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Nanomaterials-Application and Techniques in Civil Engineering

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Abstract—*The advanced research on nanomaterials and nanotechnologies have highlighted the potential use of these materials in different sectors like medicine, automobile industry, energy, telecommunications, informatics and also in construction field. This is due to the special characteristics of nanomaterials in construction techniques. Building materials domain can be one of the main beneficiaries of these researches, with applications of these materials that will improve the characteristics of concrete, steel, glass, wood, light equipment, plumbing works and insulating materials. Nanotechnologyin water proofing building materials and self-healing concrete. Improving the materials resistances and the increasing of their durability will reduce environmental pollution by reducing the carbon footprint of the building. In general, the largest amount of pollutants are due to the production of various construction materials and to the energy required during their service. The use of nanomaterials in the composition of some materials such as cement and concrete will result in significant reductions of Co_2 pollution.*

Keywords: *Nanomaterials, Nanotechnology, Application*

1. INTRODUCTION

Nanomaterials are materials having particles or constituents of nanoscale dimensions, or one that is produced by nanotechnology. Nanomaterials describe the materials of which a single unit is sized between 1 to 1000 nanometers (10^{-9} meter) but is usually 1—100 nm (the usual definition of nanoscale).

The nanoscience represents the study of phenomena and the manipulation of materials at nanoscale and is an extension of common sciences into the nanoscale. 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 behaviour and for designing and producing very fine powders, liquids or solids state of materials with particle size between 1 and 100 nm, known as nanoparticles[7].

This paper contains research on nanomaterials its applications and nanotechnology used in construction field.

Currently, the use of nanomaterials in construction is reduced, mainly for the following reasons: the lack of knowledge concerning the suitable nanomaterials for construction and their behaviour; the lack of specific standards for design and execution of the construction elements using nanomaterials; the lack of detailed information regarding the nanomaterials content; high costs; the unknown health risks associated with nanomaterials.

In order to be able to use nanomaterials in the construction industry the at wide scale it is necessary that the experiment and researches to be conducted following the next stages: the choice of nanomaterials with potential use in construction and the study of their characteristics; the behavior study of the building elements that contain nanomaterials under various loads; the development of specific design and construction standards [16].

2. NANOMATERIALS FOR CONSTRUCTION

The size of nanoparticles in construction industry is a critical factor, the material properties are significant and differ at the nanoscale from larger scale. The proportion of atoms on the surface increases when compared to inside molecules creating so-called “nano-effect”. All these nano-properties actually affect the materials behavior at macro-scale and, from this point, the power of nanotechnology is emphasized: if the elements are proper manipulated at the nanoscale, the macro-properties are affected and new materials and processes can be developed [6].

The commonly usable, easy applicable and important nanomaterials in construction industry are;

a) Carbon Nanotubes
b) Nanocement
c) Nanocrystaline Materials
d) Nanosilica
e) Nanofibers
f) Nanometals
g) Tungsten Oxide Nanoparticles

2.1 Carbon Nanotubes

Carbon nanotubes are a form of carbon having a cylindrical shape, the name coming from their nanometre diameter. They can be several millimetre in length and can have one "layer" or wall (single walled nanotube) or more than one wall (multi walled nanotube) [13].

Nanotubes are members of the structural family and exhibit extraordinary strength and unique electrical properties, being efficient thermal conductors. For example, they have five times the Young's modulus and eight times the strength of steel, whilst being 1/6th the density.

The advantages 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[14].

Table 1: The Properties of Carbon Nanotubes[1]

Name of the property	Characteristics
Length of diameter ratio	60 (SWCNT's)
Surface area	~300 m2/gm (SWNT's)
Density	Less (2.60g/cm3 for MWNT's)
Thermal conductivity	350K-8K (SWCNT's)
Elongaion	100% (CNT based interconnects which are stretchable)
Young`s Modulus	1.25 TPa (SWCNT's), 0.9 TPa (MWCNT's)
Poission`s ratio	0.06-0.55 (SWCNT's)
Tensile strength	75 GPa (SWCNT's) <60 GPa (MWCNT's)
Compressive strength	100-150 GPa (MWCNT's)

2.2 NanoCement

A mixture of nanosilica, sodium aluminate, and sodium hydroxide gives nanocement. Reducing carbon-dioxide emissions alongside providing high compressive strength (50% replacement of nanocement along with mortar gives strength upto 86.97 N/mm2 at the end of 21 days) [10]-[3] and avoiding air gaps by virtue of large specific surface area (3582400 cm2/gm) are some of the properties offered by addition of nanocement to the construction materials. 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 like CNT's and composites, in the conventional cement. High magnitudes of tensile and flexular strength that is strong enough to withstand vibrations due to earthquakes with a prolonged longevity coupled with immunity against attack of corrosion, chemicals, penetration of water, is obtained on incorporation of nanocementfibers in the ultra high performance materials[2,12].

2.3 Nanocrystaline Materials

When applied on the construction materials besides enhancing the structural strength of the structures, nanocrystalline coating films made from the materials like nickel, gold, silver and others (possion's ratio for nanocrystalline Cu = 0.33), also help to reduce corrosion by controlling the oxidation reactions. Varying characteristics like enhanced diffusion, shifting of zero current potential (ZCP), more number of atoms in intercrystalline regions, higher passive current (as in case of nanocrystalline Ni) marks a line of difference between properties exhibited by the nanocrystalline materials and their microcrystalline counterparts[4,15].

As part of the building materials, for providing of reinforcement and increasing the longtivity of paints and varnishes nanocrystalline cellulose are to be used[9].

2.4 Nanosilica

Nano Silica mixed in Concrete can improve;Mechanical properties can control the degradation of the fundamenta lC-S-H(Calcium-Silicate-Hydrate) reaction of concrete. Can block water penetration and therefore lead to improvements in durability. They also increase strength as well as offering the benefit of monitoring stresslevels through the measurement of section electrical resistance.

Nano-SiO2 could significantly increase the compressive strength of concrete containing large fly ash volume at early age, by filling the pores between large fly ash and cement particles. Nano-silica decreases the setting time of mortar when compared with silica fume (microsilica) and reduces bleeding water and segregation by the improvement of the cohesiveness[14].Besides tensile strength, high surface area, ability to prevent silicosis, reducing percentage of CO2, nanosilica also helps in checking solid waste pollution when mixed with recycled concrete aggregates[1].

2.5 Nanofibres

High temperature withstanding(upto 3000C in case of Aramid Nanofibre) insulation (0.96 for 10% weight of carbon nanofibres put into graphite, other sources say that graphitized ones have a value of 0.0520) services are provided by the nanofibres. Temperatures are brought down in summer by presence of thin film nano-scale stainless steel coatings in masa curtains [5,18].

2.6 Nanometals

Being light weight, self healing i.e. exhibiting different properties like soft or hard, when the need arises, mechanically stronger and more durable when compared to the microscopic particles makes nanometals like nanosilver find application in electrical contacts, indoor insulation purposes of buildings whereas others find application in being parts of circuit boards[8,21].

2.7 Tungsten Oxide Nanoparticles

Tungsten trioxide has been employed in the production of electrochromic windows, or smart windows. These windows are electrically switchable glass that change light transmission

properties with an applied voltage. This allows the user to tint their windows, changing the amount of heat or light passing through. The equipment and maintenance cost is not economical[16].

3. APPLICATION OF NANOTECHNOLOGY IN CONSTRUCTION INDUSTRY

Construction Industry is one of the most booming industries in the whole world. This industry is mainly an urban base done which is concerned with preparation as well as construction of real estate properties. There pairing of any existing building or making certain alterations in the same also comes under construction industry.

Construction Industry has under gone tremendous change in the past two centuries. What affected it most was the industrial revolution and its resultant out come in terms of steel, cement and other building materials.

Twentieth century saw further refinement in the same with even more sophisticated techniques and devices. Now it has to move in the next phase where inputs are less and lighter, they are smooth and they are cost effective, cleaner and sustainable. It has to move towards more sophistication with the help of emerging technologies like the Nanotechnology[17].

Nanotechnology can generate products with many unique characteristics that can improve the current construction materials: lighter and stronger structural composites, low maintenance coatings, better cement content materials, lower thermal transfer rate of fire retardant and insulation, better sound absorption of acoustic absorbers and better reflectivity of glass[13].

Some of the important nanotechnologies are;
a) Nanotechnology for materials coating
b) Nanotechnology for concrete
c) Nanotechnology for steel
d) Nanotechnology for glass
e) Nanotechnology for water proofing building materials.

3.1 Nanotechnology for Materials Coating

Coatings are expected to constitute the largest application for nanomaterials in construction. Architectural paints, watersealers and decktreatments, and treatments applied during fabrication, such as scratch-resistant coatings on vinyl or wood flooring are meant for protection.

Various Nanocoatings can provide are:
1. Fire Protection
2. HeatInsulation
3. CorrosionProtection

3.1.1 Fire Protection Coatings

Important and common safety construction for all the components of the building. Fire resistance of steel structures is often provided by a coating produced by a spray-on cementitious process. Nano-cement that consists of nano sized particles has the potential to create a tough, durable and 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[16]. And the other material is Blister-DM It is designed forinner &outer applications of surfaces for metal, wood,brick and other surfaces in the living ,public and production facilities as well as supply pipelines, tanks,storage buildings. The coating is liquid compounding onthebasis of organic disolvents and consisting of polymers ,inorganic pigments and modified functional additives improving rheological and adhesive characteristics of the coating[17].

3.1.2 Heat Insulating Coatings

The main problem in buildings are heat absorption by building components. Depending on climatic conditions the heat inside the building increases. To overcome these problems heat-insulating nanotechnology can be preferred.

“Thermo-S” is a real alternative to all heat-insulating technologies. Thermo-s is an atmospheric-resistant energy efficient paint coating consisting of microscopical ceramic balls which are in a suspension state in a liquid composition of synthetic rubber, polymers and inorganic pigments. This can provide the ultimate economical effect while solving any heat, noise damp,proof problem as well as corrosion and fire resistance.

The Product can be manufactured on the fabric in a flexible roller deposited on toplates of required thickness &quality[17]. The coating can be applied on metals, plastics, concrete, brick, wood and any other brick building material in any dry weather. It is safe and economical.

3.1.3 Corrosion Protection Coatings

Nanotechnology is applied 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. Others applications refer to coatings that have self healing capabilities through a process of “selfassembly”. 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[14].

3.2 Nanotechnology for Concrete

Concrete is a macro-material strongly influenced by its nano-properties. The addition of nano-silica (SiO2) to cement based materials can control the degradation of the calcium-silica hydrate reaction caused by calcium leaching in water, blocking water penetration and leading to improvements in durability[14]. Nano-sensors have a great potential to be used in concrete structures for quality control and durability monitoring. Carbon nanotubes increase the compressive

strength of cement mortar specimens and change their electrical properties which can be used for health monitoring and damage detection. The addition of small amounts (1%) of carbon nanotubes can improve the mechanical properties of mixture samples of portland cement and water. Oxidized multi-walled nanotubes show the best improvements both in compressive strength and flexural strength compared to the reference samples[16].

3.3 Nanotechnology for Steel

The addition of copper nanoparticles reduces the surface unevenness of steel which then limits the number of stress risers and hence fatigue cracking, leading to increased safety, less need for monitoring and more efficient materials use in construction subjected to fatigue issues. Vanadium and molybdenum nanoparticles improve the delayed fracture problems associated with high strength bolts, reducing the effects of hydrogen embrittlement and improving the steel micro-structure. The addition of nanoparticles of magnesium and calcium leads to an increase in weld toughness. The carbon nanotubes have little application as an addition to steel because of their inherent slipperiness, due to the graphitic nature, making them difficult to bind to the bulk material[14].

3.4 Nanotechnology for Glass

The use of TiO2 nanoparticles to glasses leads to self cleaning technology. Due to the nanoparticles photocatalytic reactions, the organic pollutants, volatile organic compounds and bacterial membranes are decomposed. As well, TiO2 being hydrophilic, his attraction to water forms drops which then wash off the dirt particles decomposed in the previous process. Fire-protective glass is obtained using fumed silica (SiO2) nanoparticles as a clear interlayer sandwiched between two glass panels which turns into a rigid and opaque fire shield when is heated[16].

3.5 Nanotechnology for Water Proofing 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 small cracks. 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 is to prevent loss of structural strength of concrete building materials, particularly due to ASR (alkali silica reaction), acid rain, sulphateattacked. It also prevents chloride penetration which can result in corrosion of the reinforced steel bars[20]. There are two methods of waterproofing products:

a) Film Formers
b) Penetrants

4. CONCLUSION

An literature review of properties and applications of nanomaterials and its technology in field of construction industry that make them useful as a part of the construction materials. This would be helpful of all the latest technology improvers in civil engineers, architects and contractors to make use of availability of the nanomaterials and nanotechnology that can be considered in the design of sustainable and stronger structures.

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