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Uses of Nanomaterials and Nanotechnologies In Construction Technology

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ABSTRACT
Recent research on nanomaterials and nanotechnologies has highlighted the potential use of these materials in various fields, such as medicine, construction, the automobile industry, energy, telecommunications and computer science. This is due to the special characteristics of nano-scale materials. The mastery of construction materials can be one of the main beneficiaries of these investigations, with applications that will improve the characteristics of concrete, steel, glass and insulating materials. Improving the strength of materials and increasing their durability will reduce environmental pollution by reducing the carbon footprint of the building. In general, the greatest amount of pollutants is due to the production of various building materials and the energy required during their service. The use of nanomaterials in the composition of some materials, such as cement, will result in significant reductions in CO2 pollution and the use of high-performance thermal insulation will result in an efficient use of energy for air conditioning. In addition, nanomaterials applied to the surfaces of the structural elements of the building can contribute to environmental cleaning through photocatalytic reactions.
Key words: *nanomaterials; nanotechnologies; structural behavior; construction.*

I. INTRODUCTION

Nanomaterials can be defined as those physical substances with at least one dimension between 1… 150 nm (1 nm = 10–9 m). The properties of nanomaterials can be very different from the properties of the same materials on a micro (10–6 m) or macro scale (10–6… 10–3 m). Nanoscience represents the study of phenomena and the manipulation of nanoscale materials and is an extension of the common sciences in the nanoscale. Nanotechnologies can be defined as the design, characterization, Production and application of structures, devices and systems by controlling the nanoscale shape and size. Nanotechnology requires advanced imaging techniques to study and improve the behavior of the material and to design and produce very fine powders, liquids or solids of materials with a particle size between 1 and 100 nm, known as nanoparticles (Gogotsi, 2006). Currently, the use of nanomaterials in construction is reduced, mainly for the following reasons: lack of knowledge about nanomaterials suitable for construction and its behavior; the lack of specific standards for the design and execution of construction elements using nanomaterials; the reduced supply of nanoproducts; the lack of detailed information on the content of nanoproducts; High prices; The unknowns of the health risks associated with nanomaterials. In order to use large-scale nanomaterials in the construction industry, it is necessary that research be carried out in the following stages: the choice of nanomaterials with possible use in construction and the study of their characteristics; the study of the behavior of building elements that contain nanomaterials under various loads; The development of specific design and construction standards. This document is part of the first stage of research and represents a synthesis of nanomaterials suitable for use in construction.

II. Nanomaterials for Construction

Because the size of the particles is a critical factor, the significant properties of the material differ in the nanoscale of the larger scales. Physical phenomena begin to occur differently below the limit: gravity ceases to be important, electrostatic forces and quantum effects begin to prevail. At the same time, the proportion of atoms on the surface increases in relation to those of the interior, creating the so-called "nanoeffect." All these nano properties really affect the behavior of macroscale materials and, from this point on, the power of nanotechnology is emphasized: if the elements are properly handled at the nanoscale, the macroproperties are affected and new materials can be generated and processes developed (Ge & Gao, 2008). Below are the most important nanomaterials with potential use in construction.

The Carbon Nanotubes

Titanium Dioxide Nanoparticles (TiO_2) Carbon nanotubes are a form of carbon that has a cylindrical shape, whose name comes from its nanometric diameter. They can be several millimeters in length and can have a "layer" or wall (single wall nanotube) or more than one wall (multiple wall nanotube) (Lu et al., 2010). The nanotubes are members of the fullerene structural family and exhibit extraordinary resistance and unique electrical properties, being efficient thermal conductors. For example, they have five times Young's modulus and eight times (theoretically 100 times) the strength of steel, while they are 1/6 of the density. The expected benefits of carbon nanotubes are: mechanical durability and prevention of cracks in concrete, improved mechanical and thermal properties in ceramics and ability to monitor structural health in real time (Mann, 2006). Titanium dioxide nanoparticles are added to the concrete to improve their properties. This white pigment is used as an excellent reflective coating. Or added to paints, cements and windows for their sterilizing properties. Titanium dioxide breaks down organic pollutants, volatile organic compounds and bacterial membranes through powerful photocatalytic reactions, reducing air pollutants when applied to exterior surfaces. Being hydrophilic gives self-cleaning properties to the surfaces to which it is applied, because rainwater is attracted to the surface and forms sheets that collect contaminants and previously decomposed dirt particles and wash them. The resulting concrete surface has a white color that retains its whiteness very effectively (Mann, 2006).

Silicon Dioxide Nanoparticles (SiO_2)

Nano-SiO_2 could significantly increase the compressive strength of concretes that contain a large volume of fly ash at an early age, by filling the pores between large fly ash and cement particles. The nano-silica decreases the setting time of the mortar compared to silica fume (microsilica) and reduces water bleeding and segregation due to improved cohesion (Sadrmomtazi and Barzegar, 2010).

Zinc Oxide Nanoparticles (ZnO)

Zinc oxide is a unique material that exhibits dual semiconductor and piezoelectric properties. It is added to various materials and products, including plastics, ceramics, glass, cement, rubber, paints, adhesives, sealants, pigments, fire retardants. Used for the manufacture of concrete, ZnO improves the processing time and resistance of concrete against water (Broekhuizen and Broekhuizen, 2009).

Silver Nanoparticles (Ag)

Nanosilver will affect, in contact with bacteria, viruses and fungi, cell metabolism and inhibit cell growth. The nanosilver inhibits the multiplication and growth of bacteria and fungi, which causes infection, smell, itching and sores. The central technology of nanosilver is the ability to produce particles as small as possible and distribute these particles very evenly. When the nanoparticles are coated on the surface of any material, the surface area increases several million times more than the normal silver foil.

Aluminum Oxide Nanoparticles (Al_2O_3)

The alumina component (Al_2O_3) reacts with calcium hydroxide produced by the hydration of calcium silicates. The velocity of the pozzolanic reaction is proportional to the amount of surface available for the reaction. The addition of high purity nano-Al_2O_3 improves the characteristics of concrete, in terms of greater tensile and flexural strength. The cement could advantageously be replaced in the mixing of concrete with nano-Al_2O_3 particles up to a maximum limit of 2.0% with average particle sizes of 15 nm, achieving the optimum level of nano-Al_2O_3 particle content with a 1.0% replacement (Nazari et al., 2010).

Zirconium Oxide Nanoparticles (ZrO_2)

Zirconium oxide (or zirconia) nanoparticles or nanoparticles are white high-surface particles with typical dimensions of 5 ... 100 nanometers and specific surface area in the range of 25 ... 50 m^2 / g. The nano zirconium shows good aesthetics (translucency), superior physical resistance (hardness, flexibility, durability), chemical resistance (practically inert) and is a very good insulator.

Wolfram (Tungsten) Oxide Nanoparticles (WO_3)

In recent years, 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.

III. Nanotechnologies for Construction

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).

3.1. Nanotechnologies 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-silicatehydrate reaction caused by calcium leaching in water, blocking water penetration and leading to improvements in durability (Mann, 2006). Nano-sensors have a great potential to be used in concrete structures for quality control and durability monitoring. (to measure concrete density and viscosity, to monitor concrete curing and to measure shrinkage or temperature, moisture, chlorine concentration, pH, carbon dioxide, stresses, reinforcement corrosion or vibration). 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.

3.2. Nanotechnologies 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 (Mann, 2006).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 (Mann, 2006). Also, the high temperatures involved in the steel elements production process enhances the vibration of carbon atoms significantly, leading to bond breaking and deffects in the nanotubes structure.

3.3. Nanotechnologies for Wood

Wood is composed of nanotubes or “nanofibrils”. Lignocellulosic surfaces at the nanoscale could open new opportunities for such things as selfsterilizing surfaces, internal self-repair, and electronic lignocellulosic devices, providing feedback for product performance and environmental conditions during service (Mann, 2006). Highly water repellent coatings incorporating silica and alumina nanoparticles and hydrophobic polymers are proper to be used for wood.

3.4. Nanotechnologies for Glass

The use of TiO2 nanoparticles to glasses leads to so-called *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.

3.5. Nanotechnologies for Coatings and Paitings

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 (Mann, 2006).

3.6. Nanotechnologies for Thermal Insulation

Micro- and nanoporous aerogel materials are appropiate for being core materials of vacuum insulation panels but they are sensitive to moisture. As a possible remedy it was produced an ultra-thin wall insulation which uses a hydrophobic nanoporous aerogel structure. Another application of aerogels is silica based products for transparent insulation, which leads to the possibility of super-insulating windows. Micro- or nanoelectomechanical systems offer the possibility of monitoring and controlling the internal environment of buildings and this could lead to energy savings

3.7. Nanotechnologies for Fire Protection

Fire resistance of steel structures is often provided by a coating produced by a spray-on cementitious process. Nano-cement (made of nanosized particles) has the potential to create a tough, durable, 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.

3.8. Nanotechnologies for Structural Monitoring

Nano- and microelectrical mechanical systems (MEMS) sensors have been developed and used in construction to monitor and/or control the environment condition and the materials/structure performance. Nanosensor ranges from 10–9 to 10–5 m. These sensors could be embedded into the structure during the construction process and could monitor internal stresses, cracks and other physical forces in the structures during the structures' life (Lee *et al*., 2010).

IV. Conclusions

Nanomaterials and nanotechnologies have attracted considerable scientific interest due to potential new uses of particles on a nanometric scale and, consequently, a large amount of funds and efforts have been used. Although construction materials may constitute only a small part of this overall effort, it could pay huge rewards in the areas of technological advances and economic benefits. Although today the total participation in the market of nano products for construction is small and it is considered to be applied in specialized markets, this participation is expected to grow in the near future, and that the nanoparticles play an important role as a basis for the design, development and production of the material construction industry. Following the synthesis achieved in this document, it can be concluded that the use of nanomaterials in construction is viable in four main directions of development: structural concrete; structural monitoring in real time; coatings and paints; Thermal insulation. The first two directions of development are of great interest. In addition, the research process will study: the possibility of replacing steel reinforcements in reinforced concrete with carbon nanotubes capable of withstanding stress tensions; the possibility of increasing the durability of concrete using nanomaterials; The development of real-time monitoring systems for structural elements using nanomaterials embedded in concrete to obtain safer buildings.

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