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Research Paper

A REVIEW OF NANOMATERIALS IN CIVIL ENGINEERING WORKS

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The performance of conventional concrete can be improved by applying nanotechnology materials in constructional industry. The properties of materials actually become affected due to particle size at the length scale of nanometer, i.e., 10^{-9} m, based on this view, researchers have been pursuing to evolve new or alternative materials towards a green and sustainable solution. The Nanotechnology deals at a scale smaller than 100 nm (1 nm = 10^{-9} m). Due to their reduced size, nanomaterials properties vary considerably from bulk and thus they present exceptional mechanical and physical properties. The engineering of complex structure of cement based materials at nano level will definitely result in new generation of concrete, stronger and more durable with whole range of newly introduced smart properties. The nanotechnology materials have many unique characteristics but their material cost is very expensive due to novelty technology.

Keywords: Nanotechnologies, Nanoscience, Concrete and Civil Engineering Materials

INTRODUCTION

Nanotechnology, introduced almost half century ago and is one of the most active research areas with both novel science and useful applications that has gradually established itself in the past two decades. The evolution of technology and instrumentation as well as its related scientific areas such as physics and chemistry are making the research on nanotechnology aggressive and evolutional. Not surprisingly, it is observed that expenditure on nanotechnology research is significant. The US National Nanotechnology Initiative (NNI) expenditure exceeds $1 bn each year with president's 2008 budget for NNI at $1.5 bn. The research is mainly moving forward motivated by immediate profitable return generated by high value commercial products.

The nanotechnologies can be defined as the design, characterization, production and application of structures, devices and systems by controlling shape and size at the nanoscale. Nanotechnology requires advanced imaging techniques for studying and improving the material behavior and for designing and producing very fine powders, liquids or solids

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of materials with particle size between 1 and 100 nm, known as nanoparticles (Gogotsi, 2006). Nanoscience can be divided into three fields (i) Nanostructures; (ii) Nanofabrication; and (iii) nanocharacterization with typical application in nanoelectronics and life science and energy. The usage of technology materials while being incorporated in constructional structures would not help in prolonging in their lifetime but would also help keep a check on the energy spent by them at the same time gauging their reaction and reacting to different agents like fire, corrosion, water penetration and cracks, etc.

The purpose of reviews is to give clear image among the nanotechnology development areas where the construction process would immediately harness nanotechnology. By specifying clear recommendations. The information would be beneficial to both construction, engineering education and research.

BASICS OF NANOTECHNOLOGY

Nanotechnology is the creation of materials and devices by controlling of matter at the levels of atoms, molecules, and nanoscale structures (Roco *et al.,* 1999). In other words, it is the use of very fine particles of materials to create new large scale materials (Mann, 2006). The key is the size of particles because the properties of materials are dramatically affected under a scale of the nanometer (nm), i.e., 10^{-9} meter (m). To better understand the difference among various scales, Table 1 shows the categories of scales and its related topics (Balaguru, 2005).

Table 1: Scales Vs. Various Topics

S. No.	Scales	Various Topics
1.	10^{-12}	Quantum Mechanics
2.	10^{-9}	Molecular Dynamics
		Nanomechanics
		Biophysics
3.	10^{-6}	Elasticity Plasticity Dislocation
4.	10^{-3}	Mechanics of Materials
5.	10^{-0}	Structural Analysis

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. Most promising developments of nanotechnology are fullerene (a new form of carbon, C60) and carbon nanotubes (Sobolev and Gutierrez, 2005). The new features of construction materials and elements accordingly change the material usage and resistance calculations of project design and its related field construction operation and management.

APPLICATION OF NANOTECHNOLOGY IN CONSTRUCTION

Nanotechnology can be used for design and construction processes in many areas due to their unique characteristics. These characteristics of nanomaterials can significantly fix current construction problems and may change the requirement and organization of construction process.

These include products that are for:

- Lighter and stronger structural composites.
- Low maintenance coating.
- Improving pipe joining materials and techniques.
- Better properties of cementitious materials.
- Reducing the thermal transfer rate of fire retardant and insulation.
- Increasing the sound absorption of acoustic absorber.

Nanotechnologies For Cement

Portland cement is a versatile materials and is widely use in construction site. It has been discussed that concrete utilized nanotechnology because it contains nano particles as ingredient including nano water particles and nano air voids. A combination of nanosilica, sodium aluminate and sodium hydroxide gives nanocement. Reducing CO_2 emissions alongside providing high compressive strength. 50% replacement of nanocement along with mortar gives strength upto 86.97 N/mm^2 at the end of 21 days and avoiding air gaps by virtue of large specific surface area (3582400 cm^2/g) are some of the properties offered by addition of nanocement to the construction materials (Jemimah *et al.*, 2012**)**. Reduction of penetration of water, filling up air spaces, increasing compressive strength over a prolonged period of time are some of the positive results obtained on mixing nanoparticles in the conventional cement.

Nanotechnologies For Concrete

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. Addition of nanoscales materials in the cement improves the compressive strength of cement mortar as well as concrete specimens. The addition of small amounts (1%) of carbon nanomaterial can increase the mechanical properties of mixture samples of concrete. (Mann, 2006) shows the best improvements both in compressive strength and flexural strength of concrete as compared to the reference samples with insertion of nanosilica in concrete. Li (2004) found that nanosilica could significantly increase the compressive strength for concrete containing large volume fly ash at early age and improve pore size distribution by filling the pores between large fly ash and cement particles at nanoscale. CO_2 emissions from the global cement industry are significant and they are increasing on high scale. Global cement production is currently around 1.6 billion tons/ year and through the calcinations of limestone approximately 0.97 tons of CO_2 is produced for each ton of clinker produced.

Nanotechnologies For Self Compacting Concrete

Self-Compacting Concrete does not need vibration in order to level off and achieve consolidation. This represents a significant advance in the reduction of the energy needed to build concrete structures. In addition SCC can offer benefits of up to 50% in labor costs, due to it being poured up to 80% faster and having reduced wear and tear on formwork. The material behaves like a thick fluid and is made possible by the use of polycarboxylates. SCC mixes, which contain a high content of fine particles, need a very effective dispersing system in order to be fluid and workable

overtime at low water/cement ratio (high W/C ratios would lead to risk of segregation) and only polycarboxylates can meet these requirements. A fibre sheet (matrix) is used, containing nano-silica particles and hardeners. These nano-particles 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. There is no decrease in the maximum load capacity after repeated cycles of wetting and drying or scaling.

Nanotechnologies For Steel

Steel is another prominent construction material and is provided in all the buildings structures. The significant properties of steel are tensile strength and corrosive resistance. In India, new low carbon high performance steel for bridges has been developed. This kind of new low carbon steel with high strength and higher corrosive resistance through the incorporation with nanomaterials reduces the surface unevenness of steel which then limits the number of stress risers and hence stress fatigue cracking.

Nanotechnologies For Structural Composites

Since, steel is a major construction unit. Its properties such as strength, corrosion resistance and weld ability play very important role for the design and construction of building. Nanotechnology materials are added to paints in order to assure the corrosion protection under insulation since it is hydrophobic and repels water from the metal pipe and can also protect metal from salt water attack. It protects the walls of building for a long period of time without need of much maintenance and acts as green product.

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

Micro and nanoporous aerogel materials are appropriate for being core materials of vacuum insulation panels and are sensitive to moisture. As a possible remedy it was produced an ultra-thin wall insulation which uses a hydrophobic nanoporous aerogel structure. Another application of aerogels is silica based products for transparent insulation, which leads to the possibility of super-insulating windows. Micro or nanoelectromechanical systems offer the possibility of monitoring and controlling the internal environment of buildings and this could lead to energy savings.

COST

At this moment the nanotechnology materials and equipment costs very 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, material cost will cut down over time as manufacturing technologies will upgrade their products.

CONCLUSION

The application of Nanomaterials and nanotechnologies has attracted considerable scientific interest in civil engineering due to the new potential uses of particles in nanometer scale. Since the construction industry is heavily involved in economic development and consumes great amount of resources and energy and its impact on environment is significant. Focused research and practice efforts are needed into nanotechology for construction products and therefore save energy, reduce resources usage and avoid damages to environment. This would significantly help the readers such as civil engineers and contractors to establish a system environmental friendly and sustainable of construction with nanomaterials and to avoid the use of harmful materials in future.

REFERENCES

1. ARI News (2005), "Nanotechnology in Construction – One of the Top Ten Answers to World's Biggest Problem", www.aggregateresearch.com/article.asp?id=6279, May 03, 2005.
2. Balaguru P N (2005), "Nanotechnology and Concrete: Background, Opportunities and Challenges." *Proceedings of the International Conference – Application of Technology in Concrete Design*, Scotland, UK; pp. 113-22, 2005.
3. Carmichael J, Prince M and Arulraj G (2013), "Influence of nano materials on consistency setting time and compressive strength of cement mortar," *IRACST-Engineering Science and Technology: An International Journal, ESTIJ,* Vol. 2, No. 1, pp. 158-162.
4. Gogotsi (2006), *Nanomaterials Handbook*. Taylor & Fraicis Group, LLC, pp 1-2.
5. Liu R, Zhang Z, Zhong R, Chen X and Li J (2007), "Nanotechnology Synthesis Study: Research Report".
6. Mann S (2006), "*Nanotechnology and Construction",* European Nanotechnology Gateway - Nanoforum Report, Institute of Nanotechnology; 2-10, November 2006.
7. NNI, Nanotechnology and the environment. Report of a National Nanotechnology Initiative Workshop, May 8-9, Arlington, VA, 2003.
8. Roco M C, Williams R S, and Alivisatos P (1999), "*Nanotechnology Research Directions*": IWGN Research Report. Committee on Technology, Interagency Working Group on Nanoscience, Engineering and Technology (IWGN), National Science and Technology Council.
9. Saafi M and Romine P (2005), "Nano- and Microtechnology", *Concrete International*; Vol. 27, No. 12, pp 28-34, 2005.
10. Sobolev K and Gutierrez M F (2005), "How Nanotechnology can Change the Concrete World", *American Ceramic Society Bulletin*; Vol. 84(10), pp. 14-16.