The use of Nanotechnology in construction sector

Lecture .Sada abdalkhaliq hasan

College of engineering

Alqadisya university

E mail : sadaalyasri2012@gmail.com

Received 20 January 2013 Accepted 29 December 2013

ABSTRACT.

The latest researches on nonmaterial's and nanotechnologies showed the potential use of these materials in deferent fields such as construction, medicine, energy automobile industry, and so on. This is due to the special characteristics of materials at the nano scale. Nanotechnology research and product development are actively conducted in industries that manufacture advanced materials. Building and construction materials sector are one of the main beneficiaries of these researches. With these applications the materials resistances can be improved and increasing of their durability of concrete ,steel, glass and buffer materials. For example self healing concrete. The largest amount of pollutants are due to the production of various construction materials and to the energy required during their service .the Improving of materials by nanotechnology will reduce environmental pollution by reducing the carbon of the building materials, such as cement, and the use of performance thermal insulations will result in efficient use of energy for air conditioning. This paper shows the principles of nanotechnology in the construction sector and explores the current status in the construction industry which is findings from a literature review ,and latest researches in the world . Development are also presented to identify the potential benefits for More Sustainable Construction .

Key ward : **nano material , nanotechnology in civil engineering, nanotechnology in the construction , smart construction, carbon nanotubes .**

استخدام تكنولوجيا النانو في حقل الإنشاء

م. صدى عبد الخالق حسن

جامعة القادسية

كلية الهندسة \قسم الهندسة المدنية

الخلاصة

البحوث الأخيرة للمواد النانوية وتكنولوجيا النانو بينت إمكانية استخدام هذه المواد في حقول مختلفة مثل الإنشاء , الطب, الطاقة , صناعة السيارات.. الخ ,وهذا يرجع الى خصائص تلك المواد عند حجم النانو ,ان بحوث تكنولوجيا النانو قد تطور نتاجها فقد اجريت بشكل فعال في الصناعة وأنتجت مواد محسنة .استطاع حقل مواد البناء والإنشاء أن يكون احد أهم المستفيدين من هذه البحوث حيث مع

هذه التطبيقات نستطيع ان نحسن مقاومة المواد ونزيد ديمومة كل من, الحديد , الزجاج , المواد العازلة , الكونكريت مثل المعالجة الذاتية للكونكريت .
ان الكمية الكبرى من الملوثات تكون بسبب انتاج مختلف مواد البناء ومتطلبات الطاقة لخدمتها , ان المواد المحسنه بتكنولوجيا النانو سوف تقلل من التلوث البيئي بواسطة تقليل الكاربون من مواد البناء مثل السمنت ,كما إن استخدام عوازل الحرارة ينتج عنه كفاءة في استخدام الطاقة اللازمة لتكييف الهواء .
في هذا البحث عرض لمفاهيم تكنولوجيا النانو في حقل الإنشاء ويتصفح المكانة الحالية لتكنولوجيا النانو في حقل التصنيع والتي تم العثور عليها في المراجع والادبيات وأحدث البحوث في العالم ويتضمن البحث التطور الحاصل لتحديد امكانية المنافع للانشاء الاكثر استدامة .

مفاتيح الكلمات : مواد النانو , تكنولوجيا النانو في الهندسة المدنية ,تكنولوجيا النانو في الانشاء ,الانشاء الذكي ,انابيب الكاربون

INTRODUCTION

Nanotechnology is a technology that allows us to develop materials and improve it s properties to product new materials”.[15] It is defined as “a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution. One or more external dimensions is in the size range 1 nm-100 nm. In specific cases and where warranted by concerns for the environment, health, safety or competitiveness the number size distribution about 50 % may be replaced by a 1 and 50 %..[6]
Civil engineering is not interested with nanotechnology in construction sector in Iraq The thought of civil engineering knowledge should address. The need to provide a broad vision, develop the higher-order skills of future civil engineers. That enable them to adopt emerging technologies, and formulate innovative solutions to complex problems. this research review the achievements of researchers in civil engineering and construction sectors in the world that related with nanotechnology for More Sustainable Construction .

NANOMATERIALS FOR CONSTRUCTION

Nanotechnology has changed and will continue to change our vision, expectations and abilities to control the materials world. These developments will definitely affect construction and construction materials. Recent major achievements include the ability to observe structure at its atomic level and measure the strength and hardness of microscopic and nanoscopic phases of composite materials.[13]
Because the size of the particles is a critical factor, the material properties significantly differ at the nano scale from that at larger scales. Physical phenomena begin to occur differently below the boundary limit: gravity becomes unimportant, electrostatic forces and quantum effects start to prevail. In the same time, the proportion of atoms on the surface increases relative to those inside, creating so-called “nano-effect”. [7]
Nanotechnology can generate products with many unique characteristics that can improve the current construction materials: lighter and stronger structural composites, low maintenance coatings, better cementations materials, lower thermal transfer rate of fire retardant and insulation, better sound absorption of acoustic absorbers and better reflectivity of glass.[14]
When the dimensions of a material are decreased from macro size to nano size, significant changes in electronic conductivity, optical absorption chemical reactivity and mechanical properties occur. With decrease in size, more atoms are located on the surface of the particle. Nano powders have a remarkable surface area **(Fig. 1)**.The surface area imparts a serious change of surface energy and surface morphology. All these factors alter the basic properties and the chemical reactivity of the nanomaterials The change in properties causes improved catalytic ability,''' tunable wavelength-sensing

ability' and better-designed pigments and paints with self-cleaning and self-healing Nano sized particles have been used.[13]

TYPES OF NANOMATERIALS FOR CONSTRUCTION

1- The Carbon Nanotubes

Carbon nano tubes (CNTs) are in the family of carbon allotropes. CNTs are cylindrical in nature and possess a hardness equivalent to that of diamond. In construction, CNTs can be used as nontoxic additives for coatings, leading to better electrical, fire resistant, and optical properties.[27]
CNTs can be used to produce protective clothing materials because of their flame retardant property. When used as an additive in concrete, CNTs improve crack resistance, compared with conventional cements.[20]
(Fig. 2) showing single-walled carbon nanotube and Multi-walled carbon [21]
Carbon nanotubes are a form of carbon having a cylindrical shape, the
name coming from their nanometre diameter. They can be several millimetres in length and can have one "layer" or wall (single walled nanotube) or more than one wall (multi walled nanotube). [14]

Expected benefits of carbon nanotubes (CNT) Reinforced Cement/Concrete

They are one-dimensional nanostructure where:
1-the length-to-diameter ratio exceeds 10,000.
2- The Young's modulus of CNTs can be as high as 1000 GPa ,5 times higher than steel.
3- The tensile strength can be up to 63 GPa, 50 times higher than steel.
4- They exhibit unique electrical properties, and are efficient conductors of heat.
5- Much research activities have focused on CNTs reinforced polymer or ceramic composite
6- Exploration of applications of this new material in cement/concrete is underway
7-Plain concrete itself is a brittle material that is much stronger in compression than in tension.
8- carbon nanotubes may be applied to improve mechanical performance of cement/carbon-nanotube composite
9- 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.
10- The addition of small amounts (1%) of carbon nanotubes can improve the mechanical properties of mixture samples of Portland cement and water.
11- 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.[7]
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. Also, the high temperatures involved in the steel elements production process enhances the vibration of carbon atoms significantly, leading to bond breaking and defects in the nanotubes structure.[15]

Nano-sensors

Nano and microelectrical mechanical systems (MEMS) -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). 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. [14]

Global Markets and Technologies for Carbon Nanotubes

The global market for various carbon nanotubes (CNT) grades was
$192 million in 2011. In 2012, it is estimated to generate nearly$239 million in revenues, and projected to grow over the next five years at a compound annual growth rate (CAGR) of 22.4%, reaching $527 million by 2016.

• The global market for multi-walled carbon nanotubes (MWNTs) is estimated to rise from $219 million in 2012 to $292 million in 2016,a CAGR of 9.1% between 2011 and 2016.

• The global market for few-walled carbon nanotubes (FWNTs) is estimated to reach $1.8 million in 2012 and $120 million in 2016, a CAGR of 131.6% between 2011 and 2016.[16]

2-Titanium Dioxide Nanoparticles (TiO2)

Nano scale TiO2 particles in the 10 to 30 nm range are chemically stable, transparent, and light- and weather-resistant. The titanium dioxide nanoparticles are added to concrete to improve its properties. This white pigment is used as an excellent reflective coating. Or added to paints, cements and windows for its sterilizing properties. The titanium dioxid breaks down organic pollutants, volatile organic compounds and bacterial membranes through powerful photocatalytic reactions, reducing air pollutants when it's applied to outdoor surfaces. Being hydrophilic gives self cleaning properties to surfaces to which it is applied, because the rain water is attracted to the surface and forms sheets which collect the pollutants and dirt particles previously broken down and washes them off. The resulting concrete surface has a white colour that retains its whiteness very effectively .[25].

Nano-TiO2 coatings can also be applied to building exteriors to prevent sticking of pollutants, and thus reduce a facility's maintenance costs.[2] It can also be used as a coating material on roadways to capture and break down organic and inorganic air pollutants by a photocatalytic process. [27]

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.

Current nano-TiO2 production levels have reached approximately 4 million metric tons at a price of approximately $45/kg to $50/kg versus $2.5/kg for conventional TiO2. Small production volumes and high cost remain the main barriers to the use of nano-TiO2.[25],[12]

3- Silicon Dioxide Nanoparticles (SiO2)

Nano-SiO2 has been found to improve concrete workability and strength, to increase resistance to water penetration, and decreases the setting time of mortar when compared with silica fume (microsilica) and reduces bleeding water and segregation by the improvement of the cohesiveness and to help control the leaching of calcium, which is closely associated with various types of concrete degradation. Nano-SiO2, additionally, was shown to accelerate the hydration reactions of both C3S and an ash–cement mortar as a result of the large and highly reactive surface of the nanoparticles. Nano-SiO2 was found to be more efficient in enhancing strength than silica fume. Nano-SiO2 has been found to increase the compressive strength of concretes containing large fly ash volume at early age, by filling the pores between large fly ash and cement particles by accelerate the hydration reactions of both C3S and an ash–cement mortar as a result of the large and highly reactive surface of the nanoparticles.[23],[1]

Another application of silica is based products for transparent insulation, which leads to the possibility of super-insulating windows. Micro- or nano electro mechanical systems offer the possibility of monitoring and controlling the internal environment of buildings and this could lead to energy savings.

Fire-protective glass is obtained using (SiO_2) nanoparticles as a clear interlayer sandwiched between two glass panels which turns into a rigid and opaque fire shield when is heated .Highly water repellent coatings incorporating silica and alumina nanoparticles and hydrophobic polymers are proper to be used for wood.[7]

The icing chemicals could penetrate concrete's porous structure and oxidize the reinforcing steel and cause cracking and deterioration to the structure. The addition of nanoscale silica fume operates at a nanoscale and can improve durability of concrete structures exposed to the-icing salts **(Fig. 3)** showing Silica fume 10nm [10].

<u>Self-Cleaning Nano-Coating by cilica</u>

lotus leaves have a fine surface with wax crystals of around 1 nm in diameter .The contact area between the water and surface is reduced to only 2-3% of the droplet-covered surface , Dirt and grime can be collected by water drops and rinses off Nanotechnology is being used to mimic the lotus leaf surface and create new painting or coating [10], [27] (**Fig. 4)** showing non treated surface and treated surface with silica nano particles ,

The new development in science & technology has allowed using the latest nano technology to produce eco-friendly Organo-Silicon products to waterproof practically in waterproofing building materials.

4 -Zinc Oxide Nanoparticles (ZnO)

ZnO is a unique material that has a diverse family of nanostructures such as nanocombs, nanorings, nanohelixes, nanobows, nanobelts, nanowires, and nanocages and exhibited semiconducting, piezoelectric, and pyroelectric multiple properties Furthermore, ZnO one dimensional (1D) nanostructures combine remarkable properties such as wide band gap, high surface area to volume ratio, high catalytic efficiency, non-toxicity, biocompatibility, chemical stability and strong adsorption ability due to the high isoelectric point . Moreover ZnO is bio-safe and having high ionic bonding (60%), while being insoluble at biological pH [5]. Zinc oxide is a unique material that exhibits semiconducting and piezoelectric dual properties. It is added into various materials and products,including plastics, ceramics, glass, cement, rubber, paints, adhesive, sealants,pigments, fire retardants. Used for concrete manufacturing, ZnO improves the processing time and the resistance of concrete against water.[3]

5- Aluminum Oxide Nanoparticles (Al_2O_3)

The addition of nano-Al_2O_3 of high purity improves the characteristics of concretes, in terms of higher split tensile and flexural strength. The cement could be advantageously replaced in the concrete mixture with nano-Al_2O_3 particles up to maximum limit of 2.0% with average particle sizes of 15 nm, the optimal level of nano- Al_2O_3 particles content being achieved with 1.0% replacement.[17]

6- *CuO* nanoparticles

CuO nanoparticles with an average particle size of 15 nm were added to self-compacting concrete and various properties of the specimens were measured CuO nanoparticles are able to improve the compressive strength of self-compacting concrete and reverse the negative effects of superplasticizer on compressive strength of the specimens.[17]

7- metals and elements nanoparticles

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 [15].

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 nanosilver will affect, in contact with bacteria, viruses and fungi, the cellular metabolism and inhibit cells growth. The nanosilver inhibits multiplication and growth of bacteria and fungi, which causes infection, odour, itchiness and sores. The core technology of nanosilver is the ability to produce particles as small as possible and to distribute these particles very uniformly. When the nanoparticles are coated on the surface of any material, the surface area is increasing several million times than the normal silver foil. [26]

Tungsten trioxide(WO3) has been employed in the production of electro chromic windows, or smart windows. These windows are electrically switch able 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.[7]

8-nano-ZrO2

Zirconia ceramics have been largely used because of their chemical and physical properties, such as excellent chemical resistance, high refractoriness and ionic conductivity.[9] it is possible to add nano-ZrO2 of a high purity (99.9%) and a high Blaine fineness value (60 m2/g) in order to improve the characteristics of cement mortars the nano-ZrO2 particles blended concrete had higher split tensile and flexural strength compare to that of the concrete without nano-ZrO2 particles. It is found that the cement could be advantageously replaced with nano-ZrO2 particles up to maximum limit of 2.0% with average particle sizes of 15 nm. Although, the optimal level of nano-ZrO2 particles content was achieved with 1.0% replacement. However, the split tensile strength of the concrete could be improved by using more suitable reinforcements such as needle type nanoparticles.[18],[24]

Nano technology and self healing concrete

Experimentation is also underway on self-healing concrete. When self-healing concrete cracks, embedded microcapsules rupture and release a healing agent into the damaged region through capillary action. The released healing agent contacts an embedded catalyst, polymerizing to bond the crack face closed. In fracture tests, self-healed composites recovered as much as 75 percent of their original strength. They could increase the life of structural components by as much as two or three times. When cracks form in this self-healing concrete, they rupture microcapsules, releasing a healing agent which then contacts a catalyst, triggering polymerization that bonds the crack closed .that is shown in(**Fig .5**)[10],[19]

Nanotechnology and Wood

Carbon nanotubes are a new discovery, whereas wood is an ancient material which has been used since the dawn of civilization. However, perhaps not surprisingly given nature's evolutionary process, wood is also composed of nanotubes or "nano fibrils"; namely, lignocelluloses (woody tissue) elements which are twice as strong as nano fibrils would lead to a new paradigm in sustainable construction as both the production and use would be part of a renewable cycle. Some developers have speculated that building functionality onto lignocellulosic surfaces at the nano scale could open new opportunities for such things as self-sterilizing surfaces, internal self-repair, and electronic lignocelluloses devices. Due to its natural origins, wood is leading the way in cross-disciplinary research and modelling techniques.

Firstly, BASF have developed a highly water repellent coating based on the actions of the lotus leaf as a result of the incorporation of silica and alumina nano particles and hydrophobic polymers. And, secondly, mechanical studies of bones have been adapted to model wood, for instance in the drying process.[24],[22]

nanotechnology on the environment

A good example illustrating the impact of nanotechnology on the environment is the cement production process. At an annual production rate of 2.35 billion tons, cement manufacturing is responsible for large amounts of carbon dioxide (CO_2) emissions and pollutants. Research expects that by reducing 10% of CO_2 in cement production facilities could accomplish 20% of the goal identified in the Kyoto Protocol For example, additives such as belite, calcium sulfo-aluminate and calcium alumino-ferrite . have been found to reduce the CO_2 emissions by nearly 25% in the production phase.[19],[4],[8] .Nanotechnology, the manipulation of matter at the molecular scale, is bringing new materials and new possibilities to industries as diverse as electronics, medicine, energy and aeronautics. Our ability to design new materials from the bottom up is impacting the building industry as well. New materials and products based on nanotechnology can 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 already brought to market self-cleaning windows, smog-eating concrete, and many other advances. But these advances and currently available products are minor compared to those incubating in the world's nanotech labs today. There, work is underway on illuminating walls that change colour with the flip of a switch, nanocomposites as thin as glass yet capable of supporting entire buildings, and photosynthetic surfaces making any building facade a source of free energy.[24],[7]

Some manufactured nanomaterials have already been in use for a long time (e.g., carbon black, TiO_2) showing low toxicity. Therefore, the hypothesis that smaller means more reactive, and thus more toxic, cannot be substantiated by the published data. In this respect nanomaterials are similar to normal chemicals /substances in that some may be toxic and some may not. As there is not yet a generally applicable paradigm for nanomaterial hazard identification, a case-by-case approach for the risk assessment of nanomaterials is still warranted.[11]

<u>MOR SUSTAINABLE CONSTRUCTION</u>

Increased consumption of raw materials in the construction industry affects the environment, economy, and society. Lack of raw materials causes prices to increase.The use of nano-based materials can reduce the amount of raw or bulk materials needed to achieve or surpass similar strength and durability properties. A good example illustrating the impact of nanotechnology on the environment is the cement production process. At an annual production rate of 2.35 billion tons, cement manufacturing is responsible for large amounts of carbon dioxide (CO_2) emissions and pollutants. Research expects that by reducing 10% of CO_2 in cement production facilities could accomplish 20% of the goal identified in the Kyoto Protocol .[19]. For example ,additives such as belite, calcium sulfo-aluminate and calcium alumino-ferrite [4]. have been found to reduce the CO_2 emissions by nearly 25% in the production phase.[8]

New materials and products based on nanotechnology can 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 already brought to market self-cleaning windows, smog-eating concrete, and many other advances. But these advances and currently available products are minor compared to those incubating in the world's nanotech labs today. There, work is underway on illuminating walls that change colour with the flip of a switch, nanocomposites as thin as glass yet capable of supporting entire buildings, and photosynthetic surfaces making any building facade a source of free energy.[24]

Most of glass in construction is on the exterior surface of buildings and the control of light and heat entering through building glazing is a major sustainability issue. Research into nanotechnological solutions to this centres around four different strategies to block light and heat coming in through windows. Firstly, thin film coatings are being developed which are spectrally sensitive surface applications for window glass. These have the potential to filter out unwanted infrared frequencies of light (which heat up a room) and reduce the heat gain in buildings, however, these are effectively a passive solution. As an active solution, thermochromic technologies are being studied which react to temperature and provide thermal insulation to give protection from heating whilst maintaining adequate lighting. [15]

Nanotechnology remains in its pre exploration stage; it is just emerging from fundamental research to the industrial application .Therefore, full scale applications, especially in construction, are limited. However, the tremendous potential of nanotechnology to improve the performance of conventional materials and processes is most promising.

CONCLUSION

Nanomaterials and nanotechnologies have attracted considerable scientific interest due to the new potential uses of particles in nanometer scale There are many potential areas where nanotechnology can benefit buildings and construction engineering like its applications in concrete, structural composites, coating materials and in nano-sensors, technologies. Work now underway in nanotech labs will soon result in new products for lighting, structures, and energy. In the building industry, nanotechnology has already brought to market self-cleaning windows, smog-eating concrete, and many other advances. The nanotechnology generated products have unique characteristics, and can importance change the requirement and organisation of construction process it could pay enormous rewards in the areas of technological The recent developments in the study and manipulation of materials and processes at the nanoscale offer the great prospect of producing new macro materials, properties and products. But till date, nanotechnology applications and advances in the construction and building materials fields have been uneven. Further, in the research process will be studied: the possibility of replacement of steel reinforcements in the reinforced concrete with carbon nanotubes able to take the tensile stresses; 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 in order to obtain safer buildings.

REFERENCE

1- Ashwani K. Rana and Shashi B.” Significance of Nanotechnology in Construction Engineering, Civil Engineering & Construction Review, 78-84, (2011)

2- Bolte, G. “Innovative building material—Reduction of air pollution through TiCem.” Proc., Nanotechnology in Construction 3, Springer ,Berlin Heidelberg, 55–61 . (2009).

3- Broekhuizen F.A, Broekhuizen J.C.," Nanotehnologia în industria europeană a construcţiilor – Stadiul actual al tehnologiei (transl. from English). 2009 page, 7-30, www.efbww.org.

4-BASF Group. http://www.basf.com . (Nov. 1, 2008).

5- Chan O.C., Syed M., Usman A. , Zafar H. Ibupotoa, Kimleang K. ,Omer N. and Magnus W. "Potentiometric creatinine biosensor based on ZnO nanowires" , JOURNAL OF NANOSCIENCE LETTERS , © 2011 Simplex Academic Publishers. www.simplex-academic-publishers.com 2012

6- European commision "Communication from the commission to the European parliament , the consol and the European economic and social committee" Brussels, Second Regulatory Review on Nanomaterials , 3\.10\2012

7- Gheorghe A. " CONSTRUCŢII. ARHITECTURĂ NANOMATERIALS AND ANOTECHNOLOGIES FOR CIVIL ENGINEERING" BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI, Technical University of Iaşi, Faculty of Civil Engineering and Building Service Received: May 19, 2011 Accepted for publication: August 27, 2011

8 -Gartner, E. "Industrially interesting approaches to 'low-CO2' cements." Cem. Concrt. Research 34(9), page 1489—1498, (2004).

9- Hee -Jin N., Dong-Seok S., Hwan K. , Jong-Kook L. , "Synthesis and crystallization of anisotropic shaped ZrO2 nanocrystalline powders by hydrothermal process" ,School of Materials Engineering, Seoul National University, Seoul,, South Korea Materials Letters 57 (2003) page 2425– 2431.

10- http://www. net \colloquium\nanotechnology –in-civil-engineering.(2012)

11 -http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_023.pdf, p. 52-53

12- Jochen T, Manu V., Winfried T.; and Jakub F. " Nanotechnology and Its Impact on Construction: Bridging the Gap between Researchers and Industry Professionals" Journal of Construction Engineering and management © ASCE / may 2012 page 594- 604

13- Konstantin S. and Miguel F. G. " How Nanotechnology Can Change the Concrete World" Part One of a Two-Part Series American Ceramic Society Bulletin(ACS), Vol. 84, No. 10 October 2005.

14- Lee J., Mahendra S., Alvarez P.," Nanomaterials in the Construction Industry" a Review of their Applications and Environmental Health and Safety Considerations.ACS, 3580-3590 (2010).

15 - Mann Surinder " Nanotechnology and Construction" Institute of Nanotechnology, European Naontechnology gateway 31/10/2006

16- Market Research Reports and Technical Publications Product Catalog November 2012.

17- Nazari A., Shadi R., Sharin R., Shamekhi S.F., Khademno A.," Al2O3 Nanoparticles in Concrete " J. of Amer. Sci., 6, 4, page 94-97 (2010). Department of Materials Science and Engineering, Saveh Branch, Islamic Azad.

18- Nazari A., Shadi R., Sharin R., Shamekhi S.F., Khademno A " Embedded ZrO2 nanoparticles mechanical properties monitoring in cementitious composites " Journal of American Science 2010 page 86-89

19-Nanowerk. (2007). "Green nanotechnology concrete could cut carbon dioxide emissions." ,[http://www.nanowerk.com] (Nov. 13, 2007).

20- National Research Council. "Investments in federal facilities." Report of the National Academies, National Academies Press, Washington, DC. (2004) .

21- Philip W. and Deji A. "Carbon Nanotube and Graphene Device physics"http//www. amazon.co.uk ,243pages

22- Pacheco-Torgal .F and Said Jalali "Nanotechnology: Advantages and Drawbacks in the field of construction and building materials," (2011), page 582-590 .

23- Sadrmomtazi A., Barzegar A.," Assessment of the Effect of Nano-SiO2 on Physical and Mechanical Properties of Self-Compacting Concrete Containing Rice Husk, Ash. Sec. Internat. Conf. on Sustain. Constr. Mater. a. Technol., U.P.M., Ancona, Italy, June 2010, page 3-8.

24-Saurav " Application Of Nanotechnology In Building Materials" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248- 9622 , www.ijera.com, Vol. 2, Issue5, September- October 2012, page1077-1082.

25-The Royal Society. (2004). "Nanoscience and nanotechnologies: Opportunities and uncertainties." London, http://www.nanotec.org.uk/report/.(Mar. 2008).

26- (www.nanosilver.com.my).

27- Zhu, W.,Bartos, P. J. M., and Porro, A. "Application of nanotechnology in construction: Summary of a state of the art report." Mater Struct., 37(9), 649–658. (2004).

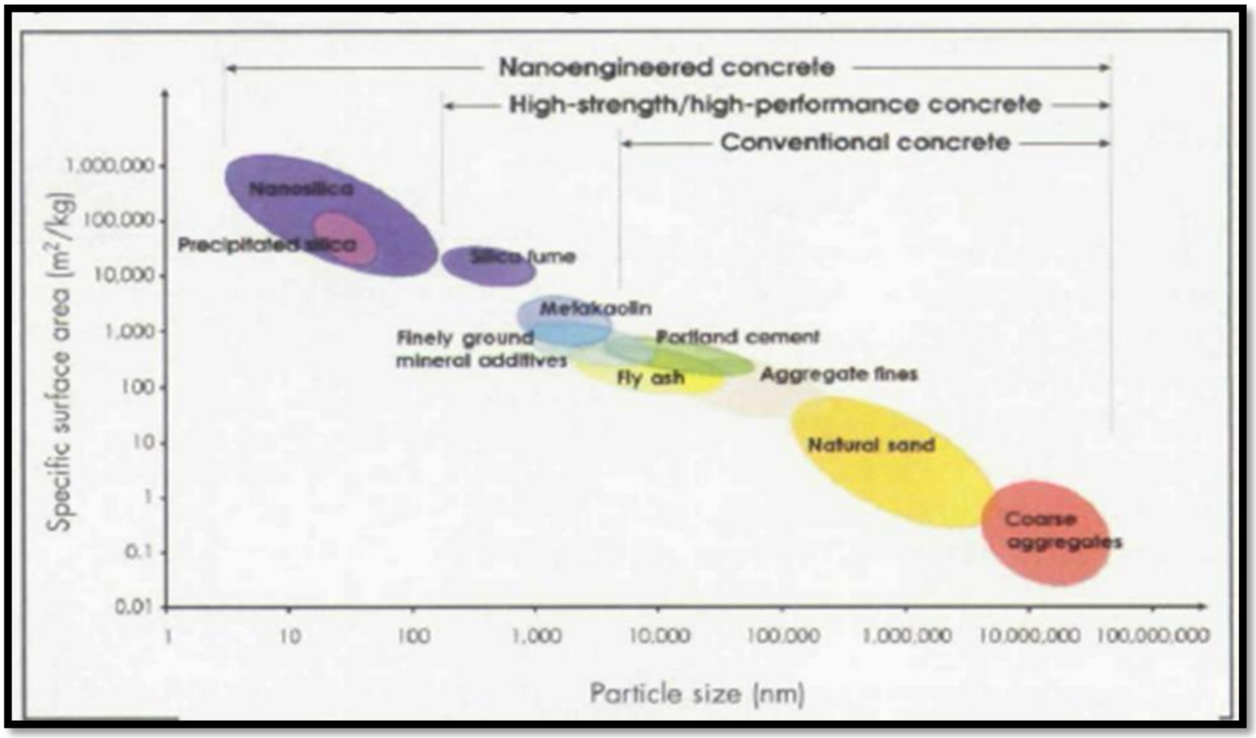

Fig .1 particle –size and specific –surface-area related to concrete materials [3]

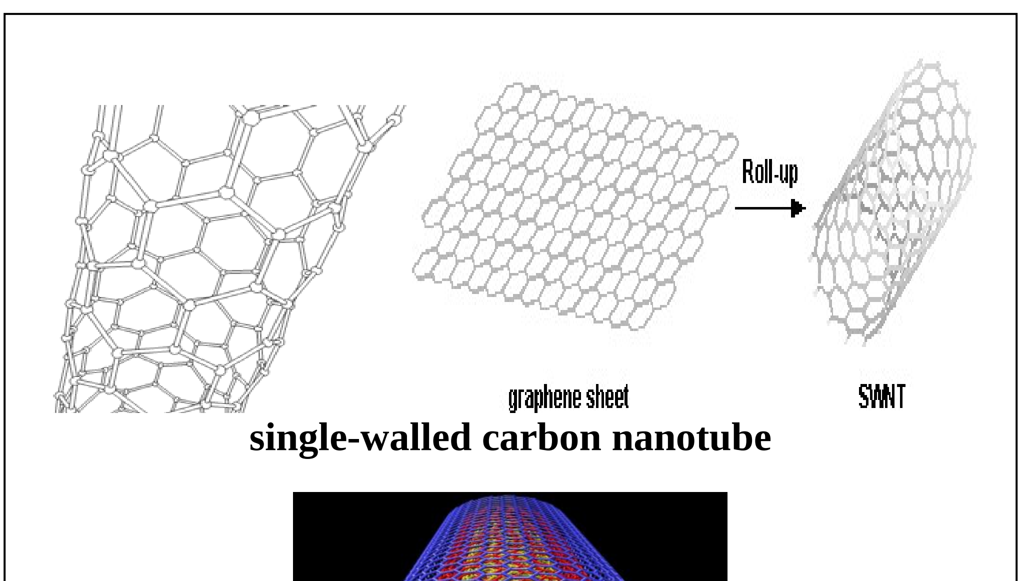

Fig .2 single-walled carbon nanotube and Multi-walled carbon nanotube [8]

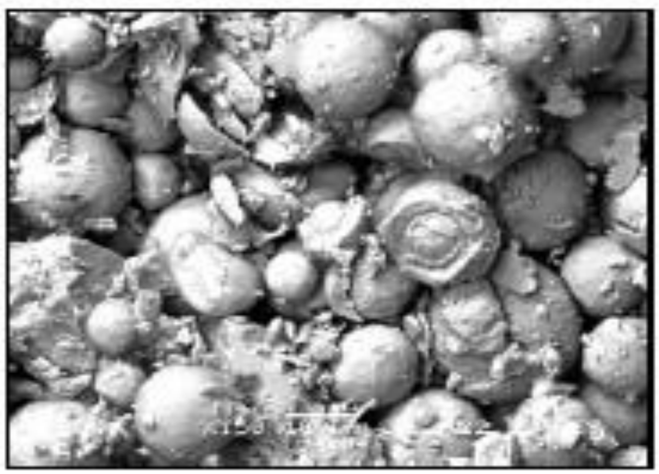

Fig.3 Silica fume 10nm [15]

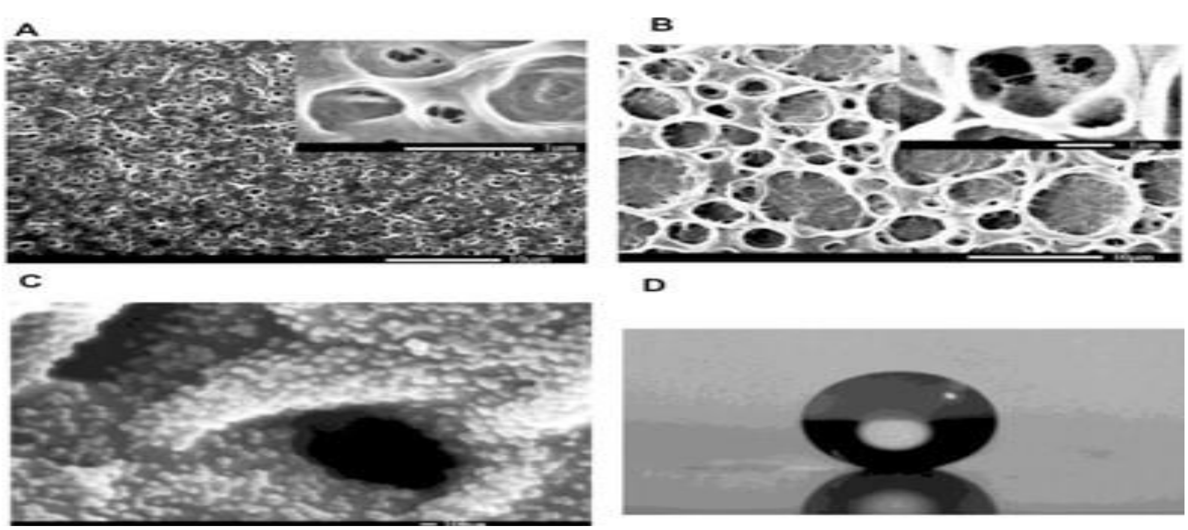

Fig. 4 (C) treated surface with silica nanoparticles. (D) Water droplet on this surface. [6]

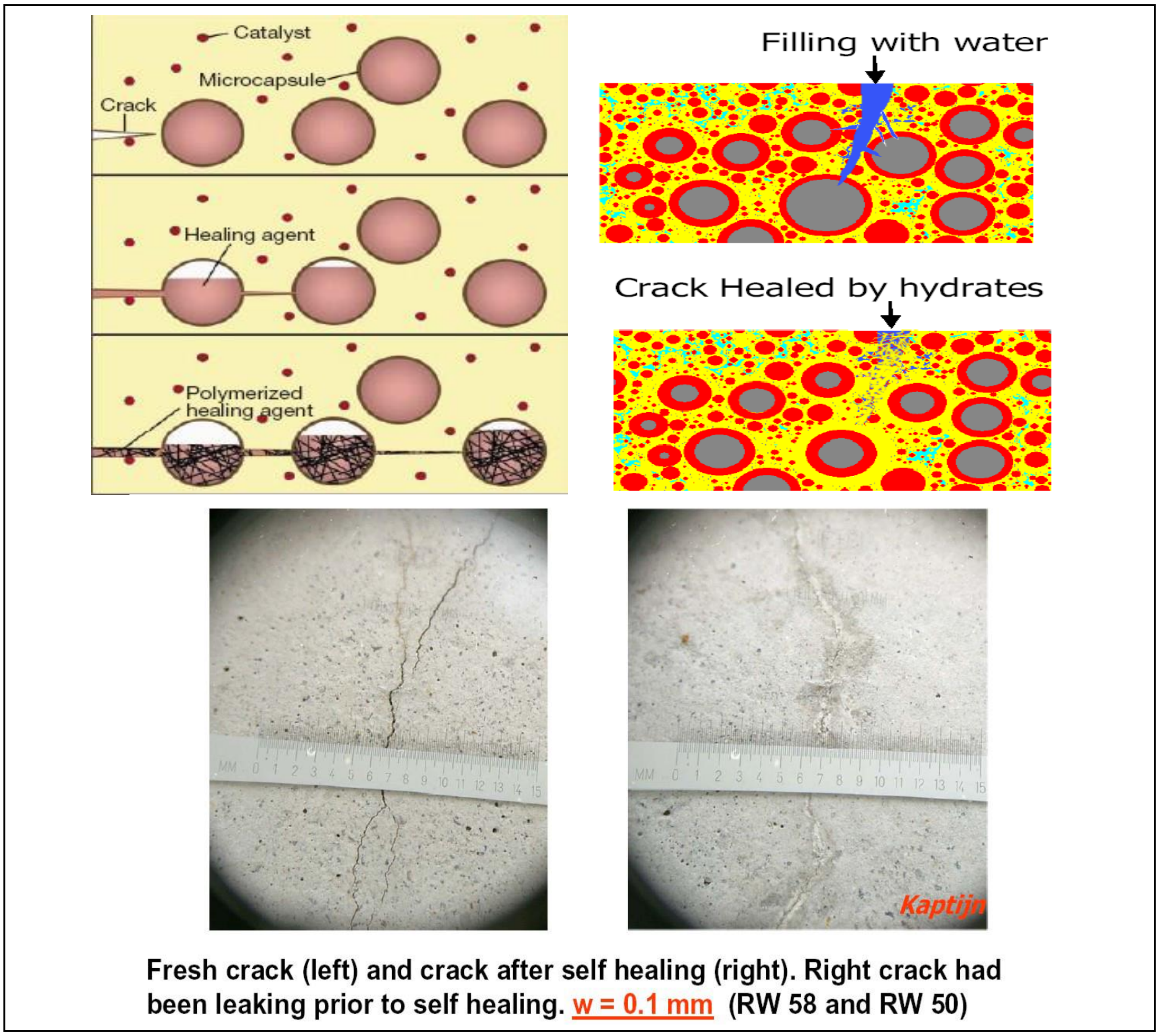

Fig. 5: Mechanism of self healing concrete [15]