semiconducting and piezoelectric dual properties. Utilization of ZnO in concrete improves the processing time and the resistance of concrete against water [9].

Nanoclay shows promise in enhancing the mechanical behavior, the resistance to chloride penetration and self compacting properties of concrete [4].The enhancement in tensile strength was 49%, whereas the enhancement in compressive strength was 7% at 8% replacement of cement with nano-metakaolin [10].

**Steel**

Steel is one of the most vital and indispensable material in construction activity. Nanotechnology has propounded different approaches to improve steel properties such as fatigue, strength, corrosion resistance, thermal insulation and heat affected zone.

Nanotechnology has proposed enhancement methods in strength of steel products by high strength cables, high strength bolts and carbon nano-tubes which can lower the material consumption and also reduces the total energy embodied in a structure. The refinement of the cementite phase of steel to a nano-size has produced stronger cable. A stronger cable material would reduce the cost and period of construction and enhanced the sustainability. These are useful in especially in suspension bridge and precast members. The use of vanadium and molybdenum nano-particles can delayed fracture problems associated with high strength bolts, reducing the effects of hydrogen embrittlement and improving the steel micro-structure [11]. Carbon nanotubes (CNT) are cylindrical form of carbon of nanometer diameter and of several millimetres in length .It can be single walled nanotube, or multi walled nanotube . Carbon nanotubes are over 100 times stronger than steel. CNT composite reinforced structures have a 50 to 150-fold increase in tensile strength, compared with conventional steel-reinforced structures.

Fatigue is a significant issue for the structures subjected to cyclic loading. Fatigue failure can occur at significantly lower stresses than the yield stress of the material which leads to reduction in service life of structure. Stress risers are responsible for initiating cracks which prompt fatigue failure. Addition of copper nano-particles reduces the surface unevenness of steel which then limits the number of stress risers and hence fatigue cracking [5].

The heat-affected zone (HAZ) is the affected area of base material in microstructure scale by welding or heat intensive cutting operations. Welds and HAZ can brittle and fail without warning under sudden dynamic loadings like earthquake. To prevent HAZ failures, there is need of oversizing of structures. The addition of nanoparticles of magnesium and calcium makes the HAZ grains finer in plate steel and increasing the toughness of welds [1].

**Wood**

Wood is also composed of nanotubes or nanofibrils, known as lignocellulosic (woody tissue) elements. Lignocellulosic surfaces at nanoscale could advances the properties such as self sterilizing and internal self repair. Lignocellulosic devices would provide feedback on product performance and environmental conditions during service. It can monitor structural loads, temperatures, moisture content, decay fungi heat losses and gains, and loss of conditioned air. Highly water repellent coating made with addition of silica, alumina nanoparticles and hydrophobic polymers to be used for wood [9].

**Glass**

The use of nanoparticle $TiO_2$ to glass formed self cleaning glass because $TiO_2$ has sterilizing and anti-fouling properties. These particles catalyze reactions which breakdown organic pollutants, volatile organic compounds and bacterial membranes. $TiO_2$ is hydrophilic and attracts water forms sheets and wash off the dirt particles.

Fire-protective glass is another application of nanotechnology. This is obtained by using a clear interlayer sandwiched between two glass panels formed of fumed silica ($SiO_2$) nanoparticle which turns into a rigid and opaque fire shield when heated. The coating of nano-$SiO_2$ on glass reduces the reflectivity of glass and provides the antireflection glass [12].

**Paints**

Nanotechnology is being applied to paints gives insulating properties. Addition of nano-sized cells, pores and particles reduces the thermal conduction. These kind of paints also

provide corrosion protection under insulation since it is hydrophobic and repels water from the metal pipe and can also protect metal from salt water attack [7]. Addition of $TiO_2$ to paints gives self cleaning properties because $TiO_2$ particles catalyze reactions which breakdown organic pollutants, volatile organic compounds and bacterial membranes.

## 3. LIMITATION IN APPLICATION OF NANOTECHNOLOGY

In the construction industry, various nanotechnology based products and solutions are commercially available. There are number of challenges exist for initiation of the application of the technology into reality.

- **Skepticism of stakeholders and consumers-** The construction sector is conventional sector and it is not easy to implement new techniques and materials. The stakeholders and contractors are unenthusiastic to change the materials therefore it is difficult to implementation of nanotechnology in the construction industry**.**
- **Cost -** The cost of most nanomaterials and equipment are high due to the complexity of the equipment used for the production of these products. It is a challenge to the construction industry to solve production and distribution problems and to provide solutions to the general public at a reasonable cost.
- **Production-** The technologies used for manufacturing of nanomaterials are complex. It is not convenient for large-scale production of nanomaterials.
- **Health**- Nanotechnology based construction products might be harmful to health. If nanomaterials of certain sizes are able to enter the body, they may pass through cell membranes or cross the blood-brain barrier because of their small size. The nanotubes might cause a lung problem to construction workers.

## 4. CONCLUSION

Nanotechnology in the civil engineering makes a huge difference in giving a benefit in various ways. Nanotechnology brings the revolution in construction world by improving the mechanical properties and durablitiy of concrete; self cleaning, fire protective and heat insulated glass; high strength cable; insulation coating etc. No doubt nanotechnology will help to bring out the materials with new properties and excellent functional ability. The materials made of nanotechnology also enhance the serviceability of structures. The scope of nanotechnology is being extended to the every nook and corner of civil engineering field, still a lot of awareness and research should be carried out to exploit its benefits.

## REFERENCES

[1] Mann S (2006) Report on Nanotechnology and Construction.

[2] Viivan I F , Pradoto R G K, Moini M and Sobolev K (2013) The use of nanoparticles to improve the performance of concrete. Reterived from http://konsyst.tanger.cz/files/proceedings/14/reports/2159.pdf

[3] Sahin R and Oltulu M (2008) New materials for concrete technology: nano powders. *33rd Conference on our world in concrete & structures: 25 - 27 August 2008,Singapore*

[4] Sanchez F and Sobolev K (2010) Nanotechnology in concrete. *Constr Build Mater* **24**:2060–71

[5] Rajput N (2015) Nanotechnology in civil engineering and construction: a review. *Int J Res Eng Appl Sci.* **5**:208-14

[6] Xiao H, Li H, Du T, Li X, Jiang J and Ou J (2015) Dispersion characteristic of nano-$TiO_2$ in cement paste and its effect on the compressive strength and permeability *Nanotechnology in Construction*

[7] Srivastava A and Singh K (2011)Nanotechnology in Civil Engineering and Construction: a review on state of the art and future prospects. Reterived from https://www.researchgate.net/publication/266602017

[8] Liu *et al* (2012) Effect of nano-$CaCO_3$ on properties of cement paste.*16th International Conference on Future Energy, Environment, and Materials.* pp991-96

[9] Olar R (2011) Nanomaterials and nanotechnologies for civil engineering *Bulletin of the polytechnic institute of jassy constructions architecture* **4**:109-18.

[10] Morsy M S, Alsayed S H and Aqel M (2010) Effect of nano-clay on mechanical properties and microstructure of ordinary portland cement mortar. *Int J Civil Environ Eng* **10**:21-25.

[11] Kheiri F(2013) Material follows function: nanotechnology and sustainability in steel building constructions. *Int J Sci Res* **2**:1-5.

[12] Rao N V, Rajasekhar M,Vijayalakshmi K, Vamshykrishna M The future of civil engineering with the influence and impact of nanotechnology on properties of materials. *Procedia Materials Science* **10**:111-15.