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APPLICATION OF NANO TECHNOLOGY IN CONSTRUCTION MATERIAL

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Abstract - In this paper, the current developments regarding use of nanotechnology in construction purpose are discussed. Now, day's nano-materials are commonly used in construction industries. In this report, introduction and application of important nano building products are present. Some major world construction projects using nanotechnology are also documented. The uses of nano technology control and modify or improve the stability, durability, strength and other physical and chemical properties.

Keywords— Nano technology, self heating concrete, Nano steel, CNT's, MNM's,

I. INTRODUCTION

Nanotechnology is the use of very small particles of material either by themselves or by their modification to create new large scale materials. Nanotechnology is not a new science and it is not a new technology, it is rather a modification or recreation of the sciences and technologies that have already Been in development for many years. Nanotechnology is the re-engineering of materials by reducing the particle at the atomic level. The key in nanotechnology is the size of particles because the properties of materials are totally affected under a scale of nano meter. Further, as particles become nano-sized the proportion of atoms on the surface increases relative to those inside and this leads to fresh and new properties. Concrete is stronger, more durable and more easily transported, steel become stronger and glass show self-cleaning property. Increased strength and durability are also a part of the drive to reduce the environmental footprint of the built environment by the efficient use of resources. Use of nano particle reduce the percentage of pollution during the production of materials (e.g. cement) and also in service, through efficient use of energy due to advancements in insulation. Two nano-sized particles used in their application to construction materials are **Titanium dioxide (TiO2)** and **carbon nanotubes (CNT's)**. These are used to break down dirt or pollution and then allow it to be washed off by rain water on everything from concrete to glass and the Latter is being used to strengthen and monitor concrete. Owing to many unique characteristics of nanotechnology derived Products, newly developed nano based products can significantly reduce current civil engineering problems. Basically, construction deals with high-tech materials and processes that have been use in construction. Hence, there is huge scope to Apply nano technology in construction materials, which can exhibit, probably one of the most prominent, societal impacts.

Literature review

II. NANOTECHNOLOGY:

Nanotechnology means use of nano particles for the further research and improvement because of which the physical and chemical properties of that particular thing is fully or partially changed or improved. The size of the particles is the critical factor for this change. There is a dramatic change in situation and this is what happens at the scale of nanotechnology. Different things start to happen at this level e.g. effect of gravity becomes unimportant, electrostatic forces are not considered and quantum effects accepted. Another important aspect is that, as particles become nano-sized, number of particles is directly proportion to the surface area which leads to change in the properties. Knowledge at the nanoscale of the structure and characteristics of materials will promote the development of new applications and new products to repair or improve the properties of construction materials. For example, the structure of the fundamental **calcium-silicate-hydrate (C-S-H) gel** which is responsible for the positive change in mechanical and physical properties of cement pastes, including shrinkage, creep, porosity, permeability and elasticity, can be modified to obtain better durability.

Types of nano materials:

i) Titanium dioxide (TiO2)
ii) Carbon nanotubes (CNT's)
iii) Nano silica (ns)
iv) Polycarboxilates
v) Nano ZrO2 e.t.c.

III. APPLICATION OF NANO TECHNOLOGY IN BUILDING MATERIALS:

Many processes of civil engineering including design and construction can be benefited from nanotechnology. For example, new structural materials with unique and modified properties, lighter and stronger composites, fire resister, sound absorber, low maintenance cost, water offensive, nano-clay filled polymers, self-disinfecting surfaces, UN light protector, self air cleaner, nano sized sensors, solar cells etc. This paper presents, in brief, the areas of application of nanotechnology in civil engineering and the science & technology behind the improved performance.

III.I Nano technology and concrete:

Concrete is, a macro-material strongly affected by its nano-properties and understanding it at this new level for improvement of strength, durability and monitoring. Many 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). Silica (SiO2) is present in conventional concrete as part of the normal mix.

However, one of the advancements made by the study of concrete at the nano scale is that void space in concrete particle reduces by using nano-silica which leads to a densifying of the micro and nanostructure resulting in improved mechanical properties. Nano-silica addition to cement based materials can also control the degradation of the fundamental C-S-H (calcium-silicate- hydrate) reaction of concrete caused by calcium leaching in water as well as block water penetration and therefore lead to improve its durability. Related to improved particle packing, high energy milling of ordinary Portland cement (OPC) clinker and standard sand, produces a greater particle size diminution with respect to conventional OPC and, as a result, the compressive strength of the refined material is also increased by 4-6 times. Another type of nano particle added to concrete to improve its properties is titanium dioxide (TiO2).

TiO2 is a white pigment and can be used as an excellent reflective coating. It is incorporated, as nano particles and it is added to paints, cements and windows for its sterilizing properties since TiO2 breaks down organic pollutants, volatile organic compounds and bacterial membranes through powerful catalytic reactions. It can therefore reduce airborne pollutant applied to outdoor surfaces. Additionally, it is hydrophilic and therefore gives self cleaning properties to surfaces to which it is applied. The process by which this occurs is that 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, already used in projects around the world, has a white color that retains its whiteness very effectively unlike the stained buildings of the material's pioneering past. A further type of nanoparticle, which has remarkable properties, is the carbon nano tube (CNT) and current research is being carried out to investigate the benefits of adding CNT's to concrete. Carbon nanotubes are a form of carbon that was first discovered in Russia but used in the late ninety's in Japan. They are cylindrical in shape, and their name comes from their nanometer diameter. They can be several millimeters in length and can have one "layer" or wall (single walled nanotube) or more than one wall (multi walled nanotube). They have 5 times the Young's modulus and 8 times (theoretically 100 times) the strength of steel while being 1/6th the density. The addition of small amounts (1% wt) of CNT's can improve the mechanical properties of samples consisting of the main Portland cement phase and water. Oxidized multi-walled nanotubes (MWNT's) show the best improvements both in compressive strength (+ 25 N/mm2) and flexural strength (+ 8 N/mm) 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. In fact, even some of the rules in structural concrete design are actually empirically derived from observed behavior. This is strongly related to the study of service life through multiscale modeling (covering multiple dimensional scales such as from nm to m). Self Compacting Concrete (SCC) is one that does not need vibration in order to level off and achieve consolidation. This represents a significant advance in the reduction of the energy needed to build concrete structures and is therefore a sustainability issue. In addition SCC can offer benefits of up to 50% in labour costs, due to it being poured up to 80% faster and having reduced wear and tear on formwork. In addition, while long term strengths of conventionally super plasticized concrete are very high, the very early strengths, especially in winter, are not high enough for a quick and safe removal of formwork and steam curing is therefore used to accelerate the hydration of cement. This can be eliminated in the precast industry through the use of the latest generations of polycarboxylates resulting in further time and energy savings. Finally, fibre wrapping of concrete is quite common today for increasing the strength of pre- existing concrete structural elements. Advancement in the procedure involves the use of a **fibre sheet (matrix)** containing nano-silica particles and hardeners. These nanoparticles penetrate and close small cracks on the concrete surface and, in strengthening applications, the matrices form a strong bond between the surface of the concrete and the fibre reinforcement. In the strengthening process pre-cut carbon tows (fibres) and sheets impregnated with the matrix are placed on the prepared concrete surface and bonded using grooved rollers. The ability of the samples to sustain load after cracking is greatly improved by the carbon tows and both the matrix and the interface are durable under wetting and drying and scaling (scraping) conditions. Additionally, there is no decrease in the

maximum load capacity after repeated cycles of wetting and drying or scaling.

III.II Nanotechnology and Steel

Steel has been widely available since the second industrial revolution in the late part of the 19th and early part of the 20th Century and has played a major part in the construction industry since that time. Fatigue is a significant issue that can lead to the structural failure of steel subject to cyclic loading, such as in bridges or towers. This can happen at stresses significantly lower than the yield stress of the material and lead to a significant shortening of useful life of the structure. The current design philosophy entails one or more of three limiting measures: a design based on a dramatic reduction in the allowable stress, a shortened allowable service life or the need for a regular inspection regime. **Stress risers** are responsible for initiating cracks from which fatigue failure results and research has shown that the addition of **copper nanoparticles** reduces the surface unevenness of steel which then limits the number of stress risers and hence fatigue cracking. Advancements in this technology would lead to increased safety, less need for monitoring and more efficient materials use in construction prone to fatigue issues.

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.

Weld and HAZ failures led to the re-evaluation of welded structural joints in the aftermath of the 1994 Addition of nanoparticles of magnesium and calcium makes the HAZ grains finer in plate steel and this leads to an increase in weld toughness. This is sustainability 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. Two relatively new products that are available today are **Sandvik Nanoflex** and **MMFX2** steel .Both are corrosion resistant, but have different mechanical properties and are the result of different applications of nano technology. Traditionally, the tradeoff between steel strength and ductility is a significant issue for steel; the forces in modern construction require high strength, whereas safety (especially in seismic areas) and stress redistribution require high 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 nano particles in the steel matrix. The use of stainless steel reinforcement in concrete structures has normally been limited to high risk environments as its use is economic. MMFX2 steel has a modified nano-structure that makes it corrosion resistant and less costly.

III.III Nano technology in waterproofing building materials

The problem has not been addressed completely due to lack of understanding at nano level of the building material. The new development in science & technology has allowed using the latest nano technology to produce eco-friendly **Organo-Silicon products** to waterproof practically all the different kinds of building materials. The nano technology has ensured that service life of this approach will lead to life cycles beyond 20 to 30 years at very economical cost. Building materials are known to have water seepage, water leakages due to implicit porosity and microcracks.Waterproofing is a treatment, which is expected to make the material waterproof. Lots of technology and product development has taken place in various waterproofing products for the last 50 years, particularly using polymeric backbone and other materials. Another serious issue waterproofing addresses is to prevent loss of structural strength of concrete building materials, particularly due to ASR (alkali silica reaction), acid rain, and sulphate attacked. It also prevents chloride penetration which can result in corrosion of the reinforced steel bars.

III.III.I Water related problems: Most of the building materials are very porous and have **surface hydroxyl groups**. These hydroxyl groups attract water because of the hydrophilic nature and similarity with the structure of water. Therefore, most of the building material easily wet and absorb water in the pores.

. The size of the water molecule is 0.18 nm (i.e. 0.00018 microns).The size of the pores in most of the building materials, range from 5 to 200 nm. The size of most of the pollutants like acids, chlorides & sulphates would range between 1 to 2 nm. Even with the dense concrete and stones the pore size is much larger than water allowing easy entry with the hydrophilic nature of the building material. The essential requirements waterproofing materials are

- Resistance it can impart to water absorption.
- Preventing of water soluble salts, particularly chloride salts.
- Penetration of waterproofing treatment to a measurable depth.
- Non-staining of treated surface areas.
- Long-term stability in an alkaline environment.
- Low environmental and health risk.
- UV stability (20+ years).

There are two classes of waterproofing products:

a). Film Formers

b). Penetrants

Film Formers: The economics and the ease of application have led to widespread use of film forming water repellents. The products like acrylic paint, silicon polymers are commonly used in the world for waterproofing application. These film formers have particle size greater than 100 nm, which will not allow them to inter inside the pores of the

materials and form a film covering and preventing the surface from water inlet. Generally, these polymer films are hydrophobic but they need to be continuous and defect-free and also must be UV resistant. It is found that during application ensuring continuous film on rough surface is not easy which leads to weak points for film former. All the typical polymer films tend to break down under UV leading to cracking of the films in 2-5 years, which leads to failure in terms of losing of hydrophobicity and water repellency.

Penetrants: Most penetrants are solvent based material with less than 6nm size. They easily penetrate inside the pores and sub-branches of the pores. There are two types of penetrants i.e. **non reactive and reactive**. Non-reactive penetrants are oils and other low viscosity hydrophobic material, which coats the pore of the substrates, and provide water repellency. However, these types of materials are also biodegradable and loose hydrophobicity within a year. Additionally, these products also

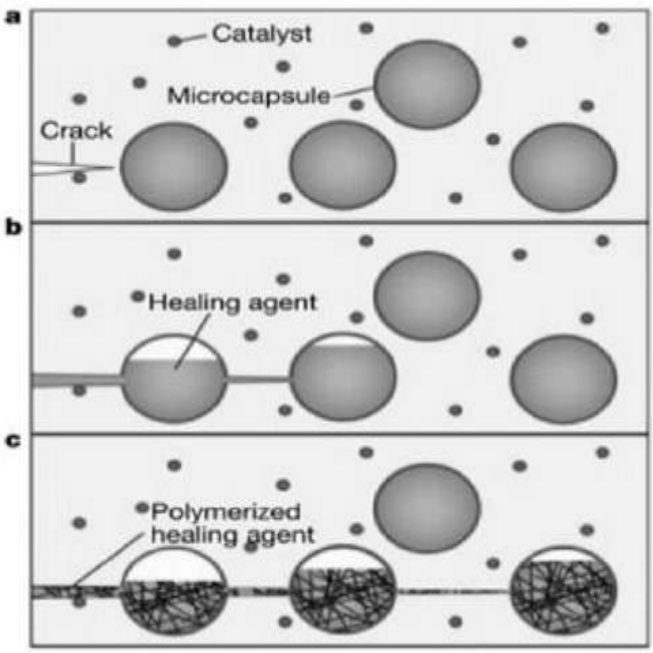
provide food for mold or fungus growth. The reactive penetrants chemically react with the substrate and provide molecular level hydrophobicity to the treated surface and 3-5mm deep in the substrate. Therefore, these types of waterproofing products provide protection for a very long period.

These products are used in USA and Europe for last 30 years. However only last few years they became available in India. The solvent based silane waterproofing compounds are used to provide long lasting performance and are used widely in USA and Europe. The various alkyl silanes that are used for waterproofing are (i) isobutyltrialkoxysilane (ii) n-octyltrialkoxysilane. Silanes are monomeric materials. The products used for waterproofing are known as alkylalkoxysilane. The products used for waterproofing are known as alkylalkoxysilane. Most building materials contains hydroxyl (OH) group. These OH groups can chemically react with alkoxy groups of Silane forming permanent siloxanes bonds with the substrate. The alkyl group R' provides hydrophobicity (water repellency) to the surface. Therefore, these types of products impart water repellency by modifying surface characteristics from hydrophilic to hydrophobic.

III.IV Nano technology and self healing concrete:

Experimentation is also underway on self-healin 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.

Sample designation	Nano Zn02 particle %	Compressive strength(MPa) 7 28 91 (days)
C0	0	25.4 34.0 42.3
N1	0.5	30.1 40.7 45.5
N2	1.0	33.4 43.9 49.0
N3	1.5	29.2 42.6 47.4
N4	2.0	28.7 39.2 43.2



Mechanism of self heating concrete

IV. CONCLUDING REMARKS AND PERSPECTIVES FOR FUTURE

The application of nano technology in construction presents a huge of opportunities and challenges. The use of micro nano materials (MNMs) in the construction industries should be considered not only to improvement in material properties and functions but also in the area of energy conservation. . An opportunity for energy conservation is really very beneficial and good for our future generation. If we want to conserve energy with using MNMs firstly we have to improve our thermal management by using silica nano particles. Use of QDs and CNTs also improve the efficiency of energy transmission and lightning. Combination of fullerene and

graphene enhance energy storage system.In order to prevent the physical exposure and hazardous impacts, nano particles are very useful. Overall, According to use of MNMs we enhance infrastructure, strength, durability, workability on a reasonable concern. This research support into safe design, production, use, recycling, reuse and remanufacturing and also improve the sustainability of both the nano technology and construction industries.

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