Chapter 51
Advances in Building Materials Industry by Annexation of Nano Materials

Ashmita Rupal, Sanjay K. Sharma, and G. D. Tyagi

Abstract With the advances in the field of nanotechnology different aspects are being explored time to time to a significant extent to take up the problems in both stages of design and construction. Amongst others, the nanotechnology sciences are the utmost dynamic research areas with great exploration potential. Its application in multidisciplinary fields has been delved into a number of other fields and disciplines for example in development of composite materials for civil, mechanical, electrical engineering and many others. This paper represents the various studies and researches carried out related to the sustainable utilization of different nano materials such as nano fibers, carbon nanotube, titanium dioxide, nano based coatings, nano silica and many others which provide significant utility in improving strength characteristics in cement and concrete materials along with other enhancements such as insulation, UV ray absorption, lighting, waterproofing, potential reinforcement, fire protection, corrosion resistance and many more when used as building materials. Also, this paper highlights the utilization of nano based structural and functional materials which are used during construction, manufacturing of building materials and also for repair and protection of structures. Hence will aid researchers about the most recent progress of using nanotechnology in field.

Keyword Nano materials · Nano technology · Sustainability · Building materials

51.1 Introduction

Nanotechnology and nanomaterials are now being used in civil engineering at the turn of the century. The recognition of nanomaterials' enhanced strength and lower density had already solved numerous building and construction constraints. The

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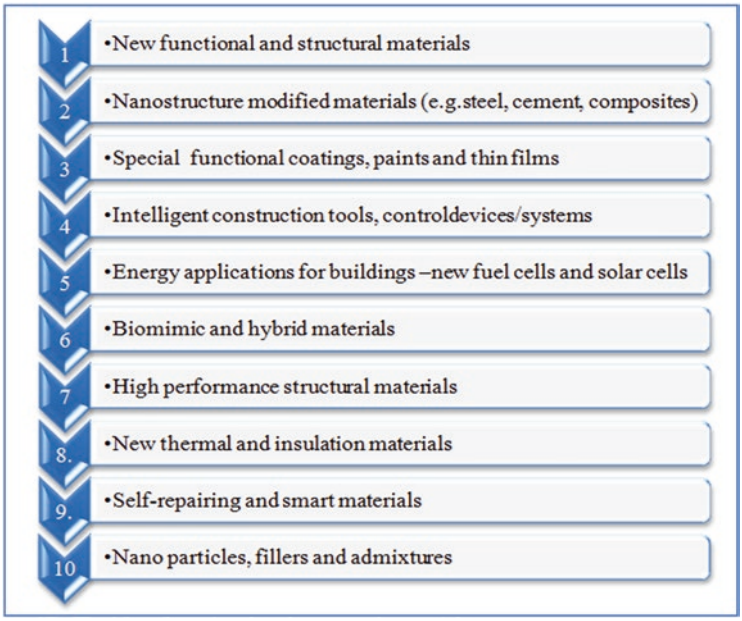
study of handling materials at the nanometre scale and then using the characteristics and properties of this dimension in different techniques, materials, and systems is known as nano science and nanotechnology. Nanotechnology is involved with particles whose size range between 1 and 100 nanometres (1×10 m = 1–9 nanometres). In analytics related to nanotechnology science, there is requirement of advanced imaging tools and different tools for optimization related to different composite material fabrication as well as their engineering from the raw base nanomaterials in form of solids, fluids, liquids or in molten form, fine powders with particle sizes ranging from 1 to 100 nanometres (Saurav 2012). Nanotechnology enables the development of matrixes with high sensitivity, high-density, specific catalytic and high strain resistance, wider coverage area, and catalytic effects (Syed 2014). However, the potential for nanotechnology to be used in the field of construction engineering is continuing to expand. According to recent researches it has been found that (Mann 2006) new nanotechnology-based goods will have a significant impact on people's quality of life, the environment, and defence capabilities. The paper reviews the application of nanotechnology in building construction material. This paper introduces and emphasizes the use of nanomaterials in construction. The purpose is to report the scientific reference of the various requisites associated with the scope of nanotechnology and hence providing an allied reference to correspond these nanotechnology science issues to various relevant stakeholders and dealers.

51.2 Importance of Nanotechnology in Building Materials

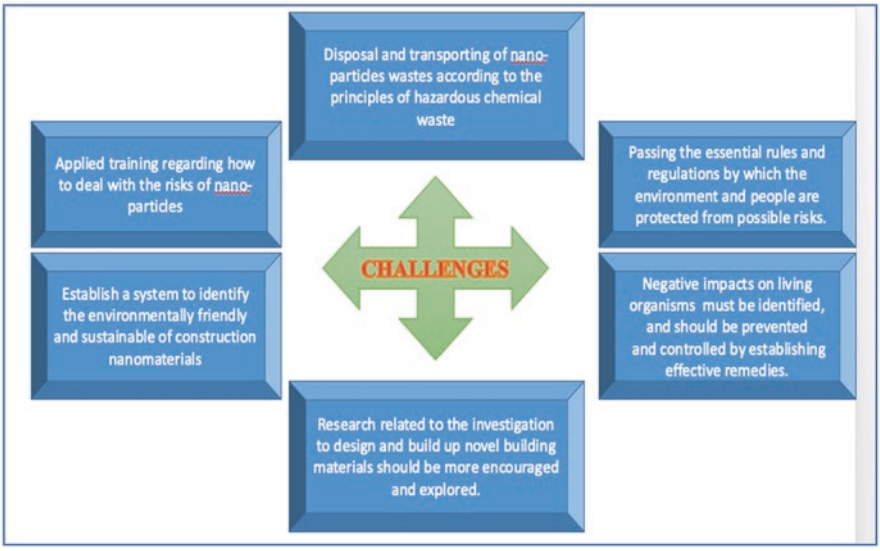
Building materials play the major role in construction industry being the main constituting material of the infrastructures. Most significant structural, economic and aesthetic aspects are associated with the building materials. Cement, bricks, concrete, timber, stones, steel, glass, polymers and a variety of metals have been among the most construction materials (Bigley and Greenwood 2003). Humans used stone and timber to build shelters against natural calamities, animals, and other calamities in the past, since these are the ancient materials. Building materials, like all other things, have continued to evolve, including concrete and steel presently dominating in the building and construction industry. New smart materials are being designed and developed by researchers and engineers across the world as a result of technological advancements, and this process is indeed maintain track.

51.3 Application of Nanotechnology in Building Materials

A brief overview of different domains of nanotechnology science in the construction and building materials is shown in the Flow Chart 51.1 below. Important environmentally safe nanomaterials with potential use in construction industry are discussed here in Table 51.1 below.



Flow Chart 51.1 Overview of use of nanotechnology in building materials



Flow Chart 51.2 Challenges faced in using nano particles and nanotechnology in construction industry

Table 51.1 Environmentally safe nanomaterials with potential use in construction

S.No	Application/ potential use area in construction industry	Nano based materials	Detail
1.	Cement and Concrete	Nano-Silica (SiO_2) Carbon Nano Tubes(CNTs)/ Multiwalled Nanotubes(MWCNTs, Titanium dioxide (TiO_2).	The adjunction of nano-silica (SiO_2) and other substances to the cement based raw material scan limit the calcium silicate hydrate (C-S-H) reaction minimizing the penetration of water and strengthening durability. The physico-mechanical properties of fabricated samples developed increase exponentially when relatively small amounts (1 percent) of carbon nanotubes are added. When compared to the reference samples, oxidised multiwalled nanotubes (MWCNTs) exhibit the significant improvements in compressive and flexural strength (Ge and Gao 2008). Addition of titanium Dioxide Nano-powder to the concrete can breakdown the grime or pollutants, enabling it to be completely removed by rainwater on everything from concrete to glass, and it can also be utilised as a reflective coating. TiO_2 uses significant catalytic end results to splitting down of the organic contaminants, VOCs (volatile organic compounds) and also presence of different bacterial membranes. It gives applied surfaces self-cleaning positive attributes (Worrell et al. 2001). The resulting concrete, which has already been utilised in projects all over the world, has a white colour that material's early stages holds its whiteness exceptionally well. In addition, concrete fibre wrapping is widely used nowadays to improve the potency of strength of different RCC structural parts. The utilization of a fibre sheet made up from composite matrix (encompassing nano-silica particles and suitable resin-hardeners has revolutionized the method. These nanoparticles infiltrate and repair the disruptions, minor cracks producing a resilient link among the substrates such as concrete surface and the fibre reinforcement making it robust for the strengthening applications (Raval et al. 2013).

(continued)

Table 51.1 (continued)

S.No	Application/ potential use area in construction industry	Nano based materials	Detail
2.	Wood	Carbon Nano Tubes (CNTs)/Multiwalled Nanotubes (MWCNTs); Silica and Alumina Nanoparticles	Wood often made by nanotube or "nanofibrils". Internal self-repair and self-sterilizing surfaces could be facilitated by lignocellulosic surfaces at the nanoscale. Wood is coated with substantially engineered water resistant coatings which hydrophobic polymers in its structure along with silica and alumina (Adams 2009).
3.	Steel	Copper Nanoparticles, Vanadium and Molybdenum Nanoparticles, Magnesium and Calcium Nanoparticles	Copper nanoparticles minimize steel's surface unevenness, which lessens fatigue cracking and results to an even more efficient material with better protection that necessitates less monitoring. By enhancing the steel microstructure, the nanoparticles of vanadium and molybdenum solve the issue of deferred fracture difficulties related to use of high strength bolts. And the weld toughness is improved by adding Magnesium and Calcium nanoparticles (Freitag and Stoye 2008). Two noval products are also available today named MMFX2 steel and SandvikNanoflex. These are manufactured as a result of different applications of nano technology making them corrosion resistant with significant mechanical properties.
4.	Glass	Titanium dioxide (TiO_2), Nano-Silica (SiO_2)	Self-cleaning technology is accomplished by coating glasses with TiO_2 nanoparticles. Because of its hydrophobic qualities, TiO_2 coatings are used in antifogging coatings and self-cleaning windows to absorb and break down different organic as well as inorganic air pollutants along with the bacterial membranes through a photo-catalytic reaction process. Nano-TiO_2 can also be used in coatings fabricated for the building facades which avert the pollutants from adhering to them, lowering maintenance expenses (Das and Mitra 2014). Fumed silica (SiO_2) nanoparticles are used as an interlayer placed between the two glass panels to create fire-resistant glass, which when heated becomes a rigid and opaque fire shield.

(continued)

Table 51.1 (continued)

S.No	Application/ potential use area in construction industry	Nano based materials	Detail
5.	Waterproofing Building Materials	Silicon, nano based polyurethane mix, polymer composites	The current advancements in science and technology have enabled the use of cutting-edge nanotechnology to create eco-friendly Organo-Silicon solutions that waterproof virtually all types of building materials. For the past 50 years, a lot of science and product development has gone into various waterproofing goods, particularly with polymeric main components and a range of other materials (Hossain and Rameeja 2015). Another important issue that waterproofing addresses is the deficit of concrete structural strength, especially as a result of ASR (alkali silica reaction), acid rain, and sulphate damage.
6.	Coating Paints and Isolation Materials	Silica aero gel particles, TiO_2 nanoparticles, C6 Nanotechnology	Coatings usually provide required protecting as well as functional properties. Usage of C6 Nanotechnology is quite useful for paints, membranes or coating for providing properties such as waterproofing property, thermal and sound insulating properties which is achieved by the addition of nano particles. Being hydrophobic, such coatings provide metal the protection from acid/saline water ingress. Nanoparticle based composite materials or matrixes with certain polymers provide enhanced adhesion, elongation and strength properties. Silica aero gel particles in blend proportioning amid reinforcing materials in various application of paints and different coatings and usually delivers insulating properties. Because of properties of TiO_2 nanoparticles, its coatings are also used for glazing and now a days research is going on to use it as an overlay material in road and highway construction (Bigley and Greenwood 2003).

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Table 51.1 (continued)

S.No	Application/ potential use area in construction industry	Nano based materials	Detail
7.	Nano technology in Fire Protection	Carbon Nanotubes (CNT's)	Steel constructions are basically made fire resistant with a spray-on cementitious coatings. Also the nano-cement comprises of nanosized particles which have the capability to boost toughness, durability and help in achievement of elevated temperature resistant coatings. Such composition is achieved by integrating carbon nanotubes in cement to develop fibre composites with multiple functionalities such as enhanced strength.
8.	Nanotechnologies for Water Purification	Carbon Nanotubes, Alumina Fibers, titanium oxide nanowires or palladium nanoparticles	Carbon nanotubes and alumina fibers are used water purification purpose also called as nanofiltration. The use of small perforations in zeolite filtration membranes, nano catalysts, and magnetic nanoparticles is its working principle. For analytical monitoring of pollutants in water samples, titanium oxide nanowires and palladium nanoparticles are employed. Charged particles, chemical effluents, sediments, bacteria, and other pathogens can all be eliminated with it.

51.5 Drawbacks and Future Challenges

Despite all the numerous advantages of Nano based materials, vast amount of confronts and challenges exist which are associated with the practical implementation and use of nano particles. Health issues is one of the main concerns associated with the use of nanoparticles and nanotechnology. As nanoscale particles are credibly extra responsive in comparison to that of the same material present in majority i.e in bulk volume. So the repercussions and effects should be potentially recognized and proper prevention and eradication methods and techniques should be employed. The main challenges which are faced in using nanoparticles and nano technology in construction industry are shown in Flow Chart 51.2 below.

51.6 Conclusions

Although the overall market segment of nanoparticle-based composite materials and products in the construction sector is not such significant and regarded as a part in only niche markets, but it is anticipated to expand in the upcoming times. Because nanoparticles are clearly imperative in providing an innovative and effective framework for the processing, designing, fabricating and manufacturing of materials in the building and construction industry. It is concluded that the usage of nanomaterials and application nano technology in construction industry is feasible and workable in four main domains of expansion: cement and concrete manufacturing; coatings and paintings; sound and thermal insulations, additive in word, glass, steel etc. Hence the application of nano based structural and functional materials during design, development, construction, manufacturing of building materials and also for repair and protection of structures should be more emphasized and research in this domain should be encouraged for attaining the desirable usage.

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