Review on Use of Nanotechnology in Civil Engineeering

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Abstract **- Nanotechnology and Nanomaterials is one of the most active research areas with both science and engineering. The term nanotechnology offers very much elaborate meaning and vast scope that may be changed from field to field. Nanotechnology has many folds and applications in almost all engineering fields. The beginning of nanotechnology has revolutionized the growth of the civil engineering. Building materials domain can be one of the main beneficiaries of these researches, with applications that will improve the characteristics of concrete, steel, glass, bricks and insulating materials. The use of nanomaterials in the composition of some materials, such as cement, will result in significant reductions of CO_2 pollution and the use of performance thermal insulations will result in efficient use of energy for air conditioning. The use of nanotechnology controls the topic at the minute level, the properties of matter are sincerely affected. Strength, durability and other properties of materials are dramatically affected under a scale of nanometer (10-9m). Due to the small particle size, nanotechnology focuses on Nanomaterials with unique functions in term of strength, durability, high speed of construction, and environmental impact reduction. This paper presents application of nanotechnology in building materials for various civil engineering works**.

Keywords: Nanotechnology, Nanomaterial.

1. INTRODUCTION

Nanomaterial is defined as a physical substance with one dimension at the lowest between 1…150 (NM) (1nm=10-9m). The characteristics of nanomaterial could be varied with the same material that has micro (10-6m) or macro (10-6…10-3m) scales [1]. Using nanotechnology in construction has been ranked 8 of 10 applications that have a significant effect on the developing world [2]. With the emergence of nanotechnology in construction, many outcomes have been achieved, which has resulted in cost effective, cleaner and sustainable materials. Applications of nanoparticles, nanotubes and nano-fibers have resulted in novel construction materials and new combinations of strength, durability and toughness. For example bio-mimetic materials with self adjusting interfaces, shape memory, self repairing and strain harden materials [3]. Nanotechnology is a smart concept of using smart technologies. It has been established by study, nanotechnology in construction ranked 8 of 10 applications that most likely have impact in the developing world [5]. The usage of Nanotechnology materials while being incorporated in constructional structures would not only help in prolonging 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 [6]. Nanotechnology also reached to the area of welding. By the addition of nanoparticles of calcium and magnesium the brittle weld can leads to the strong weld [7]. Further, as particles become nano-sized the proportion of atoms on the surface increases relative to those inside and this leads to novel properties. Concrete is stronger, more durable and more easily placed, steel tougher and glass self-cleaning. Increased strength and durability are also a part of the drive to reduce the environmental footprint of the built environment by the efficient use of resources [8]. In 1959, Richard Feynman published an article about the potential of nanotechnology in the future. Despite many situations and successes acquired by many scientists till that time, Richard Feynman has recognized as the founder of nanotechnology science [9]. Concrete is the most widely used material in the world. It is estimated that its annual production is about 20 billion tons higher than any other material on this planet earth [10, 11]. Generally, in design of concrete mix, cement, fine aggregates and coarse aggregates are used from long back, which plays a crucial role in designing of a particular grade of concrete. But now-a-days there are some new materials which are locally available with low cost which can be introduced for replacing the fine aggregates, coarse aggregates as well as cement to get the comparable strength, the present study involves understanding the behavior and performance of ceramic waste in concrete. The need to reduce the high cost of Ordinary Portland Cement requires intensified research into the use of locally available materials that could be used as partial replacement for Ordinary Portland Cement (OPC) as well as the aggregate which is use in construction work. In India, the amount of waste in the different production stages of the ceramic industry reaches nearly to 3–7% of its global production meaning millions of tons of calcined-clays per year that are just land filled [12]. Indian ceramic production is 100 Million ton per year. In the ceramic industry, about 15% - 20% waste material is generated from the total production [13]. Steel is an iron-carbon alloy. But not every iron carbon alloy is steel. Steel is defined as an iron carbon alloy having carbon content up to 1.7 % [10]. In addition to carbon, some other elements like manganese, copper, silicon, nickel and molybdenum are also present in minor quantities [14]. Paints or coatings are frequently used in construction to protect the surface from harmful weathering effects. Additionally, they also provide beauty to the surface. Paints are composed of base, vehicle or binder, solvent or thinner, drier and coloring pigments. Various materials are used to make paint [15].

1.1. Types of Nanomaterials

There are different types of nanomaterials are available for different purposes which is for the construction or any other purpose which is belonging to nano technology.

a. Titanium dioxide (TiO2)
b. Carbon nanotubes (CNT's)
c. Nano silica(ns)
d. Polycarboxilates
e. Zirconium Oxide Nanoparticles (ZrO2)
f. Silver Nanoparticles (Ag)
g. Aluminum Oxide Nanoparticles (Al2O3)
h. Zirconium Oxide Nanoparticles (ZrO2)
i. Wolfram (Tungsten) Oxide Nanoparticles (WO3).[28]

2. HISTORY

Nano, which comes from the Greek word for dwarf, indicates a billionth. One nanometre is a billionth of a metre. Definitions of 'nanotechnology' vary, but it generally refers to understanding and manipulation of matter on the Nano scale, say, from 0.1 nm to 100 nm. The significance and importance of controlling matter at the nanoscale is that at this scale different laws of physics come into play like quantum physics. There are two ways to approach the nanoscale: shrinking from the top down, or growing from the bottom up. The 'top down' approach entails reducing the size of the smallest structures towards the nanoscale by machining and etching techniques, whereas the 'bottom up' approach, often referred to as molecular nanotechnology, implies controlled or directed self-assembly of atoms and molecules to create structures [4]. The construction industry was the only industry to identify nanotechnology as a promising emerging technology in the UK Delphi survey in the early 1990s [16]. Furthermore, ready mix concrete and concrete products were identified as among the top 40 industrial sectors likely to be influenced by nanotechnology in 10-15 years [17]. However, construction has lagged behind other industrial sectors where nanotechnology R&D has attracted significant interest and investment from large industrial corporations and venture capitalists. Recognising the huge potential and importance of nanotechnology to the construction industry, the European Commission in late 2002 approved funding for the Growth Project GMA1-2002-72160 "NANOCONEX" - Towards the setting up of a network of excellence in nanotechnology in construction [18].

3. APPLICATION OF NANOTECHNOLOGY IN CONSTRUCTION

Due to the unique properties, nanotechnology can be used for design and construction processes in many areas .There are large numbers of applications of nanotechnology in construction engineering. Some of these applications are

3.1 Brick

Brick is a versatile component in the field of architectural and construction engineering. It is composed of cement, sand, water, lime and clay-bearing soil. Some of the properties such as hardness, absorption, compressive strength, frost resistance, efflorescence etc vary from brick to brick depending upon the type of brick, namely, common burnt clay bricks, sand lime bricks, fly ash clay bricks, engineering bricks etc. The different categories of bricks are manufactured so that it must fulfill the respective purpose. Water is a component that can be hazardous to any structure, if surplus in existence. Likewise if water comes to contact of bricks where not needed can affect the properties of bricks negatively and can prove to destroy the bricks and so the structure where the bricks are used. To overcome this problem, water repellent is introduced in the form of hydrophobic coating. The hydrophobic coating of brick helps it to repel the unwanted water and to retain the strength, durability, toughness, hardness and other physical properties [19].

3.2 Concrete

Concrete is, a macro-material strongly influenced by its nano-properties and understanding it at this new level is yielding new avenues for improvement of strength, durability and monitoring. Much of the analysis of concrete is being done at the nano-level in order to understand its structure using the various techniques developed for study at that scale such as Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM) and Focused Ion Beam (FIB) [20]. Concrete, a composition of portland cement as binder and water as well as aggregates as fillers, is a porous material with pores ranging in size from millimeters to nanometers. In most applications concrete surface is subjected to external abrasion, environmental exposure and erosion to aggressive liquids, such as water, mineral solutions, oil, solvents, etc. When dry concrete deals with liquid such as water, most of the water is absorbed by the pores due to the capillary forces. The durability (i.e. freeze-thaw and sulfate attack) of concrete depends on its overall absorption and porosity to aqueous solutions. For example, freeze-thaw damage occurs when water in saturated concrete freeze due to temperature variations causing substantial stresses within the material. The cumulative effect of freeze-thaw cycles eventually cause cracking, crumbling, expansion and scaling of the concrete. It is therefore crucial to synthesize waterrepellent concrete in order to improve its durability, and, in particular, to produce the ultra-durable concrete.[19] Much analysis of concrete is being done at the nano-level in order to understand its structure. Such analysis uses various techniques developed for study at that scale such as Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM) and Focused Ion Beam (FIB). This has come about as a side benefit of the development of these instruments to study the nanoscale in general, but the understanding of the structure and behavior of concrete at the fundamental level is an important and very appropriate use of nanotechnology [25].

3.3 Structural composites

Steel is a major construction material. FHWA together with American Iron and Steel Institute and the U.S. Navy developed new, low carbon, high-performance steel (HPS) for bridges in 1992 with higher corrosion-resistance and weld ability by incorporating copper nanoparticles from at

the steel grain boundaries [29]. Carbon nanotubes are over 100 times stronger than steel and only one-sixth of the weight in addition to its high thermal and electrical conductivities. A CNT composite has recently been reported to be six times stronger than conventional carbon fibre composites [30].

3.4 Steel

Steel has been widely available since the second industrial revolution in the late part of the 19th and early part of the 20th Century and has played a major part in the construction industry since that time. Fatigue is a significant issue that can lead to the structural failure of steel subject to cyclic loading, such as in bridges or towers. This can happen at stresses significantly lower than the yield stress of the material and lead to a significant shortening of useful life of the structure. The current design philosophy entails one or more of three limiting measures: a design based on a dramatic reduction in the allowable stress, a shortened allowable service life or the need for a regular inspection regime. Stress risers are responsible for initiating cracks from which fatigue failure results and 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 [20]. Steel is another material used mainly in construction and applied in almost all structures. The significant properties of steel are strength and corrosion resistance. The new kind of steel through the integrating of copper Nano material, offers higher corrosion resistance and weld capability. Nano particles of vanadium and molybdenum can solve the fracture problems connected to the high strength bolt and reduction of hydrogen embrittlement [21]. According to Mann integration of carbon Nanotube with steel, has little application owing to its graphic nature. It can cause some problem to bind the bulk material in addition to high temperature included in the process of steel elements which increases the vibration of carbon atoms significantly ending up bond breaking and defects in the steel structure [22]. Steel is a widely available material that has a major role in the construction industry. The use of nanotechnology in steel helps to improve the physical properties of steel. Fatigue, or the structural failure of steel, is due to cyclic loading. Current steel designs are based on the reduction in the allowable stress, service life or regular inspection regime. This has a significant impact on the life-cycle costs of structures and limits the effective use of resources. Stress risers are responsible for initiating cracks from which fatigue failure results. The addition of copper nanoparticles reduces the surface un-evenness of steel, which then limits the number of stress risers and hence fatigue cracking. Advancements in this technology through the use of nanoparticles would lead to increased safety, less need for regular inspection, and more efficient materials free from fatigue issues for construction steel cables can be strengthened using carbon nanotubes. Stronger cables reduce the life cycle costs and period of construction due to easy handling, especially in suspension bridges, as the cables are run from end to end of the span [25].

3.5 Glass

Self cleaning technology for glass is created by the integration of Tio_2 Nano particles to glasses. Disintegration of bacterial membranes and any organic pollutants from glass could be implemented by the reaction of Nano particles photo catalytic. Previous disintegration (dirt particle) can be also washed off from glass by using Tio_2 Nano particles being hydrophilic to glass. Moreover, using fumed silica (sio_2) Nano particles as an interlayer between two panels of glass can be changed from a rigid to opaque fire cover after warming known as fire-protective glass [23]. Research is being carried out on the application of nanotechnology to glass, another important material in construction. Titanium dioxide (TiO_2) nanoparticles are used to coat glazing since it has sterilizing and anti-fouling properties. The particles catalyze powerful reactions that break down organic pollutants, volatile organic compounds and bacterial membranes. TiO_2 is hydrophilic (attraction to water), which can attract rain drops that then wash off the dirt particles. Thus the introduction of nanotechnology in the glass industry incorporates the self-cleaning property of glass [25].

3.6 Coatings

Coatings are anticipated to comprise the largest application of nano-material in construction. Major applications of coating in construction can be conducted in architectural paints, water sealers, and deck treatment. The coating combination with Nano particle or Nano tube have been progressing for many targets which involves one of the main application of Nanotechnology in building construction. Tio2 (dioxide, titanium) has the characteristics of sterilizing and antifouling, so it can be utilized to coat glazing. Tio_2 will break down the organic dirt by the catalytic reaction. Moreover, it is hydrophilic, which induce water to move quickly over the surface and wash away organic dirt, broken down in the past, and the other exceptional coating which also have been used, including anti- Graffiti, energy saving, thermal control and anti-reflection coating [24].

3.7 Fire protection

Fire resistance of steel structures is often provided by a coating produced by a spray-on-cementations process. However, research into nano-cement (made of nano-sized particles) has the potential to create a new paradigm in this area of application because the resulting material can be used as a tough, durable, high temperature coating around steel. This is achieved by the mixing of carbon nanotubes (CNT's) with the cementitious material to fabricate fiber composites that can inherit some of the outstanding properties of the nanotubes such as strength. Nano-sized polypropylene fibers also are being considered as a method of increasing fire resistance and this may be a cheaper option than conventional insulation [25].

3.8 Plastics

The carbon fibre reinforced plastics (CFRP) being light weight material does not exhibit good electrical properties. CNTs are among the stiffest and strongest fibers known, and can improve electrical conductivity and heat dissipation properties. At IFAM in Bremen, researchers employed plasma technology in order to transfer their properties to CFRPs since these micro- or nanoparticles must be highly homogeneous, and made such as to readily bound to the polymer [26]. Dr. Jörg Ihde explains: "We spray the particles i.e. the nanotubes into this atmospheric plasma." They immediately fall into the selected solvent, which can then be used to further process the polymer. The whole procedure takes just a few seconds". This can be pressed onto an electronic component so heat is dissipated directly [27].

3.9 Bitumen

The bentonite (BT) and organically modified bentonite (OBT) were used to reinforce and modify asphalt binder by melt processing under sonication and shearing stresses. The BT modified asphalt possess intercalated structure while OBT modified asphalt possessed exfoliated structure. The BT and OBT modified asphalts have shown greater softening point, viscosity, higher complex modulus, lower phase angle and higher rutting parameter and better rheological properties than the base asphalt. But the ductility of the modified asphalts decreased with the addition of BT and OBT. They have significantly lower creep stiffness. Therefore, the low temperature cracking resistance was improved by addition of BT and OBT. The OBT modified asphalts has better properties than the BT modified asphalts [27].

3.10Waterproof building material

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 serious issue waterproofing addresses is to prevent loss of structural strength of concrete building materials, particularly due to ASR (alkali silica reaction), acid rain, sulphate attacked. It also prevents chloride penetration which can result in corrosion of the reinforced steel bars [20].

4. CONCLUSION

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. Even though construction materials may constitute only a small part of this overall effort, it could pay enormous rewards in the areas of technological breakthroughs and economic benefits. Research in nanotechnology that is related to construction is still in its infancy. 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. From the information embodied in the paper the future of the construction industry can be predicted because of the enhanced properties of the basic civil engineering raw materials.

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