A

Seminar report

On

NANO CONCRETE

Submitted in partial fulfillment of the requirement for the award of degree
Of Civil

SUBMITTED TO: **SUBMITTED BY:**

Preface

I have made this report file on the topic **NANO CONCRETE ;** I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

Thirdly, I would like to thank my friends who helped me to make my work more organized and well-stacked till the end.

Next, I would thank Microsoft for developing such a wonderful tool like MS Word. It helped my work a lot to remain error-free.

Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

1. INTRODUCTION

Nanotechnology is one of the most active research areas that include a number of disciplines including civil engineering and construction materials. Nanotechnology is the understanding, control, and restructuring of matter on the order of nanometers (i.e., less than 100 nm) to create materials with fundamentally new properties and functions. Nanotechnology encompasses two main approaches: (i) the ‘‘topdown” approach, in which larger structures are reduced in size to the nanoscale while maintaining their original properties or deconstructed from larger structures into their smaller, composite parts and (ii) the ‘‘bottom-up” approach, also called ‘‘molecular nanotechnology” or ‘‘molecular manufacturing,” in which materials are engineered from atoms or molecular components through a process of assembly or self-assembly. Traditionally nanotechnology has been concerned with developments in the fields of microelectronics, medicine and material sciences. However the potential for applications of many developments in the nanotechnology field in the area of construction engineering is growing. The evolution of technology and instrumentation as well as its related scientific areas such as physics and chemistry is making the nanotechnology aggressive and evolutional. There are many potential areas where nanotechnology can benefit construction engineering like its applications in concrete, structural composites, coating materials and in nano-sensors, etc. Nanotechnology products can be used for design and construction processes in many areas. The nanotechnology generated products have unique characteristics, and can significantly fix current construction problems, and may change the requirement and organisation of construction process. 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. Exploitation of nanotechnology in concrete on a commercial scale remains limited with few results successfully converted into marketable products. The main advances have been in the nanoscience of cementitious materials with an increase in the knowledge and understanding of basic phenomena in cement at the nanoscale.

2. APPLICATIONS OF NANOTECHNOLOGY IN CONSTRUCTION

2.1. NANOTECHNOLOGY AND CONCRETE

Concrete, the most ubiquitous material in the world, is a nanostructured, multi-phase, composite material that ages over time. It is composed of an amorphous phase, nanometer to micrometer size crystals, and bound water. The amorphous phase, calcium–silicate–hydrate (C–S–H) is the ‘‘glue” that holds concrete together and is itself a nanomaterial. Viewed from the bottom-up, concrete at the nanoscale is a composite of molecular assemblages, surfaces (aggregates, fibres), and chemical bonds that interact through local chemical reactions, intermolecular forces, and intraphase diffusion. Properties characterizing this scale are molecular structure; surface functional groups; and bond length, strength (energy), and density. The structure of the amorphous and crystalline phases and of the interphase boundaries originates from this scale. The properties and processes at the nanoscale define the interactions that occur between particles and phases at the microscale and the effects of working loads and the surrounding environment at the macroscale. Processes occurring at the nanoscale ultimately affect the engineering properties and performance of the bulk material.

There are two main avenues of applications of nanotechnology in concrete research;the nanoscience and nano-engineering. Nanoscience deals with the measurement and characterization of the nano and microscale structure of cement-based materials to better understand how this structure affects macroscale properties and performance through the use of advanced characterization techniques and atomistic or molecular level modeling. Nano-engineering encompasses the techniques of manipulation of the structure at the nanometer scale to develop a new generation of tailored, multifunctional, cementitious composites with superior mechanical performance and durability potentially having a range of novel properties such as: low electrical resistivity, self-sensing capabilities, self-cleaning, self-healing, high ductility, and self-control of cracks. Concrete can be nano-engineered by the incorporation of nanosized building blocks or objects (e.g., nanoparticles and nanotubes) to control material behavior and add novel properties, or by the grafting of molecules onto cement particles, cement phases, aggregates, and additives (including nanosized additives) to provide surface functionality, which can be adjusted to promote specific interfacial interactions.

At the basic science level, much 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). 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 behaviour of concrete at the fundamental level is an important and very appropriate use of nanotechnology. One of the fundamental aspects of nanotechnology is its interdisciplinary nature and there has already been cross over research between the mechanical modeling of bones for medical engineering to that of concrete which has enabled the study of chloride diffusion in concrete (which causes corrosion of reinforcement). Concrete is, after all, 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.

Crystallised C-S-H **Atomic resolution**

2*2 *µm²* **20*20 *nm²***

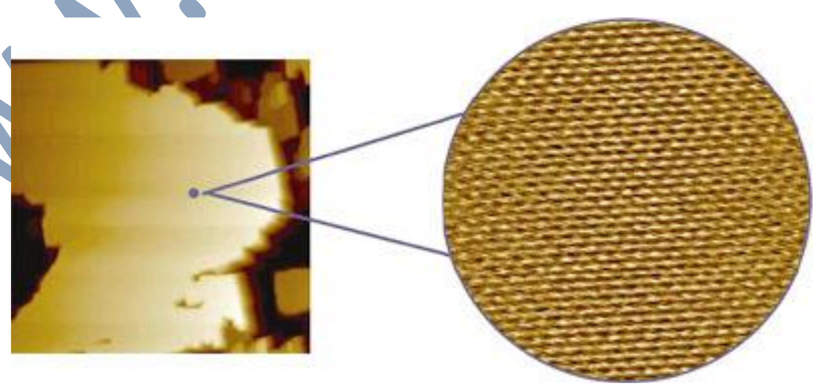

Fig 2.1. Nanoscale structure of C-S-H crystallized on calcite substrate and revealed by AFM

(from the American Ceramic Society Bulletin, 2005, Vol. 84).

Nano-engineering, or nanomodification, of cement is a quickly emerging field. Synthesis and assembly of materials in the nanometer scale range offer the possibility for the development of new cement additives such as novel superplasticizers, nanoparticles, or nanoreinforcements. These techniques can be used effectively in a bottom-up approach to control concrete properties, performance, and degradation processes for a superior concrete and to provide the material with new functions and smart properties not currently available. Engineering concrete at the nanoscale can take place in one or more of three locations: in the solid phases, in the liquid phase, and at interfaces, including liquid–solid and solid–solid interfaces. While nano-engineering of cement-based materials is seen as having tremendous potential, nonetheless, several challenges will need to be solved to realize its full potential, including the proper dispersion of the nanoscale additives, scale-up of laboratory results and implementation on larger scale, and a lowering of the cost benefit ratio.

2.1.1. Addition of nanosized and nano-structured materials

Nanosized particles have a high surface area to volume ratio, providing the potential for tremendous chemical reactivity. Much of the work to date with nanoparticles has been with nano-silica (nano-SiO_2) and nano-titanium oxide (nano-TiO_2) .There are a few studies on incorporating nano-iron (nano-Fe_2O_3), nano-alumina (nano-Al_2O_3) , and nanoclay particles . Additionally, a limited number of investigations are dealing with the manufacture of nanosized cement particles and the development of nanobinders . Nanoparticles can act as nuclei for cement phases, further promoting cement hydration due to their high reactivity, as nanoreinforcement, and as filler, densifying the microstructure and the ITZ, thereby, leading to a reduced porosity. The most significant issue for all nanoparticles is that of effective dispersion. Though it is particularly significant at high loadings, even low loadings experience problems with self-aggregation, which reduces the benefits of their small size and creates un-reacted pockets leading to a potential for concentration of stresses in the material.

Nano-SiO_2 has been found to improve concrete workability and strength, to increase resistance to water penetration, and to help control the leaching of calcium, which is closely associated with various types of concrete degradation. Nano-SiO_2, additionally, was shown to accelerate the hydration reactions of both C_3S and an ash–cement mortar as a result of the large and highly reactive surface of the nanoparticles. Nano-SiO_2 was found to be more efficient in enhancing strength than silica fume. Addition of 10% nano-SiO_2 with dispersing agents was observed to increase the compressive strength of cement mortars at 28 days by as much as 26%, compared to only a 10% increase with the addition of 15% silica fume. Even the addition of small amounts (0.25%) of nano-SiO_2 was observed to increase the strength, improving the 28 day compressive strength by 10% and flexural strength by 25%. It was noted that the results obtained depended on the production route and conditions of synthesis of the nano-SiO_2 (e.g., molar ratios of the reagents, type of reaction media, and duration of the reaction for the sol–gel method) and that dispersion of the nano-SiO_2 in the paste plays an important role. Nano-SiO_2 not only behaved as a filler to improve the microstructure but also as an activator to promote pozzolanic reactions .

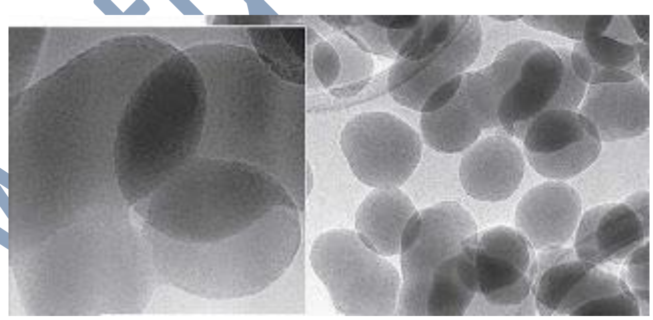

Fig 2.2 Spherical nano-SiO2 particles of uniform distribution observed using TEM(of size 20 nm and 100 nm)

(Courtesy of I. Flores and E.L. Cuellar)

Nano-TiO_2 has proven very effective for the self-cleaning of concrete and provides the additional benefit of helping to clean the environment. Nano-TiO_2

containing concrete acts by triggering a photocatalytic degradation of pollutants, such as NOx, carbon monoxide, VOCs, chlorophenols, and aldehydes from vehicle and industrial emissions. ‘‘Self-cleaning” and ‘‘de-polluting” concrete products are already being produced by several companies for use in the facades of buildings (e.g., the Jubilee Church in Rome, Italy). In addition to imparting self-cleaning properties, a few studies have shown that nano-TiO_2 can accelerate the early-age hydration of Portland cement, improve compressive and flexural strengths, and enhance the abrasion resistance of concrete. However, it was also found that aging due to carbonation may result in loss in catalytic efficiency.

Fig 2.3. Building made by using self-cleaning concrete (Church ‘‘Dives in Misericordia”, Rome, Italy)

(from *Construction and Building Materials* 25 (2011), 587)

Nano-Fe_2O_3 has been found to provide concrete with self-sensing capabilities as well as to improve its compressive and flexural strengths. Nano-Al_2O_3 has been shown to significantly increase the modulus of elasticity (up to 143% at a dosage of 5%) but to have a limited effect on the compressive strength. Nanosized cement particles and nanobinders have been proposed as a way to improve cement performance while reducing carbon emissions. Cement pastes made with nanosized cement particles have shown faster setting times and an increase in early compressive strength compared to pastes prepared with common. The concept of a nanobinder involves mechano-chemical activation that is obtained by inter-grinding cement with dry mineral additives in a ball mill. Mechano-chemical modification of cement with high volumes of blast furnace slag has been shown to increase the compressive strength by up to 62%.

Nanoclay particles have shown promise in enhancing the mechanical performance, the resistance to chloride penetration, and the self-compacting properties of concrete and in reducing permeability and shrinkage. Natural clay particles are micron and sub-micron in size, and the base structure of clay is composed of crystalline layers of aluminum phyllosilicates with thicknesses on the order of 1 nm. Chemical binding of PVA (polyvinyl alcohol) to exfoliated clay particles recently has been proposed to create linked clay particle chains that, when incorporated in cement, were shown to improve the post-failure properties of the material.

2.1.2 Use of Nanoreinforcements

Carbon nanotubes/nanofibers (CNTs/CNFs) are potential candidates for use as nanoreinforcements in cement-based materials. CNTs/CNFs exhibit extraordinary strength with moduli of elasticity on the order of TPa and tensile strength in the range of GPa, and they have unique electronic and chemical properties.

CNTs/CNFs, thus, appear to be among the most promising nanomaterials for enhancing the mechanical properties of cement-based materials and their resistance to crack propagation while providing such novel properties as electromagnetic field shielding and self-sensing. Single-wall CNTs (SWCNTs), multi-wall CNTs (MWCNTs), and CNFs are highly structured graphene ring-based materials with very large aspect ratios (of 1000 or more) and very high surface areas. SWCNTs are single graphene cylinders and MWCNTs are multiple, concentric graphene cylinders coaxially arranged around a hollow core. Unlike CNTs, CNFs present numerous exposed edge planes along the surface that constitute potential sites for advantageous chemical or physical interaction. Compared to CNTs, vapor grown CNFs have a lower production cost (about 100 times lower than SWCNTs) and are suitable for mass production. While CNTs/CNFs have been extensively studied in polymeric composites, their use in cement has, to date, remained limited. Most research efforts have focused on CNTs compared to CNFs and have been performed on cement pastes. One of the main challenges is the proper dispersion of CNTs/CNFs into cement paste, partly due to their high hydrophobicity and partly due to their strong self-attraction. Incorporating the unique mechanical properties of CNTs/CNFs in cement composites has proven to be rather complex and to date mixed results have been obtained. A number of methods have been investigated to improve dispersion and to activate the graphite surface in order to enhance the interfacial interaction through surface functionalization and coating, optimal physical blending, and the use of surfactant and other admixtures.

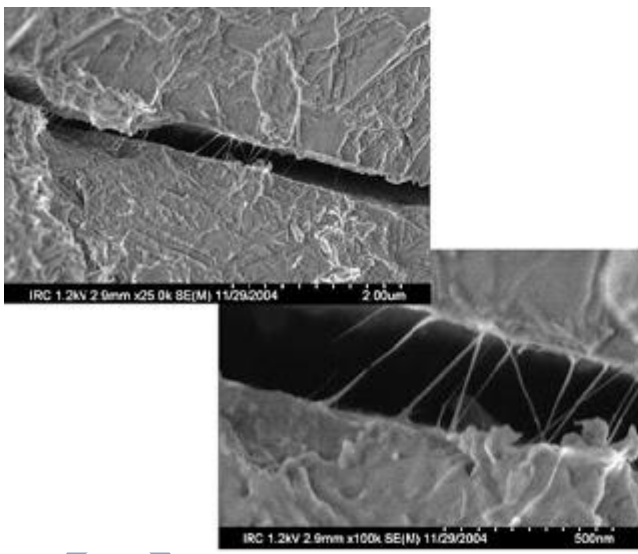

Fig 2.4 Crack bridging observed in cement-CNT composites.

(from the proceedings of ‘‘The 3rd International Conference on Construction Materials:Performance, Innovations and Structural Implications”)

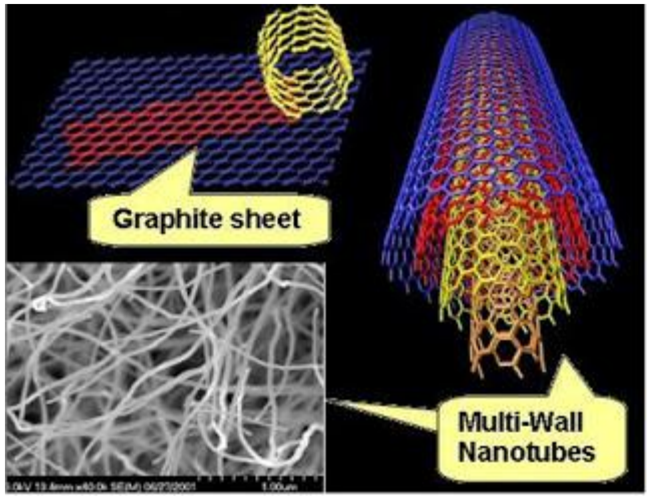

Fig 2.5. Graphite sheets of nanotubes

CNTs can affect early-age hydration and that a strong bond is possible between the cement paste and the CNTs. Their dispersion process consisted of sonication in isopropanol followed by cement addition, evaporation, and grinding, which produced cement particles coated with CNTs. Both MWCNTs and SWCNTs, when added to cement paste as a pre-mix with gum Arabic (a water-soluble gum used as a dispersing agent), were shown to increase the Young's modulus and hardness. But the mechanical properties got worsen when no dispersing agent was added. When MWCNTs was introduced as a water suspension with added surfactant admixtures , did not increase the compressive and bending strengths, though good dispersion was obtained. They also found the bonding between the MWCNTs and the cement matrix to be very weak, where, under tension, the MWCNTs were easily pulled off the matrix. But the combination of MWCNTs with polyacrylic-acid polymers found improved dispersion, good workability, and increased compressive strength. In mortar, a study using untreated CNTs and CNTs pre-treated with sulfuric and nitric acid found an increase in compressive strength up to 19% and in flexural strength up to 25% and that CNTs can decrease the electrical resistivity and improve the pressure sensitive properties of mortars. Oxidized multi-walled nanotubes (MWNT's) show the best improvements both in compressive strength (+ 25 N/mm²) and flexural strength (+ 8 N/mm²) compared to the reference samples without the reinforcement. It is theorized the high defect concentration on the surface of the oxidized MWNTs could lead to a better linkage between the nanostructures and the binder thus improving the mechanical properties of the composite rather like the deformations on reinforcing bars. However, two problems with the addition of carbon nanotubes to any material are the clumping together of the tubes and the lack of cohesion between them and the matrix bulk material. Due to the interaction between the graphene sheets of nanotubes, the tubes tend to aggregate to form bundles or “ropes” and the ropes can even be entangled with one another. To achieve uniform dispersion they must be disentangled. Further more due to their graphite nature, there is not a proper adhesion between the nanotube and the matrix causing what it is called sliding. An alternative approach was recently developed by Cwirzen et al. for a hybridized Portland cement that incorporated CNTs and CNFs grown in situ on the cement particles using a modified chemical vapor deposition method. The resulting hybrid cement, called Carbon Hedge Hog (CHH), allows for a composite containing up to 20% CNTs/CNFs. No significant change in the flexural strength was found; however, the electrical conductivity was increased by one order of magnitude. The cost of adding CNT’s to concrete may be prohibitive at the moment, but work is being done to reduce their price and at such time the benefits offered by their addition to cementitious materials may become more palatable.

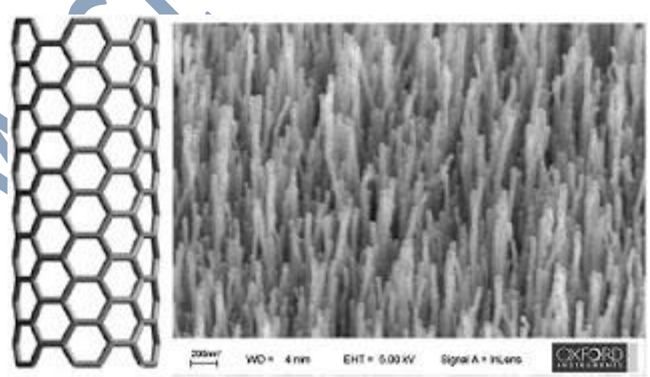

Fig.2.6 Carbon nanotubes: right schematics; left microstructure

(from *Construction and Building Materials* 25 (2011), 583)

2.2. NANOTECHNOLOGY IN STRUCTURAL COMPOSITES

2.2.1. Applications in Steel Structures, joint and welds

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. This has a significant impact on the life-cycle costs of structures and limits the effective use of resources and it is therefore a sustainability as well as a safety issue. Stress risers are responsible for initiating cracks from which fatigue failure results and research has shown that the addition of copper nano particles 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.

Current research into the refinement of the cementite phase of steel to a nano-size has produced stronger cables. High strength steel cables, as well as being used in car tyres, are used in bridge construction and in pre-cast concrete tensioning and a stronger cable material would reduce the costs and period of construction, especially in suspension bridges as the cables are run from end to end of the span. Sustainability is also enhanced by the use of higher cable strength as this leads to a more efficient use of materials

High rise structures require high strength joints and this in turn leads to the need for high strength bolts. The capacity of high strength bolts is realized generally through quenching and tempering. When the tensile strength of tempered steel exceeds 1,200 MPa even a very small amount of hydrogen embrittles the grain boundaries and the steel material may fail during use. This phenomenon, which is known as delayed fracture, has hindered the further strengthening of steel bolts and their highest strength has long been limited to somewhere around 1,000 to 1,200 MPa. Research work on vanadium and molybdenum nano particles has shown that they improve the delayed fracture problems associated with high strength bolts. This is the result of the nano particles reducing the effects of hydrogen embrittlement and improving the steel micro-structure through reducing the effects of the inter-granular cementite phase.

Welds and the Heat Affected Zone (HAZ) adjacent to welds can be brittle and fail without warning when subjected to sudden dynamic loading, and weld toughness is a significant issue especially in zones of high seismic activity. The current design philosophies include selective weakening of structures to produce controlled deformation away from brittle welded joints or the deliberate over-sizing of structures to keep all stresses low. Research has shown that the addition of nanoparticles of magnesium and calcium makes the HAZ grains finer (about $1/5^{th}$ the size of conventional material) in plate steel and this leads to an increase in weld toughness. This is a sustainable as well as a safety issue, as an increase in toughness at welded joints would result in a smaller resource requirement because less material is required in order to keep stresses within allowable limits.

Although carbon nano tubes (CNT's) have tremendous properties of strength and stiffness, they have found little application as an addition to steel as their inherent slipperiness (due to their graphitic nature) makes them difficult to bind to the bulk material and they pull out easily, rendering them ineffective. In addition, the high temperatures involved in steel manufacture and the effects of this on CNT's presents a challenge for their effective use as a composite component.

2.2.2. Nano-composites

Two relatively new products that are available today are Sandvik Nanoflex (produced by Sandvik Materials Technology) and MMFX2 steel (produced by MMFX Steel Corp). Both are corrosion resistant nano-composite, but have different mechanical properties and are the result of different applications of nanotechnology.

The modern construction requires steel of high strength and ductility. This has led to the use of low strength ductile material in larger sizes than would otherwise be possible with high strength brittle material and consequently it is an issue of sustainability and efficient use of resources. Sandvik Nanoflex has both the desirable qualities of a high Young's Modulus and high strength and it is also resistant to corrosion due to the presence of very hard nanometre-sized particles in the steel matrix. It effectively matches high strength with exceptional formability and currently it is being used in the production of parts as diverse as medical instruments and bicycle components, however, its applications are growing. The use of stainless steel reinforcement in concrete structures has normally been limited to high risk environments as its use is cost prohibitive. However, MMFX2 steel, while having the mechanical properties of conventional steel, has a modified nano-structure that makes it corrosion resistant and it is an alternative to conventional stainless steel, but widely not accepted due to its high cost.

2.2.3. Applications in Wood

Wood is also composed of nanotubes or “nanofibrils”; namely, lignocellulosic (woody tissue) elements which are twice as strong as steel. Harvesting these nanofibrils would lead to a new paradigm in sustainable construction as both the production and use would be part of a renewable cycle. Lignocellulosic surfaces at the nanoscale could open new opportunities for such things as self-sterilizing surfaces, internal self-repair, and electronic lignocellulosic 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. In the broader sense, nanotechnology represents a major opportunity for the wood industry to develop new products, substantially reduce processing costs, and open new markets for bio-based materials

2.3. APPLICATIONS IN COATING

Coating is an area of significant research in nanotechnology. Much of the work involves Chemical Vapour Deposition (CVD), Dip, Meniscus, Spray and Plasma Coating in order to produce a layer which is bound to the base material to produce a surface of the desired protective or functional properties.

Nanotechnology is being applied to paints and insulating properties, produced by the addition of nano-sized cells, pores and particles. This type of paint is used, at present, for corrosion protection under insulation since it is hydrophobic and repels water from the metal pipe and can also protect metal from salt water attack. TiO_2 nano particles are also being used in coating material. The TiO_2 coating captures and breaks down organic and inorganic air pollutants by a photo catalytic process (a coating of 7000m²of road in Milan gave a 60% reduction in nitrous oxides). TiO_2 is used to coat glazing because of its sterilizing and anti-fouling properties. The TiO_2 will break down and disintegrate organic dirt through powerful catalytic reaction. Furthermore, it is hydrophilic, which allow the water to spread evenly over the surface and wash away dirt previously broken down. Other special coatings also have been developed, such as anti-fraffiti, thermal control, energy sawing, anti-reflection coating. This research opens up the intriguing possibility of putting roads to good environmental use.

Another application is coating of glass materials. The current state of the art in cladding is an active system which tracks sun, wind and rain in order to control the building environment and contribute to sustainability, but this is unreliable and difficult to calibrate and maintain. Consequently, there is a lot of research being carried out on the application of nanotechnology to glass so as to improve its properties. Titanium dioxide (TiO2) is used in nano particle form to coat glazing. Glass incorporating this self cleaning technology increases the efficiency of buildings. Fire-protective glass is another application of nanotechnology. This is achieved by using a clear intumescent layer sandwiched between glass panels (an interlayer) formed of fumed silica (SiO2) nanoparticles which turns into a rigid and opaque fire shield when heated.

Most of glass in construction is, of course, on the exterior surface of buildings and the control of light and heat entering through building glazing is a major sustainability issue. Research into nano technological solutions are mainly done 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 building, however, these are effectively a passive solution. As an active solution, thermo chromic technologies are being studied which react to temperature and provide thermal insulation to give protection from heating whilst maintaining adequate lighting. A third strategy, that produces a similar outcome by a different process, involves photochromic technologies which are being studied to react to changes in light intensity by increasing absorption. And finally, electrochromic coatings are being developed that react to changes in applied voltage by using a tungsten oxide layer; thereby becoming more opaque at the touch of a button. All these applications are intended to reduce energy use in cooling buildings and create a sustainable built environment. .

Fig 2.7. Using TiO2 photocatalytic material as coating on roadway for pollution reduction: left; right – finished road showing a lighter colour (From *Construction and Building Materials*, 25 (2011), 588)

Nanotechnology and fire protection

Fire resistance of steel structures is often provided by a coating produced by a spray-on cementitious process. Current portland cement based coatings are not popular because they need to be thick, tend to be brittle and polymer additions are needed to improve adhesion. 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. 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 such as strength. Polypropylene fibres also are being considered as a method of increasing fire resistance and this is a cheaper option than conventional insulation.

2.4. NANOSENSORS

Nano and microelectrical mechanical systems (MEMS) sensors have been developed and used in construction to monitor and control the environment condition and the material performance. When embedded into concrete, the sensor system can provide crucial information about the curing process of the cement paste through the sensed temperature and internal humidity. The sensed temperature and internal humidity also can be integrated into available maturity methods to predict the strength of the young concrete . Knowing the strength of concrete at early ages has great benefits such as an increase in the productivity and acceleration of the construction process through the reduction of the formwork structure removal period, and an increase in the productivity of prefabricated elements and pre-stressing concrete members. When a concrete structure is in service, continuous monitoring of temperature and internal humidity will provide information about the damage process of the concrete structure due to environmental effects such as freeze/thaw cycles, chloride diffusion, alkali-silica reaction, carbonation and dimensional changes caused by temperature changes.

MEMS devices are being manufactured using the same materials and processes as microelectronic devices such as microprocessors and memory chips. There are several advantages of a MEMS-based monitoring system over other methods of condition assessment and monitoring. MEMS devices can be embedded, bringing their readings closer to the true in situ properties of the structure and not estimates based on external visual inspections or expensive non-destructive tests. MEMS technology has the potential to measure the properties of interest directly. Batch processes are used to fabricate MEMS devices, introducing high quantity, low cost and ensuring good coverage of a structure. Finally, MEMS devices are robust and bring improved ease of use. Their small, encapsulated nature makes them difficult to damage while wireless technologies make them easy to embed and interrogate. MEMS-based systems for distributed infrastructure monitoring will have integratable technologies for sensing, powering, wireless communication, device location, computation, interrogation, storage, and data analysis for condition assessment.

One advantage of these sensors is their dimension. Nanosensor ranges from 1 nm to 10000 nm. These sensors could be embedded into the structure during the construction process. Smart aggregate, a low cost piezoceramic-based multi-functional device, has been applied to monitor early age concrete properties such as moisture, temperature, relative humidity and early age strength development. The sensors can also be used to monitor concrete corrosion and cracking. The smart aggregate can also be used for structure health monitoring. The disclosed system can monitor internal stresses, cracks and other physical forces in the structures during the structures' life. It is capable of providing an early indication of the health of the structure before a failure of the structure can occur.

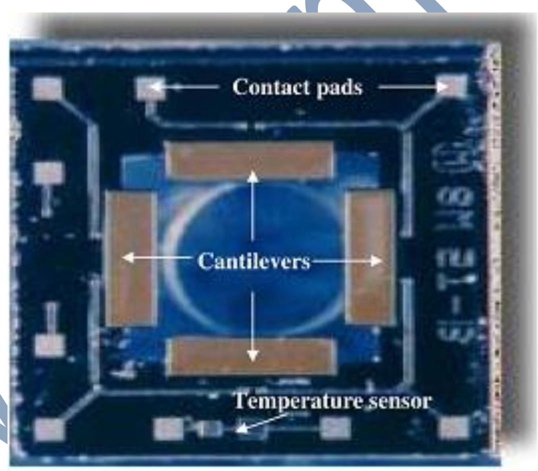

Fig 2.8. Manufactured MEMS chip

(from *Construction and Building Materials*, 22 (2008), 116)

The use of processors in fire detection systems which are built into each detector head is fairly well established these days. These improve relaibility allowing better addressability and the ability to identify false alarms. The use of nanotechnology in the future through the development of nano-electromechanical systems (NEMS) could see whole buildings become networked detectors, as such devices are embedded either into elements or surfaces.

3. FUTURE CHALLENGES AND DIRECTIONS

As with most developing technologies, a major number of challenges exit during the initiation of the application of technology into reality. It is important to be realistic and identify and plan for the limitations and challenges inherent in this technology. The challenges and limitations affecting applications of nanotechnology in construction engineering are therefore considered and studied with great importance.

3.1 FABRICATION

Current efforts in the field of nanotechnology are focussed on the fabrication, characterization and use of these materials on a nano scale domain. This leads to most of the developmental work focussing on very small quantities of material that is typically far removed from the type of quantities required for typical construction infrastructure. One of the potential solutions to this is to focus on the nano materials to act as catalyser, thereby reducing the amount of nanomaterials required substantially. Another viewpoint is that for many applications, the material does not necessarily have to be used on a nano scale to obtain a major improvement in benefits. This would be the case with reduction of the dimensions of cement, where a substantial improvement in strength can already be obtained through the large scale milling of the cement to a finer form than traditional form. Although the cement may not be purely a nanomaterial as yet, the benefits obtained would already be substantial.

3.2 HEALTH

Nanotechnology based construction products might be harmful to health. The use of nanoparticles is very recent, it has already raised issues concerning its potential toxicity.For example, the nanotubes might cause lung problems to the workers as nanoparticles can cause symptoms like the ones caused by asbestos fibers. The effects related to the inhalation of TiO_2 particles with a primary particle size between 2 and 5 nm, reporting lung inflammation for a concentration of 8.8 mg/m³. These symptoms have been confirmed and it is recommended that the use of nanoparticles should be made with the same care already used in Universities for materials of unknown toxicity, i.e., by using air extraction devices to prevent inhalation and gloves to prevent dermal contact. The possibility of DNA damage resulting in later cancer development. The nanotoxicity risk depends on the nanoparticles type, concentration volume superficial characteristics

3.3 ENVIRONMENT

The effect of various nanomaterials on the natural environment is hotly debated in nanotechnology and environmental research. Various ongoing investigations focus on the uncertainty regarding the potentials effects of materials that can exist on the nanoscale with properties that are different that when using the material on micro or macroscale. Some works in this regard shows that the potential effects may be minimal. As constructed infrastructure is provided in the natural environment, all materials used in the construction and maintenance of these facilities need to be compatible to the natural environment and their effects on the natural environment should not be negative. Typical potential problems in this regard include leaching of minerals into ground water, release of minerals into airways through the generation of dust and exposure to potentially harmful materials during construction and maintenance operations. . The Environment Protection Agency has considered that carbon nanotubes are a new form of carbon that must be treated under the toxic products Act. Moreover it will create a new category of nanowaste which has to be extracted and treated. The nanotechnology becomes a double edge sword to the construction industry. More research and practice efforts are needed with smart design and planning, construction projects can be made sustainable and therefore save energy, reduce resource usage, and avoid damages to the environment.

3.4. COST

The cost of most nanotechnology materials and equipment are relatively high. This is due to the novelty of the technology and the complexity of the equipment used for preparation and characterization of the materials. However, costs have been shown to decrease over time and the expectations are that, as manufacturing technologies improve, these costs may further decrease. Whether the expected decrease will render the materials as run-of-the-mill construction engineering materials will have to be seen, and depends largely on the benefits rendered through the applications of these materials. Current option is that in special cases, the materials will unable unique solutions to complicated problems that cause them to be cost effective, which will lead to large scale application of these specific technologies. In other cases the traditional methods for treating the problem may still remain the most cost effective. It's is a challenge for construction engineer to solve real world transportation infrastructure problem and provide a facility to the general public at a reasonable cost.

4. CONCLUSION

Nanotechnology offers the possibility of great advances whereas conventional approaches, at best, offer only incremental improvements in the field of construction engineering. Nanotechnology is not exactly a new technology, rather it is an extrapolation of current ones to a new scale and at that scale the conventional tools and rules no longer apply. Nanotechnology is therefore the opposite of the traditional top-down process of construction, or indeed any production technique, and it offers the ability to work from the "bottom" of materials design to the "top" of the built environment. However, many of the advances offered by nanotechnology, be they for economic or technical reasons, are years away from practical application, especially in the conservative and fragmented construction business. The main limitation is the high costs of nanotechnology, also concerns with the environmental and health effects. The waves of change being propagated by progress at the nanoscale will therefore be felt far and wide and nowhere more so than in construction due its large economic and social presence. There are three main issues that are preventing the widespread use of the nanotechnology (1) Lack of vision to identify those aspects that could be changed through its use, (2) Lack of skilled personnel and (3) Level of investment. The potential of nanotechnology to improve the performance of concrete and to lead to the development of novel, sustainable, advanced cement based composites with unique mechanical, thermal, and electrical properties is promising and many new opportunities are expected to arise in the coming years. However, current challenges need to be solved before the full potential of nanotechnology can be realized in concrete applications, including proper dispersion; compatibility of the nanomaterials in cement; processing, manufacturing, safety, and handling issues; scale-up; and cost.

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