Preface

Nanotechnology is a subject of material science that encompasses nano particles. A nano particle has at least one of its dimensions in nanometers. Its significance was revealed when it was observed that the materials drastically change their characteristics when they are ground to nano size. The importance of nanotechnology related research and development is now well-recognized worldwide. A huge public and private investment is now involved into research and development in a number of industrial sectors, where nanotechnology has become established and has led to new commercial products.

During the last few years, nanotechnology has offered vast opportunities from microelectronics to aerospace and civil engineering is not an exception. Nanomaterials are gaining very rapid recognition in all engineering fields due to some unique advantages, they offer over conventional materials. Its utilization in civil engineering is twofold: Direct incorporation in existing materials like concretes and paints or grinding of materials itself like cement to nano-scale. During the past few years, it has been well established that nano materials owing to their higher strength and lower density are very useful for construction industry.

A DESCRIPTION OF WHERE THE TOPIC FITS IN THE WORLD TODAY

Construction industry faces broad range of challenges ranging from performance of materials to the health & environmental issues. Recent improvements in various areas of nanotechnology have shown noteworthy promise in addressing many of these challenges. Application of nanotechnology can improve the performance of traditional construction materials; such as concrete, glass, steel, paint, insulating materials, etc. Significant improvements in concrete strength, durability and sustainability are being achieved with considered use of nanoparticles nanoparticles. A range of nanomaterials are also being used to add new functionalities, such as self-cleaning properties, to traditional construction industry products, for example paint, glass,
mortar, cement and concrete. Nanomaterials such as nano-alumina and nano-silica may be used for the stabilization of the concrete mixes in reinforced concrete pavement. Nano-silica has been observed to improve the rheological characteristics and microstructural properties of cement paste. The fabrication of nanoclays composites has also been conducted by researchers to produce engineered nanoclays which have mineralogical materials such as montmorillonite. It has been used by researchers along with other sedimentary clays to produce the nanosoils. These nanoclays can then be used as an additive that may enhance the asphalt binders’ mechanical characteristics. Researchers have observed that the addition of nanoclays may increase the complex shear modulus and the asphalt binders’ viscosities and may also produce significant effects on the lower temperature resistance against cracking depending upon the percentage, type and mixing procedure of the nanoclays and the asphalt binders. Our ability to design new materials from the bottom up is influencing the building industry. New materials and products based on nanotechnology can also be found in building insulation, coatings, and solar technologies. Work now underway in nanotech labs will soon result in new products for lighting, structures, and energy. In the building industry, nanotechnology has by now brought to market self-cleaning windows, smog-eating concrete, and many other progresses. But, these developments and currently available products are slightly compared to those incubating in the world’s nanotech labs these days. There, work is happening on illuminating walls that change color with the flip of a switch, nanocomposites as thin as glass yet capable of supporting entire buildings, and photosynthetic surfaces making any building frontage a source of free energy. Furthermore, treatment procedure of wastewater, which is one of the major issues in the current era, can also be enhanced by the use of nanoparticles. The TiO2 nanoparticles can also attach themselves to the chitinous exoskeleton of the animals leading to obstruct molting, which is necessary for the growth in juveniles. This phenomenon may kill such animals thus having serious negative effects on the environmental balance in long term. Nano scale adsorbents exhibit remarkable adsorption performance which owes to its enhanced characteristic features such as extremely high specific surface area, small size, availability of good number of active sites for different kind of pollutants, short intraparticle diffusion distance tunable porosity and easily recyclable without significant loss in adsorption capacity. In short, the application of nanotechnological innovations deals with a highly multidisciplinary field of engineering. Nanotechnology is expected to bring massive changes in robotics, chemical, mechanical, biological, civil as well as electrical engineering. This book deals especially with the application of nanotechnology in Civil Engineering/construction industry.
A DESCRIPTION OF THE TARGET AUDIENCE

Nanotechnology in Construction will attract the researchers already working in this field as well as those deciding to make carrier in it. It will also inform governmental and other endowment agencies of the potential future implications. Practical applications are considered and explanations of the underlying basics are given, raising awareness and understanding of what nanotechnology can offer to construction professionals in general. Furthermore applications of nanotechnology in Civil Engineering can also be taught at undergraduate and postgraduate level in universities and this book will be of great help to all the students and teachers. Lastly, workers who are dealing with nanotechnology are also very important targeted audience of this book as it covers health and safety aspects of technology in detail.

A DESCRIPTION OF THE IMPORTANCE OF EACH OF THE CHAPTER SUBMISSIONS

This book is organised into many broad sections; the first chapter covers an overview of the classical construction materials and the significance of nanotechnology for the construction industry. Concrete, the backbone of civil engineering is conventionally a mixture of cement, sand, gravel and water. Along with its conventional components, some ancillary materials are also sometimes added into concrete, to gain some additional advantages like strength, workability and crack control. One such addition is silica fume, which apart from some other useful effects, predominantly makes concrete resistant against chemicals. Steel is an iron-carbon alloy having carbon content up to 1.8% along with some other elements like manganese, copper, silicon, nickel and molybdenum present in minor quantities. Apart from iron, the other alloying elements are intended to increase strength, hardness and corrosion resistance of steel. Paints or coatings are intended to protect the surface from harmful weathering effects as well as to provide beauty to the surface. Paints are composed of many constituent materials for example, lead or aluminium are used as base; resins are used as vehicle or binder; oil or water are used to adjust the viscosity; lead or cobalt are used as drier. In the presence of so many useful materials, the question arises, as what the nanotechnology is going to offer in addition?

Chapter 2 gives a comprehensive review about nano cement and concrete. Firstly, the morphology of C-S-H, the nano characteristics of C-S-H at elevated temperatures, and the effects of C-S-H on the elasticity, durability, creep and shrinkage of cement and concrete materials are introduced for comprehensively understanding nano-scale gene and behaviors of cement and concrete materials in nature and describing the nano-scale blueprint to control properties in nano-scale of cement and
concrete materials. Secondly, the effects of nano-binders and other nano materials on the rheological behavior and workability, the hydration, the mechanical properties, the durability, the functional properties and the smart/intelligent properties of the cement and concrete materials are presented. Thirdly, the underlying modification mechanisms of nano materials to cement and concrete materials are summarized. Finally, the challenge and future development and deployment of nano-modificated cement and concrete materials are discussed.

It is essential to adopt new tactics of making things through understanding and control over the fundamental building blocks (i.e. atoms, molecules and nanostructures) of all physical things. It is fact that, potential properties of nanomaterials have been brought out in the construction industries but still there is a long way to go. There have been many limitations mainly due to the insufficient control of interfaces and edges of the nanomaterials with the conventional building materials. Considering the recent rapid advances in technology, the control of interfaces and edges is expected to be possible to provide a sustainable solution for nanoscale engineering of cementitious materials. Characterization of nano materials poses enormous challenges to researchers. Thus nano characterization of materials has become a significant field of research now-a-days. In this book chapter 3, author has chosen some frequently used characterization techniques of nano materials, briefly mentioned their basic principles and current research trends with these methods. Furthermore, emphasis has been given on various case studies published in the literature on cement based materials.

Usually, nanotechnology has been related with developments in the areas of microelectronics, medicine and materials sciences. However, the potential for application of many of the developments in the nanotechnology field in the area of construction engineering is growing. Though different chapters cover application of nanotechnology to specific civil engineering fields. However, in chapter 4 a wide overview of the potential application of various nanotechnology developments in the construction engineering field is considered, and the potential for further basic research that may lead to improved systems is also evaluated.

It is true to say that the potential effects of nanotechnology on construction are mostly unidentified to the construction profession in general, although specific research is being done in universities and other institutes all over the world. These provide indicators to what would soon be available to industry. Many of these developments are in line for arriving within the next five years. In order to fully benefit from this new industrial revolution, a concerted effort is needed to overcome the vital barriers of lack of knowledge and conservatism in construction as regards nanotechnology. Nanotechnology is a multifaceted and deep subject and it is nearly impossible to grasp for those who are not actively involved; thus, awareness of research done can simply be increased by educating students and professionals through
easily digestible information made available by universities, relevant institutions, journals and other sources. Focused research into the timeous and directed research into nanotechnology for construction infrastructure should be pursued to ensure that the potential benefits of this technology can be harnessed to provide longer life and more economical infrastructure. This chapter concludes with a roadmap and strategic action plan on how nanotechnology can have its biggest impact on the field of civil engineering.

Chapter 5 is an attempt to cover the recent developments in the field of nanotechnology for the construction industry, with an emphasis over the sector of geotechnical engineering. The global initiatives on the R&D and practical use of nanotechnology has garnered a certain buzz around nanomaterials, nano-probing and nano-sensing and nanoscale modelling is the new interest of researchers and innovators alike. As such, the chapter provide a brief background and introduction to nanotechnology, including nanoscale properties and classes of nanomaterials, and role of carbon nanotubes in concrete for enhanced durability, safety, strength and performance results. The nature of underlying soil plays a vital role in geotechnical and pavement structures as the durability of overlying structures is highly dependent upon the soil characteristics, behavior and composition. Clay particles have a nanostructure, as 2D sheets of SiO4 tetrahedrons linked by sharing of corners, forming hexagonal meshes, where particle interactions and factors like van der Waals forces are more dominant than gravity and ratio of surface area to particle mass is important. To broaden study on nanotechnology applications, like engineered clay particles, nanoindentation, MEMS, FTIR and AFM, self-assembling clay particles, CNT-reinforced clay matrixes and nano, nanoscale Monte Carlo techniques and molecular dynamic simulations, this chapter covers three primary aspects of nanosensors for soil characterization, numerical modelling and empirical relations for soil and rock behavior and soil.

In summary, the applications of nanotechnology in the field of geotechnical and pavement engineering hold great potential. Nano-modification of ground under foundations or subgrades may increase the mechanical and chemical characteristics and produce economical, greener and safer structures that are more durable. All these mentioned applications and future research potential are briefly described in this chapter.

Chapter 6 deals with the application of nanotechnology in the field of transportation engineering. Transportation Engineering is one of those fields that got benefitted from this tremendous growth in engineering sciences. Not very far back into the history, the engineers used to chew bitumen in order to have an idea of its consistency (hardness or softness). The aggregates were just hammered or crushed to determine their suitability for a certain project or application. Similar practices are still being used but they are now complimented by more refined tools and
sophisticated techniques. ‘State of Practice’ is now approaching the ‘State of the Art’. The pavement design techniques are now progressing from the ‘Empirical’ to the ‘Mechanistic-Empirical’ and purely ‘Analytical’. Material characterization techniques are now moving from just ‘Physical’ to ‘Physico-chemical’ and ‘Chemical’. Similarly, science is moving from ‘Macro’ to ‘Micro’, to ‘Nanotechnology’. Now we are even using Atomic Force Microscopy (AFM) for research on materials. Nanotechnology being one of the most emergent fields of the current age affects all the disciplines of the science, technology and engineering. The chapter gathers the literature unfolding the use and importance of this emerging field in Transportation Engineering. It organizes all the elementary information in such a manner that it becomes very easy for the readers to understand the technology under discussion. The chapter summarizes all the basic nanomaterials that can and have been used in the Transportation Engineering for enhancing the function and life of the pavements. It also discusses the aspects in which the nanotechnology can benefit Pavement Engineering including economy, sustainability and safety etc. The potential hazardous effects of nano-materials in Pavement Engineering have also been discussed. Overall, the chapter is a very good attempt to summarize the advantages and disadvantages of using nano-materials in a literature perspective. It will also be very beneficial for the researchers as it has been tried to collect and condense the literature related to the topic in a single chapter.

Chapter 7 titled “Recent Trends and Advancement in Nanotechnology for Water and Wastewater Treatment: Nano-Technological Approach for Water Purification” helps in providing a brief overview to the readers regarding various possible synthesis techniques of nano scale materials. Moreover, the chapter also entails a concise outline about some of the basic instrumentation techniques that helps in ascertaining the size as well as various physical and chemical properties of the nano materials. Besides, the chapter also focused on the application of the some of the recently synthesized nano materials in resolving many problems related to water purification and water quality. The chapter also encompasses the role of various process parameters influencing the adsorption behaviors of nanomaterials. Furthermore, a general idea on the limitation aspect of the nano engineered materials was also briefly represented.

Lastly, Chapter 8 deals with the risks associated with the dealing and usage of nanotechnology. The use of nanotechnology in any field requires great care and any sort of negligence is likely to bring negative effects for the environment and its habitats. Usually, nanomaterials become threat when they are discharged in undesirable quantities into the wrong destinations. Exposure to nanomaterials may occur unintentionally in the environment or through the use of nanotechnology based products in our daily lives. Some examples include physical contact at manufacturing
units, inhalation of nanomaterials released to the atmosphere and use of drinking water or food having accumulated nano particles. Moreover, absorption by soil and then transportation in saturated and unsaturated regions in the subsurface leading to the final destination at vegetation is also possible. Nanoparticles are so small when absorbed; they may reach the inner bio molecules in the body. Studies have shown that inhaling nanoparticles can even affect the central nervous system. Moreover, their extremely small size is very tangible to affect the skin and eyes of people exposed to them. Some nanoparticles may even cause mesothelioma and lungs cancer. So, there is need to adopt wide precautions. The chapter covers risks of nanotechnology to the environment and its habitats in detail. Furthermore, it also discusses remedial measures from public awareness to the engineering control. Important precautionary aspects including hazard identification, dose response assessment, exposure assessment as well as risk characterization are also discussed in this chapter. Lastly considering above mentioned disastrous effects, waste monitoring and recycling have also been included in this chapter. In short, this chapter brings forth both the bright and dark side of nanotechnology and discusses important aspects to get benefits from it by keeping the harmful impacts at minimum level.

CONCLUSION

Nanotechnology has tremendous potentials in construction industry. The examples are germ-free laboratories and hospitals, waterproof buildings, urban environmental protection. The important developments made in concrete technology are ultra high strength concrete, photo-catalytic concrete, self-heating concrete, bendable concrete and concrete containing CNTs. Nano Silica Concrete incorporates nano silica instead of micro silica particles or well known silica fumes. This concrete results in higher initial and final compressive strengths, higher workability, and lower permeability. Additionally, higher tensile strength and segregation resistance are also achieved. The new concrete is named as Ultra High Strength Concrete. The advantages of this concrete are numerous: the column sections in buildings can be reduced. The amount of steel reinforcement in concrete can also be reduced. And in highways and railway tunnels, thinner tunnel segments can be constructed leading to a great saving in excavations. It is a well-known fact that nano TiO$_2$ on UV irradiation can be used as an effective way to reduce the contaminants and enhance environmental safety. Photocatalytic concrete is a green material. With this concrete, structures looking new for decades can be constructed. Inside hospitals and laboratories, the spread of germs can be minimized and urban air quality can be improved. Various contaminants like algae and barnacles cannot cling to CNT-containing nano paints,
which can increase the time saving in repainting massive marine structures. Serious health issues related to the use of nano materials must be well understood and remedies are mandatory; these risks are remedial measures are also well discussed in this book. The investigation for various applications of nanotechnology to build up novel building materials continues. It is by now obvious that the science of the very small is creating big changes, with various economic benefits to the construction industry.