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A REVIEW ON EFFECT OF NANO CELLULOSE ON CONCRETE

[1]Namrata Bhalerao, [2]A. S. Wayal, [3]P. G. Patil, [4]A. K. Bharimalla

[1]Civil and Environmental Engineering Department, V.J.T.I, Mumbai, India
[2]Associate Professor, Civil & Environmental Engineering Department, V.J.T.I, Mumbai, India
[3]Director, ICAR- Central Institute for Research on Cotton Technology, Mumbai, India
[4]Senior Scientist, ICAR- Central Institute for Research on Cotton Technology, Mumbai, India

Abstract: **Plain concrete possesses a very low tensile strength, limited ductility, and little resistance to cracking. Internal micro cracks are inherently present in the in the concrete mainly due to drying shrinkage and its poor tensile strength is due to propagations of these micro-cracks eventually leading to brittle nature of concrete. Addition of nano fibres will result into arresting of micro-cracks and which will lead to improvement of static and dynamic properties of concrete. Cellulose nano-materials, cellulose nanocrystals (CNC) or cellulose nanofibrils (CNF), offer new possibilities for endowing cementations composites with improved mechanical performance. Their small size can allow a smaller inter-fibre spacing and more interactions between the cellulose and the cement system, and as a result, the CNC and CNF have a greater potential to combat micro-cracking and increase the strength of the system. This paper focuses on benefits which can be obtained by adopting Nanocellulose as a reinforcing material in concrete and review of research work carried out by various researchers to study effects of nano cellulose on concrete and benefits**

***Keywords*: Nano-fibres, Nano-particles, Sustainable Material, Nanocrystals, concrete.**

I. INTRODUCTION

Nanocellulose is a term which is referred to nano-structured cellulose. It has been in development for about 40 years, getting its start in New Jersey at ITT Rayonier Labs in 1977.

When hardened concrete cracks, crack-ends tend to be branched, often run through cement matrix material and sand grains, and are often discontinuous. Windings of these cracks on the microscopic level results into pulling out of the aggregates from the cement matrix, as the aggregates generally have a higher strength than either the cement matrix or the interfacial bond which leads to that the failure of concrete.

The incorporation of cellulose nanocrystals in inorganic construction material have the potential to improve the time and the lifecycle cost of engineering projects due to their strengthening properties and chemical reactivity. The use of cellulose fibres as reinforcing agents in composite building materials offers many advantages over glass fibres, such as the possibility to manufacture products with low density ,good biodegradability and low cost.

II. TYPES OF NANO CELLULOSE

The family of nano cellulose can be divided in three types, (1) cellulose nanocrystals (CNC), with other designations such as nanocrystalline cellulose, cellulose (nano) whiskers, rod-like cellulose micro-crystals; (2) cellulose nano-fibrils (CNF), with the synonyms of nano-fibrillated cellulose (NFC), micro-fibrillated cellulose (MFC), cellulose nanofibres; and (3) bacterial cellulose (BC), also referred to as microbial cellulose. (Ning et al. 2014)

Nanocrystalline cellulose (CNC) is a novel class of biomaterials with wide ranging applications having 10 nm diameter and 100 nm to 200 nm long. The incorporation of cellulose nanocrystals in inorganic construction material have the potential to improve the time and the lifecycle cost of engineering projects due to their strengthening properties and chemical reactivity.

NFC consists of aggregates of cellulose micro fibrils and have fibril diameter in the range of 2-10 nm and are several tens of micrometres in length. Fibre of nano-scale are used to engage bridging mechanism of fibre reinforcements in the nano-sized voids that exist in concrete microstructure.

BC is superior to plant cellulose, in purity and super-molecular structure and has unique physical and chemical properties that plant cellulose cannot provide, including high mechanical strength, high water absorption capacity, high crystallinity, ultra-fine and finely pure fibre network structure, good transparency, fibre-binding ability, adaptability to the living body, biodegradability and mouldability during formation.

III. MANUFACTURING

To produce Nano-cellulose there are two important but completely different ways:

I) The bio-formation of cellulose by bacteria and

II) The disintegration of plant celluloses using shear forces in refiner techniques.

The bacterial cellulose is produced mainly by Gluconacetobacter strains as their biofilms formed in high yields up to 40% in relation to the carbon source, e.g., glucose.

The sources for CNC and CNF extraction are wood, cotton, hemp, flax, wheat straw, sugar beet, potato tuber, mulberry bark, ramie and algae. Wood nano cellulose can be prepared by electro spinning from pulp solutions. The microfibrills of cellulose formed during biosynthesis are 2-20 nm in diameter depending on the source, and can be several micrometres in length; each microfibril consists of crystalline domains interspersed with disordered amorphous region. Materials that fall into general category of nano cellulose are obtained either by mechanical treatments to obtain nano-fibrillated cellulose or by acid hydrolysis to remove the amorphous segments and leave highly crystalline cellulose whiskers, otherwise known as cellulose nanocrystals, nano-rods, or nanowhiskers. When nano cellulose is produced, it forms a stable colloidal suspensions (in water and in some organic solvents), and the particles are charged and hydrophilic

IV. APPLICATION OF NANO CELLULOSE IN CONCRETE

One of the largest appeals of cellulose nanocrystals are their inherent renewability. Cellulose nano particles are the ideal green material as they are made from infinitesimally small pieces of cellulose, the most abundant biomaterial on the planet. Sources include trees, algae, and bamboo. Cellulose material from trees can also be derived from lumber and paper waste. Algae and bamboo are ten times invasive species and have a fast growth rate making them ideal cellulose sources.

Professor Pablo Zavattieri et al. (2013) examined how the addition of cellulose nanocrystals (CNCs) modified the performance of cement paste. Mechanical tests show an increase in the flexural strength of approximately 30% with only 0.2% volume of CNCs with respect to cement utilized. He used quantum mechanics to show cellulose nanocrystals have stiffness comparable to that of steel, based on experimental young's moduli values, due to the extreme anisotropies in the density of cellulose nanocrystals. Because cellulose nanocrystals have a high young's modulus value but also a potentially high ratio of crystals per unit of density they have the potential to help resist material deformation in response to an applied force

A study was conducted by Peters et al. (2010), in which reactive powder concrete was reinforced with a combination of nano cellulose and micro cellulose fibres to increase the toughness of an otherwise brittle material. These fibres could provide the benefit of other micro- and nano-fibre reinforcement systems at a fraction of the cost. Notched-beam tests were performed under crack-mouth opening displacement control to measure fracture energy under stable crack-growth conditions. Preliminary results show that the addition of up to 3% micro- and nano fibres in combination increased the fracture energy by more than 50% relative to the unreinforced material, with little change in processing procedure.

Peters et al. (2009) carried out experimental study on ultra high performance concrete by reinforcing it with a combination of micro- and nano- scale cellulose fibres to increase the toughness of the brittle material. Micro and nano-cellulose fibres were used both separately and in combination, at volume fractions of 0, 1%, 3% and 5%. Results from split cylinder and three-point bend notched beam tests indicate that 3% micro cellulose reinforcement is most effective in increasing the fracture energy performance of the material. The three-point notched beam tests indicated that the inclusion of micro fibres into the concrete increased the fracture energy by 53%. A hybrid mix consisting of both micro and nano cellulose fibres increased the fracture energy response, but to a lesser degree, 26% greater than the unreinforced material.

A market study was performed by John Cowie et al. (2014) on a material with near-term potential for commercialization. The potential market size for cellulose nano materials was determined from complementary goods that are targeted for displacement by cellulose nano material enhanced products. Total market sizes for new products containing cellulose nano materials were estimated from available data pertaining to the existing targeted products. Market penetration rates were estimated assuming favourable performance, technological readiness, and economics, projected 6 to 10 years forward.

Annual U.S. market potential for high-volume applications of nano cellulose is estimated at 6 million metric tons, Cement has a potential nano cellulose market size of over 4 million metric tons on a global basis, but the U.S. market share estimated for cement is 21,000 metric tons, assuming market penetration is initially limited to the ultra-high performance concrete market. (Jo Anne Shatkin et al. 2014)

V. SUSTAINABILITY

Cellulose nanocrystal production factories can be built in proximity to paper and lumber mills, helping eliminate sawdust waste or wood pulp scraps. Innventia, a company in Stockholm, is pioneering nano cellulose research and has shown that cellulose nanocrystals can be produced with the same equipment readily available in other industries. Another company, CelluForce, manufactures nano crystalline cellulose in Canada is utilizing the waste from an adjacent paper mill. The new Celluforce plant is the first of its type in the world, producing one ton of cellulose nanoparticles per day.

While it's true that algae also release that carbon dioxide when it breaks down as waste or is absorbs carbon dioxide while it produces the nano cellulose, it will burned for fuel, meaning that it is essentially carbon-neutral, but not carbon negative.

VI. DISADVANTAGES

Nano cellulose is not highly effective in improving compressive strength. Due to porosity and permeability the cement composite and the health of cellulose gets affected mainly due to attack of penetrated water on lignin content of natural fibres and weakens the individual fibre cell. Cellulose nano particles decompose in alkaline environment of cement matrix and are susceptible to biological attack. They have variable mechanical and physical properties. (Sarah at al. 2010)

Furthermore, the incorporation of cellulose fibres in a polymer or mineral matrix can involve an interface incompatibility between fibres and matrix, which may be overcome through the chemical pre-treatment of fibres, with the aim of modifying either the chemical nature of the fibre surface or the surface properties. (R. Jaraboa et al. 2012)

The effect of fibre length on the mechanical properties is inversely proportional to mechanical properties. This fact suggests that the short fibre become mineralized earlier than the long fibres. Short fibres are more difficult to align and pack densely as compared to the long fibres. Another strong reason that contributing to the low strength properties of FRC is too short fibres allow a faster penetration of cement hydration. Further more if the fibre is too short then the energy required to pull the fibre through the matrix will be low and this can contribute to the dissipation of energy contained in the advancing crack.

VII. CONCLUSION

Literature reveal that nano cellulose can enhance mechanical properties and fracture characteristics of concrete by arresting micro-cracks formed during hydration and preventing their further growth. Chemical properties, mechanical properties and sustainability of nano cellulose can also be advantageous in adopting it as a component of concrete. It can be made available at very low cost and in large quantity in future due to abundance of its sources. Nanocellulose can be easily adopted as a sustainable reinforcing material as it is renewable, and bio-degradable.

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