APPLICATIONS OF NANOTECHNOLOGY IN TRANSPORTATION INFRASTRUCTURES

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***Abstract* --** Nanotechnology is an area of study dealing with structures having characteristics dimensions between 1 nm and 100 nm that exhibit a variety of unique and merging chemical and physical properties. Even combining the small amount of nanoparticle can improve the engineering properties of concrete. This study is an overview of previous studies of nanotechnology and its applications in construction of infrastructures. Using Nano-particles as an additive in concrete improves physical properties. In this paper, the attempt has been made to show that nanotechnology can fix current construction problem and can alter the requirement of construction process. This study highlights main application of Nano Titanium Dioxide, Fiber Reinforced Polymer (FRP), Nano-sensors, Micro silica and Carbon Nano Tubes.

Key words –Carbon Nano tubes, Concrete, FRP, Micro-silica, Nano particles, nanotechnology, Nano Titanium Dioxide.

I. INTRODUCTION

In any infrastructure, concrete is most usable material in construction industry, so it is essential to improve its quality. Nanotechnology is one of the most active research areas which has wide applications in almost all the fields. Merging Nano particles with concrete have shown significant improvement than conventional concrete. Nano particles like Nano silica, carbon Nano-tubes, silica fumes etc. But, the behavior of concrete can be uncertain using these Nano particles. So, it is very important to review these nanoparticle's effect on concrete. This review paper primarily focuses on each of these nanoparticles used in concrete and in what way it affects the concrete's physical properties.

II. NANOTECHNOLGY

Nano materials are defined as a set of substances where at least one dimension is less than approximately 100 Nanometers. Nanomaterial's are of interest because at this scale unique optical, magnetic, electrical, and other properties emerge. These emergent properties have the potential for great impacts in electronics, medicine, and other fields. Nano particles which are used in Construction industry are

- Titanium dioxide nanoparticles – Expected benefits are rapid hydration, increased degree of hydration, and self-cleaning (in concrete); superhydrophilicity, anti-fogging, and fouling-resistance (in windows); non-utility electricity generation (in solar cells).

- Carbon nanotubes – Expected benefits are mechanical durability and crack prevention (in cement); enhanced mechanical and thermal properties (in ceramics); real-time structural health monitoring (NEMS/MEMS); and effective electron mediation (in solar cells).

A. Nano Titanium Dioxide

Titania is widely used to produce concrete pavements by mixing the Nano-particles within the pavement surface. The cleanability of the substrate can be enhanced by nanostructured titania. When light and heat strike the concrete's surface, catalysts (titanium oxides) use that energy to break down the dirt into molecules like oxygen, water, carbon dioxide, nitrates, and sulphates. Gases float away, while liquids or solids are left on surface to be washed away by rain. The reason behind, Nano TiO_2 was loaded with cementitious materials because water, oxygen and solar light required for photocatalysis reaction. Nano TiO_2 photocatalyst are usually coated on a surface as thin films. Most photocatalytic coatings are prepared by post- deposition of the catalyst, and then apply onto substrate. They're various method of coating TiO_2 with the cementitious materials such as sputtering, spray coating, sol-gel dip coating, electrodeposition and etc. These techniques of coating are used to incorporate the photocatalysts into the building materials. When the properties of nanoparticles are transferred to the surface of substrates, it will become functionalization for self-cleaning application. Some research indicated that both Nano- and micro-TiO_2 -infused concrete can remove air pollutants that interact with concrete's surface. Titanium oxide has the ability to remove pollutants from the air and reduce them into less harmful components. The researchers from Eindhoven University of Technology installed concrete paving which included titanium dioxide – called photocatalytic pavement – on a lock in the city of Hengelo, Netherlands. The study looked at reductions in nitrogen oxides (NO_x), a group of poisonous gases produced by cars and power plants that react with other compounds in the atmosphere to form smog.After analyzing measurements gathered over the course of a year, the researchers found that the treated street reduced NO_x air pollution by 19 percent on average; the figure bumped up to 28 percent during the afternoon and a remarkable 45 percent under ideal weather conditions (high radiation and low relative humidity).

B. Fiber Reinforced Polymer (FRP)

Infrastructure deterioration has been a global crisis in the recent decade. The most common method for repair and strengthening is externally bond steel plates to the structure, but lately, fiber reinforced polymers (FRPs) are slowly replacing steel. Fiber-reinforced plastic (FRP) (also called fiber-reinforced polymer, or fiber-reinforced plastic) is a composite material made of a polymer matrix reinforced with fibers. The fibers are usually glass (in fibreglass), carbon (in carbon-fiber-reinforced polymer), aramid, or basalt. Rarely, other fibers such as paper, wood, or asbestos have been used. The polymer is usually an epoxy, vinyl ester, or polyester thermosetting plastic, though phenol formaldehyde resins are still in use. They have been largely used in new construction and repair and rehabilitation of existing structures. Figure shows an application of FRP in repairing Sins Bridge, Switzerland. It was built in 1992, images shown are before and after the implementation of FRP.

Fig. 1- In 1992

Fig. 2- In 2016

Fig. 3- Overview of Sins Bridge

Advantages of FRP

- Relatively lower weight structures with high strength and stiffness can be designed
- Better seismic resistance
- Easy application

- Improves live load capacity without expense of new structures
- Corrosion resistant.
- Provides long service life without additional maintenance cost.
- Quick transportation and installation of FRP materials.
- Resistance to frost and de-icing.

2.3 Nano sensors

Nano sensors are nanoscale devices that measure physical quantities and convert those quantities to signals that can be detected and analyzed. Our modern lives rely on sensors to allow society to run smoothly. Sensors in the road detect cars at traffic lights and adjust the flow through intersections accordingly. Sensors at shopping malls detect your presence and open doors to allow you to enter. Sensors measure the water level in your washing machine and ensure it doesn't overflow. Nano sensors work in much the same way but they can detect either minute particles or miniscule quantities of something. Nano sensors have already been used in a wide range of engineering and science fields such as transportation, communication, military and medicine.

Nano sensors are based on microelectromechanical systems (MEMS), sensors which range from 10-9 m to 10- 5 m which could be embedded into the structure during the construction process. Their use in civil engineering is a new application with great potential. Such as these sensors are designed to monitor temperature, crack and moisture within the concrete. Wireless MEMS and nanotechnology-based sensors could be used as embedded components to form self-sensing concrete structures, such devices would gather and transmit information about the health of a structure by detecting the early formation of tiny cracks and measuring the rate of key parameters, such as temperature, moisture, chloride, acidity and carbon dioxide levels each of which might reflect a decrease in structural integrity. Also, it can provide an early indication before a failure of the structure occurs. Thus, the sensors are able to work as self-health monitoring system. For instance, in order to improve safety, there are Nano sensors on the Golden Gate Bridge to monitor its behavior

2.4 Micro Silica

Microsilica is a mineral admixture composed of very fine solid glassy spheres of silicon dioxide. Microsilica in concrete contributes to strength and durability two ways: as a pozzolan, microsilica provides a more uniform distribution and a greater volume of hydration products; as a filler, microsilica decreases the average size of pores in the cement paste. Used as an admixture, microsilica can improve the properties of both fresh and hardened concrete. Used as a partial replacement for cement, microsilica can substitute for energy-consuming cement without sacrifice of quality.

Addition of microsilica to a concrete mix alters the cement paste structure. Micro-silica can fill the remaining voids in the young and partially hydrated cement paste, increasing its final density. The resulting paste contains more of the strong calcium-silicate hydrates and less of the weak and easily soluble calcium hydroxides than do ordinary cement pastes. Because the microsilica particles are so small they disperse among and separate the cement particles. The resulting fine, uniform matrix can give markedly higher compressive, flexural, and bond strength. Consistency of cement depends upon its fineness. Micro silica is having greater fineness than cement and greater surface area so the consistency increases greatly, when micro silica percentage increases. Some researchers found that the addition of 1kg of micro-silica permits a reduction of about 4 kg of cement, and this can be higher if nano-silica is used.

Microsilica reduces the rate of carbonation, decreases permeability to chloride ions, imparts high electrical resistivity, and has little effect on oxygen transport. Therefore, microsilica concrete can be expected to be strongly protective of reinforcement and embedment.

2.5 Carbon Nanotubes

Carbon Nanotubes (CNTs) are incredibly strong hollow strings of carbon atoms that bond together in a tube or pipe-like fashion with unique properties which can be added to a multitude of materials to enhance durability or strength. CNTs could potentially be added to concrete or asphalt in a similar fashion to the way rebar reinforcement is used in modern construction, greatly increasing the structural strength and longevity of roads, foundations, load-bearing columns and walls, etc.

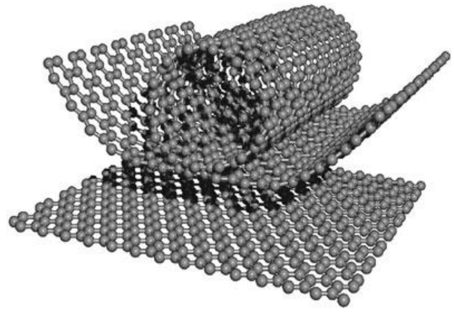

Fig. 4 Schematic of how graphene could roll up to form a carbon nanotube.

Carbon Nano- tubes properties

• Very High Tensile Strength

• Very Elastic in Nature

• Highly Flexible; Can be bent considerably without damage

• High Electrical Conductivity

• High Thermal Conductivity

• Low Thermal Expansion Coefficient

CNTs in concrete increase its tensile strength. The highest tensile strength of an individual multi-walled carbon nanotube has been tested to be is 63Gpa. They help in controlling the crack propagation. The addition of CNT to concrete can significantly enhance some mechanical as well as physical properties of the material. Use of carbon nanotubes increases the strength and durability of cementitious composites as well as for pollution reduction. When researchers think of nanomaterials reinforcements for concrete, carbon nanotubes come as the first option. The strength and flexibility of carbon nanotubes makes them of potential use in controlling other nanoscale structures, which suggests they will have an important role in nanotechnology engineering. It has been proved that there is good interaction between CNTs and cement phases indicating the potential for crack bridging and enhanced stress transfer.

Type of Nanotechnology	**Applications**
Nano Titanium Dioxide	Self-Cleaning of concrete and air pollutant.
FRP	Used in repairs and rehabilitation
Nano-sensors	To monitor and control temperature, moisture, cracks and corrosion.
Micro-silica	Improves concrete characteristics.
Carbon Nano- Tubes	Improves compressive strength and flexural strength in concrete.

Table 1: Summary of Nanotechnology applications

3. CONCLUSION

- **Thi**s paper demonstrates the main benefits of nanotechnology in construction of infrastructure.
- Nanotechnology like Titanium dioxide Nano particles helps to produce concrete that can clean itself and air around it
- Use of Nano technology has increased and will continue to improve repairs and safety in construction
- Use of Micro-silica with concrete helps to decrease Air Pollution.
- Carbon Nano- tubes can be most beneficial for Concrete as it improves strength and help in controlling cracks.
- Even with the benefits the Nano particles are quite expensive which becomes uneconomical.

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