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Review

REVIEW OF USE OF NANO MATERIAL IN MODIFYING THE PROPERTIES OF CONCRETE

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ABSTRACT

Modern technologies have affected all fields of human activities. Traditionally nanotechnologies deal with material having a dimension in the range of one billionth of a meter or 100 Nano meter in size. It has been widely used in natural sciences and biomedical sciences in the fields like microbiology, medicine, electronic, chemical, and materials sciences. The application of nontechnology and Nano material in Civil Engineering is still under active research in the areas of Concrete Technology, Construction management, water purification systems, Properties of Concrete at early ages and use of modern polymers in producing High Performance Concrete (HPC). The use of Nano material to produce relatively sustainable concrete represents a promising area of research in Nano material. In this paper the State of the Art of application of Nanotechnologies to Civil Engineering and its future prospects with special reference to sustainability in construction.

KEYWORDS: nanotechnologies, civil Engineering, concrete technology, construction.

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INTRODUCTION

Civil Engineering is a diverse field of education and practice which incorporates interdisciplinary and trans-disciplinary domains. Some of the specific discipline of Civil Engineering include Structural Engineering, Water supply & Waste Treatment, Transportation Engineering, Geotechnical Engineering, Construction Management. The Civil Engineering generally aims at creating a sustainable built environment for the humanity, which incorporates the use of traditional and modern material like Supplementary Cementitious Material (SCM) such as Pulverized Fly Ash (PFA), Rice Husk Ash (RHA), Silica fumes (SF), Ground Granulated Blast Furnace Slag (GGBFS). These materials are extensively used to rationalize the Building Environment for improvements and conservation (Elvin, 2007). Today Cement concrete is the most widely used material in construction, which is not sustainable in terms of emissions of Green House Gases (GHG), as on ton manufacturing of cement produces an equal amount of CO_2, which is one of the major GHG. Concrete is one of the world's most versatile and widely used construction materials. More than 30 billion tons of concrete is produced and consumed around the world annually (Atakan *et al.* 2014). The world cement production has reached at the level of 4.3 billion tones during 2014. The extensive production of cement also leads to enormous emissions of CO_2, as with every tone of cement production an equivalent amount of CO_2 is produced. The world cement industry is

responsible for about 8% of the total CO_2, production (Alaa *et al*,2014).

The Nano material have been widely used in all discipline of Engineering mainly for improving the performance and productivity of structures and material. One of the aims of use of Nano material in Civil Engineering has been, ensuring use of sustainable material. Extensive research on use of Nano material in modifying the properties of cement and concrete has been undertaken in last few years (Sanchez and Sobolev, 2010). In this research, the use of Nano material in Civil Engineering material in improving its properties both in fresh and hard forms are discussed, on the basis of current state of research and knowledge.

NANO TECHNOLOGY AND MATERIAL

Nano material is a material having one of its dimensions as billionth of a meter. Nanotechnology is the re-engineering of materials and devices by controlling the matter at the atomic level (Roco et al., 1999). The use of such material is mainly advocated and researched by the Physics and chemistry fields to modify the properties of material (Chong 2004). A more exact definition of the Nano material can be found as the production with dimensions and precision between 0.1 and 100 nm. In medium terms, nanotechnology involves the study at microscopic scale (1 nm = 1 × 10^{-9} m) (Drexler 1981). The use of Nano material has been adopted in all fields and research is underway extensively to use such material in the Civil Engineering projects. These applications include (Zhu et al., 2004):

i. The use of Nano-particles, carbon Nano-tubes, and Nano-fibers to increase the strength and durability of cementitious composites, as well as for pollution reduction
ii. Production of cheap corrosion free steel.
iii. Production of thermal insulation materials with performance of 10 times the current commercial options.
iv. Production of coats and thin films with self-cleansing ability and self-color change to minimize energy consumption

The application of Nano material in various fields of Civil Engineering is discussed further as follows:

Nano cement

The Ordinary Portland Cement (OPC), which is also called Type-1 Cement, is the most widely used type of cement, which has the following major constituents given in Table 1.

Some of the Nano material used in concrete include Nano silica, Nano clays, Nano titanium Oxide (TiO2), Nano Iron (Fe2 O3), Nano alumina (Al2 O3), Cuo, ZnO2 and ZrO2. Nanomaterials in concrete will improve the pore structure of concrete, speed up the C-S-H gel formation and improve the concrete mechanical and durability properties. The use of Nano Silica improved the properties of concrete such as reactivity, strength development, refinement of pore structure and densification of interfacial transition zone. The large surface is of the Nano material provide better bonds and better filler properties, which increase the density and strength of concrete (Zaid *et al*. 2012).

Table 1. Composition of Cement Clinker (Brown and Brownyard, 1974)

Compound	Formula	Notation	wt.%
Celite (tricalcium aluminate)	$Ca_3Al_2O_6$ [$3CaO \cdot Al_2O_3$]	C_3A	10
Brownmillerite (tetracalcium aluminoferrite)	$Ca_4Al_2Fe_2O_{10}$ [$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$]	C_4AF	8
Belite (dicalcium silicate)	Ca_2SiO_4 [$2CaO \cdot SiO_2$]	C_2S	20
Alite (tricalcium silicate)	Ca_3SiO_5 [$3CaO \cdot SiO_2$]	C_3S	55
Sodium oxide	Na_2O	N	2
Gypsum (calcium sulphate dihydrate)	$CaSO_4 \cdot 2H_2O$ [$CaO \cdot SO_3 \cdot 2H_2O$]	CSH_2	≤5

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The use of Micro Nano clays in concrete has been tested in many ways to alter its properties both in the fresh and hardened forms. Nano Clays has improved the consolidation of the concrete with minimum energy and it could settle easily in the formwork (Tregger, Pakula and Shah SP,2010, Chang, Shih, Yang, & Hsiao, 2007; Farzadnia, Abang Ali, Demirboga, & Anwar, 2013, Nehdi,2014). The use of Nano Clay particles has improved the flow-ability of and resistivity of Self Compacting Concrete (SCC). The water penetration depth was decreased and anti-corrosive properties in SCC increased (Styliani P, Kevin P,2017).

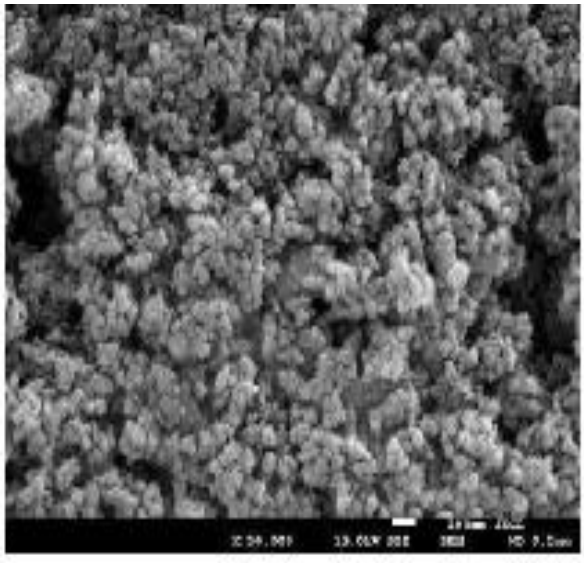

Fig 2. SEM of Nano Alumina (Al2O3) [P. Jaishankar and C. Karthikeyan, 2017]

Titanium dioxide (TiO2) is present in minerals like rutile, anatase and brookite etc. TO is used in paints, cosmetics and drugs because of its low toxicity, semi-conductivity, high chemical

stability, availability and low industrial cost (Hamdy and Ion 2011). TiO2 has historically been used the use of Nano Titanium (NT) has been used to later the properties of cement and concrete. NT has been used to increase the strength of concrete at later ages. The electrical conductivity of concrete was also decreased (Zhen Li,2017). The use of NT material has been extensively used in cement in recent research (Diamanti et al. 2008, Chen *et al*. 2012, Jalal *et al.* 2012).

Iron oxide Nano (ION) material were used for healing of concrete through immobilization of bacterial cells. IONs were successfully synthesized using a co-precipitation method (Seifan *et al*. 2017). In recent years, various bacterial and techno-biological processes have been widely used to repair concrete. Wang *et al* (2012), tested the bio-self healing efficiency of bacterial cells in hydrogel for repairing concrete. Van Tittelboom *et al.* (2010) reported the positive effect of silica gels on protection of bacteria in the concrete matrix. These silica gels have, however affected the mechanical properties of concrete negatively (De Belie 2016). The microscopic study of concrete has shown that ION has helped in healing the concrete. The influence of bio-agent on the water absorption of the concrete samples revealed that the presence of magnetic immobilized cells in concrete decreased the water absorption by filling the microspores and cracks (Seifna *et al*, 2018).

Use of Carbo Nano Tubes (CNT) in Cement

Carbon Nano Tubes (CNT) are long cylindrical molecules made only of carbon atoms and discovered by Iijima in 1991 (Iijima, 2019). The use of Carbon Nano Tubes in cement has exceeded many times in last decade. This is expected to reach USD 4 billion in next year. CNT are used for various improving various properties of concrete such as enhanced strength, stiffness and toughness without added weight, Improved durability, Increased functionality, reduced flammability etc. CNT has more specific area and high thermal and electrical conductivity (Khare and Bose, 2005). The Young's Modulus of CNT is 50 time more than the steel and thus possesses high potentials for used as reinforcing material for concrete (Rashad, 2017). One of the major challenges in use of CNTs, its agglomeration which seriously affect the mechanical properties of concrete, therefore some mechanism for dispersion of the material in concrete will be required (Saez de Ibarra *et al.* 2006). Wang et al. found that the addition of multi-walled carbon nanotubes (MWCNTs), with surfactant GA and sonication treatment, improved the mechanical properties of cement composites (2013). It was reported that the incorporation of CNTs increased compressive strength by up to 30% and flexural and tensile strengths by up to 50% (Laura et al,2020). The use of Multi-Walled CNTs (MWCNTs) and Single Walled CNTs (SWCNTs) when used can lead to prevention of cracks propagation due to high interfacial areas (B.Han and X.Ju,2011; M.Szela,2019). The MWCNTs improved the mechanical properties of concrete up to 29% at 0.03% by weight of cement. The lengths of CNTs had limited effect on the strength of concrete. The Scanning Electronic Microscopic (SEM) images of MWCNTs in concrete are shown in Fig2. (Mohamed O. M, 2020).

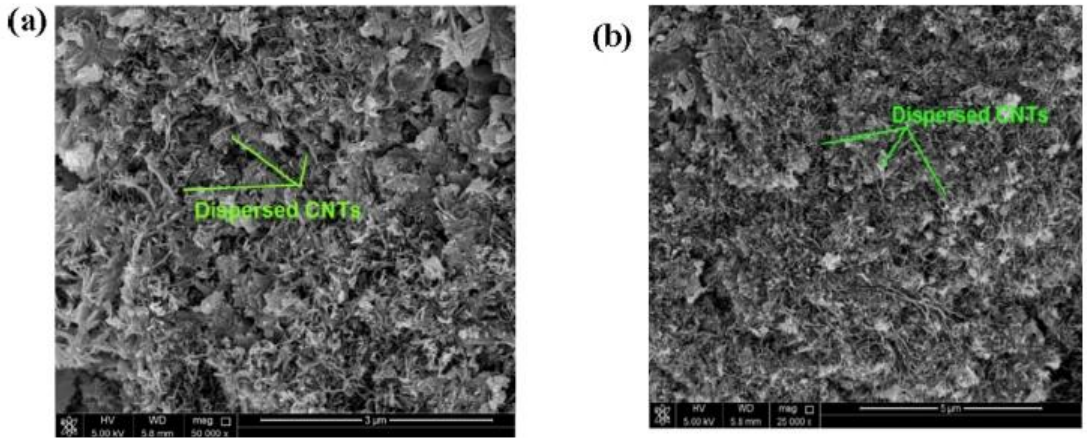

Fig 2. SEM images of long non-treated CNT-concrete batch of: (a) 0.03 wt% CNTs' content, and (b) 0.08 CNTs' content (Mohammed,2020).

In addition to use of Nano material in producing concrete, these are used in preparing durable paints, self-cleaning glass coating etc. The thin sheet of Nano material increased the life of paints against scratch and fatigues.

CONCLUSION

Nano technology and Nano material offers a vast application in producing concrete and other construction material. The use of most commonly used Nano material includes Nano silica, Nano clays, Nano titanium Oxide, Nano Iron and Nano alumina. Due to large surface areas of the Nano material, the mechanical properties of concrete like compressive strength, tensile strength, modulus of rapture, fatigue and reduced cracks developments. The Carbon Nano Tubes (CNTs) are widely tested in concrete but its application has several issues. The use of coatings made from nanotechnology helps improve fire-resistance, corrosion protection, insulation, and countless other applications. More research is however required for use of Nan technology and Nano material in civil engineering material.

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