NANOTECHNOLOGY IN CIVIL ENGINEERING AND CONSTRUCTION: A REVIEW

Namita Rajput

Departmentt of Science & Humanities,

Govt. Polytechnic College,

Balaghat (M.P.) India 482001

Abstract :Nanotechnology is one of the most active research areas that encompass a number of disciplines, including civil engineering and construction materials. However, the potential for application of many of the developments in the nanotechnology field in the area of construction engineering has been growing. The paper review the sustainable usage of nano based materials like carbon nanotube, electrochromic windows,sandviknanoflex™, nanowires, titanium dioxide, nanoceramic coating, nanocrystalline materials, nanosilica, nanocomposites, MMFX2 steel, nanometals, nanofibres, nanomyte™ mend MW, nanocement, which could be used for providing singular or multiple functions of potential reinforcement, corrosion resistance, insulation, fire protection, temperature resistance, reducing air conditioning loads, pollution control, UV ray absorption, lighting, when used as a part of building materials.

Keywords *: Civil Engineering, Nano-materials, Nanotechnology,nanoscale, Sustainability.*

1. Introduction

Because nanotechnology is still evolving, there doesn't seem to be any one definition that everybody agrees on. Nanotechnology is the creation of materials and devices by controlling matter at the level of atoms, molecules, and superamolecular (nanoscale) structures. In other words, it is the use of very small particles of materials to create new large scale materials [Mann, 2006]. Depending on the size Nanotechnology is define as the study and use of structures between 1 nanometer (nm) and 100 nanometers in size. The word Nano is a scientific prefix that stands for 10^{-9} or one-billionth; the word itself comes from the Greek word NANOS, meaning dwarf [Patel et. al., 2013].

Different things start to happen at nano level e.g. gravity becomes unimportant, electrostatic forces take over and quantum effects get in. 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 change in the properties [Saurav, 2012]

Nanotechnology can generate products with many unique characteristics that can improve the current construction materials: lighter and stronger structural composites, low maintenance coatings, better cementitious materials, lower thermal transfer rate of fire retardant and insulation, better sound absorption of acoustic absorbers and better reflectivity of glass [Lee et al., 2010].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.[Olar, 2011] . With the help of nanotechnology, concrete is stronger, more durable and more easily placed, steel is made tougher, glass is self cleaning and paints are made more insulating and water repelling.[Srivastava et. al., 2011]

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 being utilized.[Olar, 2011]Compared with other major industrial sectors, construction industry has lagged behind in awareness of the potential for exploitation of nanotechnology. Both the awareness and actual exploitation in construction are now increasing, however, progress is uneven, especially in the current early stages of its practical exploitation.[Peter, 2006]

The report of RILEM TC 197-NCM, "Nanotechnology in construction materials" [Zhu et al., 2004], is the first document that establish 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 increase 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.

Current researchers dealing with nano- science and nanotechnology are exploring these novel properties since at nano- scale, we can alter the macro-properties and produce significantly new materials and processes. Discussion on the application of nanotechnology in civil engineering, specifically in construction, is extremely important.[Firoozi et al., 2014,]

2. Applications Of Nanotechnology In Civil Engineering

However, the potential for application of many of the developments in the nanotechnology field in the area of construction engineering is growing[Rana et al, 2009]. The usage of nanotechnology materials while being incorporated in constructional structures would not only help in increasing their lifetime, but would also keep a check on the energy spent by them and at the same time gauging their reactions and reacting to different agents like fire, corrosion, water penetration, fractures, cracks, etc.[Das et. al. 2014] These characteristics can, again, significantly fix current construction problems, and may change requirement and organization of construction process. Some of its applications are discussed in detail below:[Ganesh, 2012]

Concrete

Concrete is one of the most common and widely used construction materials is, a macro-material strongly influenced by its nano-properties. Addition of nanoscale materials into cement could improve its performance. Li (2004) found that nano-SiO2 could significantly increase the compressive 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. The dispersion/slurry of amorphous nanosilica is used to improve segregation resistance for self-compacting concrete [Rana et al, 2009].

Addition of nano-silica 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 improve its durability. Nano-silica particles, better known as silica fume, improve the overall panicle packing in concrete matrix resulting in very high compressive strengths (>15,000 psi1) [Saurav, 2012].

Another type of nano particle added to concrete to improve its properties is titanium dioxide (TiO2). Titanium Dioxide Nano-powder added to concrete can give ability to break down dirt or pollution and then allow it to be washed off by rain water on everything from concrete to glass. TiO2 is a white pigment and can be used as an excellent reflective coating. It is incorporated, in sun-block to block UV light and it is added to paints, cements and windows for its sterilizing properties since TiO2 breaks down organic pollutants, volatile organic compounds, and bacterial membranes through powerful catalytic reactions. It gives self-cleaning properties to surfaces to which it is applied. The resulting concrete, already used in projects around the world, has a white colour that retains its whiteness very effectively unlike the stained buildings of the material's pioneering past. [Saurav, 2012]

A further type of nanoparticle, which has remarkable properties, is the carbon nano tube (CNT) Nanotubes are members of the fullerene structural family and exhibit extraordinary strength and unique electrical properties, being efficient thermal conductors. For example, they have 5 times the Young's modulus and 8 times (theoretically 100 times) the strength of steel, whilst being 1/6th the density. 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/mm2) and flexural strength (+ 8 N/mm) compared to the reference samples without the reinforcement.[Saurav, 2012, Lee et al., 2010].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 [Olar, 2011, Mann, 2006].

The Shewanella microorganism was used at a concentration of 105 cells/ml and nanoscale observations revealed that there was a deposition of sand-cement matrix on its surface. This led to the growth of filler material within the pores of the cement- sand matrix and resulted in increased strength.[Saurav, 2012, Ganesh, 2012]

Finally, fibre wrapping of concrete is quite common today for increasing the strength of pre-existing concrete structural elements. An advancement in the procedure involves the use of a fibre 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 fibre reinforcement.[Saurav, 2012, Ganesh, 2012]

Steel

Steel has played a major role in the construction industry since past two centuries. Fatigue is a significant issue for the structural failure of steel subjected to cyclic loading, such as in bridges, towers, and off-shore platforms. Fatigue failure can occur at significantly low stresses than the yield stress of the material and lead to a significant reduction in service life. 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. Furthermore, it has been reported that vanadium and molybdenum nano-particles can improve the fracture problems associated with high strength bolts. The addition of nanoparticles of magnesium and calcium leads to an increase in weld toughness[Nippon 2005, Firoozi et al., 2014,].

Two relatively new products that are available today are SandvikNanoflex and MMFX2 steel .Both are corrosion resistant, but have different mechanical properties and are the result of different

applications of nano technology. SandvikNanoflex 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. MMFX2 is nanostructure-modified steel. Due to the modified nanostructure, MMFX steel has superior mechanical properties, e.g. higher strength, ductility and fatigue resistance, over other high-strength steels. These material properties can lead to longer service life in corrosive environments and lower construction costs. .[Saurav, 2012, Ganesh, 2012]

Wood

Carbon nanotubes are a new discovery, whereas wood is an ancient material which has been used since the dawn of civilization. Wood is also composed of nanotubes or "nanofibrils";namely, lignocellulosic (woody tissue) elements which are twice as strong as nanofibrils would lead to a new paradigm in sustainable construction as both the production and use would be part of a renewable cycle. Lignocellulosic surfaces at the nanoscale could open new opportunities for such things as self-sterilizing surfaces, internal self- repair, and electronic lignocellulosic devices, providing feedback for product performance and environmental conditions during service (Mann, 2006). Due to its natural origins, wood is leading the way in cross-disciplinary research and modelling techniques. Highly water resistant coating, integrated by silica and alumina Nano particle and polymer of hydrophobic are implemented for wood.[Saurav, 2012, Ganesh, 2012, Olar, 2011]

Glass

Fire-protective glass is another application of nanotechnology. This is achieved by using a clear intumescent layer sandwiched between glass panels (an interlayer) formed of fumed silica (SiO2) nanoparticles which turns into a rigid and opaque fire shield when heated. TiO2 coating captures and breaks down organic and inorganic air pollutants and bacterial membranes by a photo-catalytic process. Because of the hydrophobic properties of TiO2, it can be applied in antifogging coatings or in self-cleaning windows . Nano-TiO2 coatings can also be applied to building exteriors to prevent sticking of pollutants, and thus reduce a facility's maintenance costs [Zhu W., 2004]. Most of glass in construction is on the exterior surface of buildings. So the light and heat entering the building through glass has to be prevented[Firoozi et al., 2014, Patel, 2013,Srivastava et. al., 2011]

Nanotechnology In Fire Protection

The application of Portland cement based coatings for fire protection of steel structures is no more popular since it is thick, tends to be brittle, and polymer additions are needed to improve adhesion with steel surface. Nano-cement (made of nano-sized particles) has the potential to create a tough, durable, high temperature coatings. This is achieved by the mixing of carbon nanotubes (CNT's) with the cementious material to fabricate fibre composites that can inherit some of the outstanding properties of the nanotubes such as strength. Polypropylene fibres are also being considered as a method of increasing fire resistance and this is a cheaper option than conventional insulation. CNTs can also be used to produce protective clothing materials because of their flame retardant property.[Firoozi et al., 2014, Ganesh, 2012]

Nano sensors

Nanotechnology enabled sensors/devices which exhibit 'self-sensing' and 'self-actuating' capability also offer great potential for developing smart materials and structures.. 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. MEMS sensors range from 10-9 m to 10-5 m which could be embedded into the structure

during the construction process. These sensors could be embedded into the structure during the construction process. 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 [Song Gl., 2008]. 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. Also it can provide an early indication before a failure of the structure occurs .Thus the sensors are able to work as self-health monitoring system.[Ge Z., 2008, Rana et al, 2009, Ganesh, 2012]

Nano technology in waterproofing building materials

Waterproofing of building materials has been a problem since last 1000 years. The problem has not been addressed completely due to lack of understanding at nano level of the building material. The new development in science & technology has allowed using the latest nano technology to produce eco-friendly Organo-Silicon products to waterproof practically all the different kinds of building materials. The nano technology has ensured that service life of this approach will lead to life cycles beyond 20 to 30 years at very economical cost. Building materials are known to have water seepage, water leakages due to inherent porosity and microcracks.Waterproofing is a treatment, which is expected to make the material impervious to water. Lots of technology and product development has taken place in various waterproofing products for the last 50 years, particularly using polymeric backbone and variety of other materials. Another seriousissue waterproofing addresses is to prevent loss of structural strength of concrete building materials, particularly due to ASR (alkali silicareaction), acid rain, sulphate attacked. It also prevents chloride penetration which can result in corrosion of the reinforced steel bars [Saurav, 2012].

Coating Paints and Isolation Materials

Coating is also one of the important area in construction; coatings are extensively use to the walls, doors, and windows. Coatings should provide a protective layer bound to the base material to produce a surface of the desired protective or functional properties. C6 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 are currently available. Since these coatings are hydrophobic and repel water from the metal pipe and can also protect metal from salt water attack. Nanoparticle based systems can provide better adhesion and transparency. Silica aero gel particles with nano sized pores in combination with reinforcing fibers paints and coatings are besides on aesthetics arguments and protection also used for insulating properties. C5 In addition to the self-cleaning coatings mentioned above for glazing, the remarkable properties of TiO2 nanoparticles are put to use as a coating material on roadways in tests around the world [Patel, 2013, Mann, 2006].

3. Future Challenge and Recommendations

As the most developing technologies, a large number of challenges exist during its practical usage. It is important to be realistic and identify and plan for the limitations and challenges inherent in this process. [Rana et al, 2009] Health and environmental issues combine in nanoparticles and nanotechnology research is one main cause of concern. It is known that nanoscale particles are likely to be more reactive than the same material in bulk, and that nanoparticles may be able to penetrate human cells [nano-jap].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[Shakibabarough et al., 2014] :

1. Applied training regarding how to deal with the risks of nano-particles.
2. Passing the essential rules and regulations by which the environment and people are protected from possible risks.
3. Disposal and transporting of nano-particles wastes according to the principles of hazardous chemical waste.
4. 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.
5. A nano particle can be designed to be completely safe for the environment which does not have any v A coating on the nano-particles reduced the formation of free radicals, causing the particles to be more secure.

4. Conclusion

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. Overall, beyond the current excitement about the possibilities of nanotechanology to enhance our infrastructure, there are reasonable concerns about unintended consequences. This underscores the need to support research into safe design, production, use, and disposal practices and associated recycling, reuse, and remanufacturing initiatives that enhance the sustainability of both the nanotechnology and construction industries.

References :

[1] Das B.B. and Mitra A., 2014, Nanomaterials for Construction Engineering-A Review, International Journal of Materials, Mechanics and Manufacturing, 2(1), pp41-46.

[2] Firoozi A. A.,Taha M.R. and Firoozi A. A., 2014, Nanotechnology in Civil Engineering, EJGE, 19, pp4673-4682.

[3] Ganesh V.K., 2012, Nanotechnology in Civil Engineering, European Scientific Journal, November edition 8(27), pp96-109.

[4] Ge Z. and Gao Z., 2008, Applications of Nanotechnology and Nanomaterials in Construction, First Internat.Conf. on Constr. In Develop. Countries (ICCIDC–I): —Advancing and Integrating Construction, Education, Research & Practice||, Karachi, Pakistan, pp235-240,

[5] Lee J., MahendraS.H. and Alvarez P.J.J., 2010, Nanomaterials in the Construction Industry: A Review of their Applications and Environmental Health and Safety Considerations., ACS Nano, 4(7), pp3580-3590.

[6] Li G., 2004, Properties of High-Volume Fly Ash Concrete Incorporating Nano-SiO2, Cement and Concrete Research, 34, pp1043-1049.

[7] Mann S., 2006, Nanotechnology and Construction. European Nanotechnology Gateway - Nanoforum Report, Institute of Nanotechnology, pp2-10.

[8] Nippon Steel Technical Report No.91 January (2005) .

[9] Olar R., 2011, Nanomaterials and Nanotechnology for Civil Engineering, Bul. Inst. Polit. Iaşi, t. Lvii (Lxi), f. 4, pp110-117.

[10] Patel A. S., 2013, An Overview on Application of Nanotechnology in Construction Industry, IJIRSET, 2(11), pp6094-6098.

[11] Peter J. M. Bartos, Nanotechanology in construction : A Roadmap for development, Proceedings of ACI Session on "Nanotechnology of Concrete: Recent Developments and Future Perspectives" November 7, 2006, Denver, USA pp1-14.

[12] Pilkington, http://www.activglass.com/.

[13] Rana A.K.,Rana S.B., Kumari A. and Kiran V., 2009, Significance of Nanotechnology in Construction Engineering, International Journal of Recent Trends in Engineering, 1(4), pp46-48.

[14] Saurav, 2012, Application Of Nanotechnology In Building Materials, IJERA,2(5), pp1077-1082.

[15] Shakibabarough A.,Valinejadshoubi M. and Valinejadshoubi Mo., 2014, Useable and PrecautionaryAspects of Using Nanotechnology and Nano- materials in the Construction Industry, International Journal of Science, Engineering and Technology Research (IJSETR), 3(4), pp841-848.

[16] Srivastava A. and Singh K., 2011, Nanotechnology in Civil Engineering and construction : A review on stste of the art and future, Proceedings of Indian Geotechnical Conference, December 15-17, Kochi, Pp1077-1080.

[17] Zhu W.,Bartos P.J.M. and Gibbs, J., 2004, Application of nanotechnology in construction, Summary of a state-of-the-art report, Journal of Material and Structures, 37, pp649-658.