Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 4, Issue 6; October-December, 2017, pp. 473-475

http://www.krishisanskriti.org/Publication.html

Application of Nanotechnology in Smart Civil Structures

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Abstract—*Nanotechnology is the use of very small particles of material either by themselves or by their manipulation to create new large scale materials. Nanotechnology has the potential to make construction faster, safer, cheaper and can show more varied composition, resulting in smart infrastructure. It can also provide self-powered failure prediction and previsingmechanisms for high capital structure which improves serviceability of structures. This paper explores the vision in making of smart and innovative infrastructure and leading a smart city with the help of application of nanotechnology in civil structures. The study of Nano science and various nanoparticles and their implementation in construction field is illustrated in this paper. Different types of Nano materials used are discussed with its wide applications in construction industry. The properties like self-sensing, self-rehabilitation, self-structural health monitoring, self-vibration damping, self-cleaning and self-healing are studied .The article further highlighted more on the futuristic demand and application of nanotechnology in constructing smart structures and providing safer future to future generations. The paper is managed to be written in simple language for easy grasping.*

Index Terms*: Civil Engineering, Nanotechnology, Nanoparticles, Smart-Construction.*

1. INTRODUCTION

A. Civil Engineering an evergreen field

Engineering has been an aspect of life since the beginnings of human existence. The earliest practice of civil engineering may have commenced between 4000 and 2000 BC in ancient Egypt, the Indus Valley Civilization, and Mesopotamia (ancient Iraq) when humans started to abandon a nomadic existence, creating a need for the construction of shelter.

Civil engineering deals with innovation at each and every step of constructing a structure .It is traditionally splintered into several sub disciplines consisting of structural, architectural, geological, geotechnical, environmental, transportation, earthquake, water resources, quantity and construction surveying, municipal or urban and construction engineering.

B. Origin ofNanotechnology

The concepts that seeded nanotechnology were first discussed in 1959 by renowned physicist *Richard Feynman* in his talk *There's Plenty of Room at the Bottom,* in which he described the possibility of synthesis via direct manipulation of atoms. Nanotechnology is the use of minute particles of material either by themselves or by their manipulation to generate new large scale materials. The size of molecule, though, is very significant because at the length scale of the nanometer, 10^{-9}m, and the properties of material affects considerably.

C. Scope of Nanotechnology in construction

Nanotechnology has emerged as a change in construction industry and abilities to have control over the materials industry. Several applications have been discovered and innovated to improve the energy efficiency, durability of construction elements, and safety of the buildings, delivering the ease of maintenance and to provide increased healthy living comfort. Nanotechnology played a vital role in transforming civil engineering. For example, new structural materials with unique properties, stronger and lighter composites, sound absorber, fire insulator, low maintenance coating, Nano-clay filled polymers, Nano sized sensors, solar cells. This article introduces, in brief, the areas of application of Nano technology in civil engineering and the science & technology behind the improved performance.

D. Application of nanotechnology in smart construction

The following table exhibits some of the nanoparticles and their relevant application areas in the field of construction industry.

Table: 1(Source: (Dewalkar et.al., 2016) International Journal of Technical Research and Applicationse-ISSN: 2320-8163, www.ijtra.com Volume 4, Issue 3 (May-June, 2016), PP. 13-17)

Sr. no.	Nanoparticles	Application Areas
1.	Nano-silica (SiO2)	Replaces part of the cement to densify the concrete and gainearly strength
2.	Polymer fibre matrix using nano-silica	Self Structural Health Monitoring system in Repairs & Rehabilitation
3.	Slurry of amorphous nano-SiO2	Improves segregation resistance in self compacting concrete (SCC
4.	Low carbon, high performance steel using copper nanoparticles	In bridges for corrosion resistance & better weld ability
5.	Fumed silica nanoparticles	Fire protective glass
6.	Nanosized Titanium dioxide (TiO2), bimetallic nanoparticles such as Fe/Pd, Fe/Ag, Zn/Pd	Anti-reflection coatings for glasses, self-cleaning windows, durable paints, anti-graffiti coatings, anti -bacterial coatings and thermal control, water repellant structures, carpets, protective clothing, reflect & transmit light in different wavebands
7.	Nanotechnology enabled sensors (Nano & Micro electrical-mechanical systems)	To monitor and control temperature, moisture, smoke, noise, stresses, vibrations, cracks and corrosion
8.	Organically modified bentonite asphalt	Road construction with more durability
9.	Micro encapsulated healing polymer (smart material)	Automatically closes the cracks in concrete when they occur
10.	Laminated nano-structure modified steel (SandvikNanoflex TM, produced by MFX Steel Corporation, USA)	Lightweight, ductile, corrosion resistant & fatigue resistant applications at lower construction costs

2. FUTURISTIC IMPLEMENTATION OF NANOTECHNOLOGY

A. Superhydrophobic coating in construction material

A material which is attractive to water is hydrophilic and displays hydrophilicity. Conversely, a material that repels water is hydrophobic and displays hydrophobicity. Self Compacting Concrete (SCC)**[1]** is one that does not need vibration to level off and achieve consolidation. This represents a significant advancement in the energy efficiency to build concrete structures. In addition SCC saves up to 50% oflabour costs, due to it being poured up to 80% faster and having reduced wear and tear formation on formwork.

1. Concrete

Concrete, a composition of portland cement as binder and water as well as aggregates as fillers, is a porous material with pores ranging in size from millimeters to nanometers. The durability of concrete depends on its overall absorption and porosity to aqueous solutions. The cumulative effect of freeze-thaw cycles eventually cause cracking, crumbling, expansion and scaling of the concrete. It is therefore crucial to synthesize water-repellent concrete in order to improve its durability, and, in particular, to produce the**[2]** ultra-durable concrete. Built-up of snow and formation of ice on paved regions of roadways or airfields can create critical problems resulting in huge traffic, economical loss and endangering passenger safety. One of the advancements that emerged at the nanoscale is the particle packing of concrete which can be improved by using nano-silica which leads to a densification of the microp articles and nanostructure resulting in improved mechanical properties. Relating to the advancement made , high energy milling of ordinary portl and cement (OPC) clinker and standard sand, produces a greater particle size diminution as compared to conventional OPC and**[1]**the compressive strength of the refined material is also 3 to 6 times higher (at different ages).

2. Steel

Nano-Composite

A nano-composite is produced by adding nanoparticles to a bulk material in order to improve the bulk material's **[1]** properties. Two relatively new products that are available today are Sandvik Nanoflex (produced by Sandvik Materials Technology) and MMFX2 steel (produced by MMFX Steel Corp). Bothare corrosion resistant, but have different mechanical properties and are the result of different applications and interpretations of nanotechnology.

3. Brick

Brick is the backbone in the field of construction engineering. It is composed of cement, sand, water, lime and clay-bearing soil. Properties such as hardness, absorption, compressive strength, efflorescenceetc. vary from brick to brick depending

upon the type of brick.Water, if in excess can harm to any structure. Likewise if water comes to contact of bricks where not needed can affect the properties of bricks negatively. The hydrophobic coating of brick helps it to repel the unwanted water and to retain the strength, durability, toughness, hardness and other physical properties. Houses**[2]** made up of brick masonry can be coated with hydrophobic coating so as to prevent the bricks from environmental pollution and calamities.

B. The thirsty concrete (Topmix Permeable concrete)

Background:

When water comes in contact with the Topmix Permeable concrete, it doesn't flow in all directions, slicking up the surface. It shows its movement only in downward direction and it disappears almost instantly. Conventional concrete has to be permeable enough to let at least 300 millimeters of water per hour through the ground level. On the other hand, Topmix Permeable, accommodates 36,000 millimeters of water an hour, or **[2]** approximately 880 gallons every minute. This disappeared water adds up in the water below earth's surface. Tarmac, a UK building materials and solutions company generated Topmix Permeable to divert rainwater during storms.

Applications:

1. Reduced construction cost – Integral waterproofing is typically up to 50% less expensive than other approaches in first-cost terms.
2. Speed of construction – Integral waterproofing eliminates the need for a membrane, allowing the Building**[3]** Team to avoid this time-consuming step. The "pour-and-you're-done" approach can shave weeks off a construction schedule, which translates to faster building occupation, lower risk, and money saved.
3. Safer working conditions – No hot rubber and less on-site labor is required. This means a lower risk of injury.
4. More durable structures – Integrals, which are physically embedded in the concrete, are inherently protected from damage. Some admixtures have also shown a double benefit of reducing corrosion.

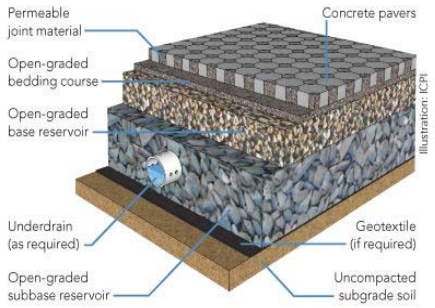

Fig 1: The formation of Topmix Permeable concrete

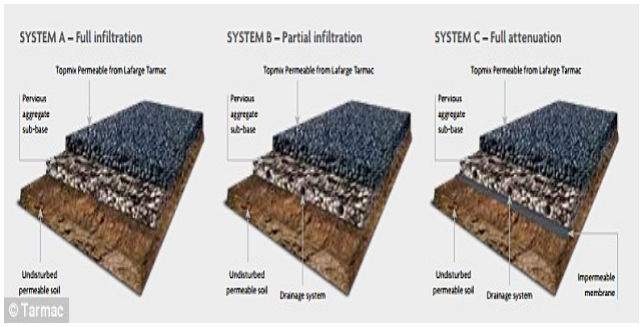

Fig 2 :Topmix Permeable Concrete

3. CONCLUSION

The root of the presented review paper swings around the implementation and innovation of nanotechnology in building a smart and efficient civil infrastructure. Various nanoparticles and their application areas in construction of smart structure are listed and setting a positive impact on environment and sustainable usage. The article further encompasses on the futuristic implementation of nanotechnology and gives an idea on applying the concept of super hydrophobic coating, water absorbing concrete and taking the nation on the ladder of progress. In short, this paper concludes with a strategic plan on how civil engineering can be discovered and innovated with the implementation of nanotechnology resulting in construction of smart structures leading to smart nation.

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