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A comparative study on nano concrete

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Abstract

Nanotechnology is among the most ongoing research topics, encompassing a variety of disciplines such as civil engineering and building materials. There have been significant advancements in the use of nanotechnology in green construction, but there is still so plenty to learn. The enhancement of concrete's rheological behaviour, strength, and durability, which has been proved to be dependent on the nanoscopic qualities of its ingredients, is one of the achievements in the use of nanotechnology in green development.

Keywords: Nano concrete; nanotechnology; sustainable construction.

1. Introduction

Nanotechnology is amongst the highly popular study topics, spanning a wide range of fields such as construction engineering.

On a microscopic level (less than 100 nanometres), the study, alteration, and reconfiguration of structure in order to generate materials with new and unique properties and uses is known as nanotechnology. There are two ways to nanotechnology:

- The "top down" technique, in which bigger objects are scaled down to the nanoscale while keeping their fundamental state, or larger constructions are deconstructed into comparatively small, composite elements;
- The "bottom-up" technique, also known as "self-assembly" or "molecular manufacturing," wherein an assembly or sintering method is used to form objects from atoms or molecular ingredients.

Traditionally, nanotechnology has been focused on breakthroughs in microelectronics, health, and materials engineering. Furthermore, several advancements in nanotechnology are conceivable to apply to the field of construction engineering is developing. As science and equipment advance, nanotechnology becomes increasingly competitive and evolutionary, as well as related scientific domains like chemistry and physics, develops. Concrete, structural hybrids, covering materials, and nano-sensors are just a few of the potential applications for nanotechnology in construction engineering. Nanotech materials are also being employed in a variety of design and construction processes. Nanotechnology-derived products offer unique properties that can help solve present building issues while also changing the requirements and structure of the construction procedures.

Current developments in the analysis and handling of nano products and processes hold a lot of potential for the development of new macro components, features, and products. Moreover, to yet, applicability of nanotechnology and accomplishments in the construction and material handling industries have been uneven.

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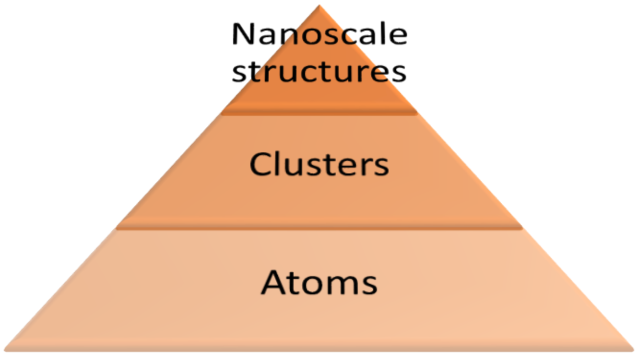


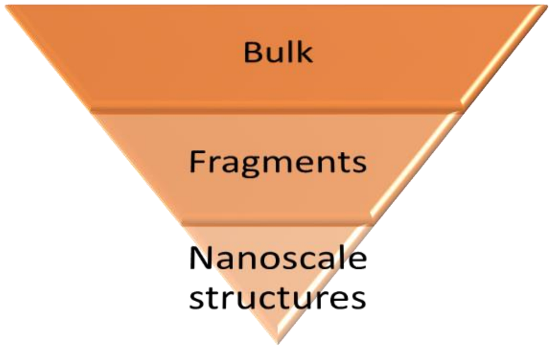


Fig 1. BOTTOM-UP APPROACH

Fig 2. TOP-DOWN APPROACH

2. Nanomaterials

Nanomaterials are defined as materials that have at least one external measurement ranging from one to one hundred nanometres. As per the European Commission, at nearly half of the nanoparticles in a numeric size distribution must be 100nm or smaller.

Nanomaterials can be found naturally as by-products of combustion processes or manufactured specifically to serve a certain function. These materials' physical and chemical characteristics can vary from those of their bulk-form analogues.[1]

2.1 Nano-silica (NS)

Because of their stability, good biocompatibility, and capability to be functionalized with a variety of chemicals and polymers, silicon dioxide nanomaterials, also known as nano-silica, are the cornerstone of many biomedical research.

NS particles are classed as either P-type or S-type on the basis of structure. The P-type are differentiated by a high pore rate of 0.61 ml/g and a higher UV reflectivity than the S-type; the latter also has a smaller surface area.[2]

2.2 *Nano alumina*

Alumina nanoparticles are frequently employed in adsorption and catalytic processes due to their acid-base properties, large specific area, mechanical, and thermal stability.[3] Nano alumina in cement reduces segregation and flocculation in concrete by speeding the first setting time for UHPC.

2.3 *Nano Kaolin*

Kaolin, commonly known as kaolinite, is a clay mineral that has the chemical formula $Al_2Si_2O_5(OH)_4$, produces nano-kaolin as a by-product. It is a stratified silicate material made up of oxygen atoms that link one tetrahedral sheet to one alumina octahedral sheet.

2.4 Titanium di-oxide

Nano-titanium-di-oxide comes in two crystal forms: anatase and rutile. With a mean grain size lesser than 100nm, high transparency, and UV absorption, it is extremely pure. It is also extremely thermally and chemically stable. The crystalline form of anatase is utilised to make photocatalysts. When exposed to light, photocatalysis can help to reduce harmful gases and organic contaminants. Vehicle exhaust and sewage can also be decomposed using the anatase form. When exposed to UV radiation and oxygen, the rutile crystal structure specializes in UV absorption, and the Nano-titanium-di-oxide powder has a powerful antibacterial powder. The rutile form has a delicate and silky feel that is perfect for sunscreens and cosmetics due to its small size of particles and wide specific surface area. It's a common ingredient in cosmetics, sunscreen, and high-quality plastics.[4]

3. Literature Review

Mohamed A et al. (2016): The effect of nanoparticles on concrete's mechanical qualities at different ages is investigated in this paper. Various mixtures have been examined, including nano-silica (NS), nano-clay (NC), and various quantities of both NS and NC. Mechanical parameters like compressive and flexural strength were investigated by evaluating concrete prisms 40 mm, 40 mm, and 160 mm at 7 days, 28 days, and 90 days to see how these nano-particles affected the mechanical attributes of concrete. This research revealed that nano-particles may be quite valuable in enhancing the mechanical characteristics of concrete, that NS is more effective than NC in increasing mechanical qualities, and that wet mix is more effective than dry mix. Mechanical properties degrade when the percentage-age of micro particles in concrete surpasses a certain level. In addition, as compared to employing the same proportion of one kind of nano particle, binary use of nano particles (NS+ NC) resulted in a significant enhancement in concrete's compressive strength.[5]

Esmaeili J et al. (2013): "This work evaluated the impact of including NS particles on the concrete's strength and concrete's perviousness, as well as comparisons to Micro-Silica. In addition, the concrete specimens formed of Nano-Silica particles have been shown to be more impervious than the other concrete mixtures examined in this study. Images were captured using a SEM (scanning electron microscope) to assess the microstructure of the concrete mixes, which demonstrated that the samples containing the Nano-particles were more consistent than the control samples. $Ca(OH)_2$ concentration of these specimen is much lower than the control specimen, according to XRD analysis."[6]

Lee J et al. (2010): They analysed state-of-the-art MNM applications that improve traditional construction materials, proposed anticipated environmental release scenarios, and summarised potential unfavourable biological and toxicological impacts and their mitigation in this work. Aligned with the multidisciplinary evaluation of emerging scientific developments' environmental implications, this review aims to raise awareness of the possible benefits of MNMs in building projects and foster the growth of guidelines to monitor and control their use and disposal in order to alleviate potential consequences for human and environmental health.[7]

Beigi M et al. (2013): "Their research sought to ascertain the impact of nano-silica and various concrete strengthening fibres such as glass, poly-propylene, and steel on the effectiveness of concrete. Mechanical parameters (compressive, splitting tensile strength and flexural strength, toughness and elastic modulus), rheological properties (L-Box, slump flow, T50), and durability (resist chloride ion penetration (RCPT) and water absorption) are also evaluated in this study. Furthermore, Atomic Force Microscopy (AFM) and X-Ray Diffraction (XRD) techniques were used to analyse the microstructures of concrete."[8]

Nasution A et al. (2013): Their research focuses on the use of nano-silica as a partial substitution for cement in concrete. The inclusion of nano-silica in concrete is meant to accept free hydroxide calcium, a by-product of cement hydration synthesis. Nano-silica will react with C3S and C2S in the cement to make CSH-2, which will form a strong and stable gel bond. The findings indicated that adding nano-silica as a cement partial substitute material could enhance the mechanical capabilities of concrete.[9]

4. Nanotechnology and Concrete

Concrete, the most commonly used substance on the planet, a multi-phase nano-structured composite mixture of cement and aggregates that has evolved over time. It is an amorphous material consisting nanocrystals ranging in size from nm in size to µm in diameter, and bonded water. C–S–H (Calcium–silicate–hydrate) is an amorphous form that acts as the "adhesive" that holds concrete intact. Concrete is a mixture made up of molecule assemblies, aggregates, fibres, and chemical bonds that interact via chemical processes, inter-molecular connections, and interphase dispersion when viewed from the bottom-up approach. This scale considers molecular composition, external functional groups, length of bonds, energy, and compactness. This scale determines the structure of the unstructured and crystal forms, as well as the interphase boundaries. The interactions that occur at the micro level between nanoparticles and components, as well as the at the macroscale, the impacts of operational loads and the environment, are dictated by the properties and activities at the nanoscale. The technical qualities and performance of larger particles are influenced by nanoscale processes.[10]

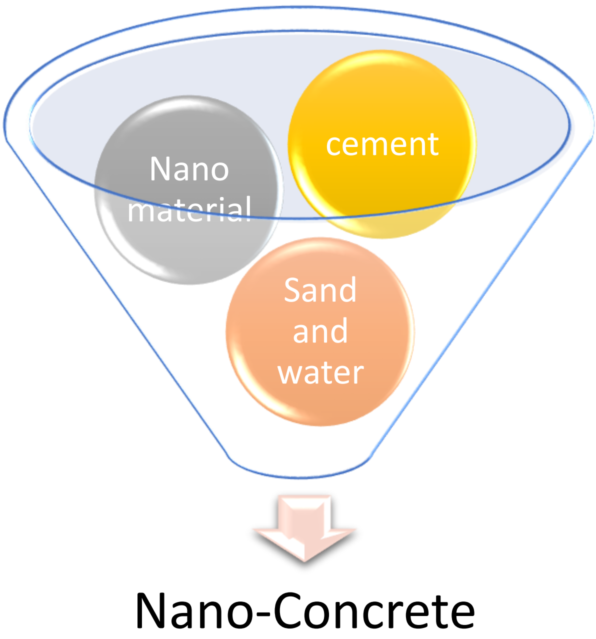
In physical research, there are two sorts of nanotech applications: nanoscience and nanoengineering. To truly understand how the minute or nano structure of mixtures or concrete made from cement, effects macroscale attributes and performance, extensive characterization methods and simulations of atomic level of the materials are used. Nanotech synthesis is the technique of modifying structures at the scale of a nanometre to create a completely unique and un-conventional generation of tailor-made cement composites, with many different uses and functions with new qualities such as good conduction of electricity, having ability to self-sense, self-clean, self-heal, formability, and can control cracks and fractures by itself. Concrete can be nano-synthesized by transplanting different nano-particles onto cement, coarse-aggregates, fine-aggregates and admixtures (including additives with size lying in nano scale), providing functionality on the surface that can be altered to promote specific interactions between different faces, or by integrating nano-scaled building objects or items (for example, nano-particles and nano-tubes) to regulate behaviour of materials and add unique properties.[10]

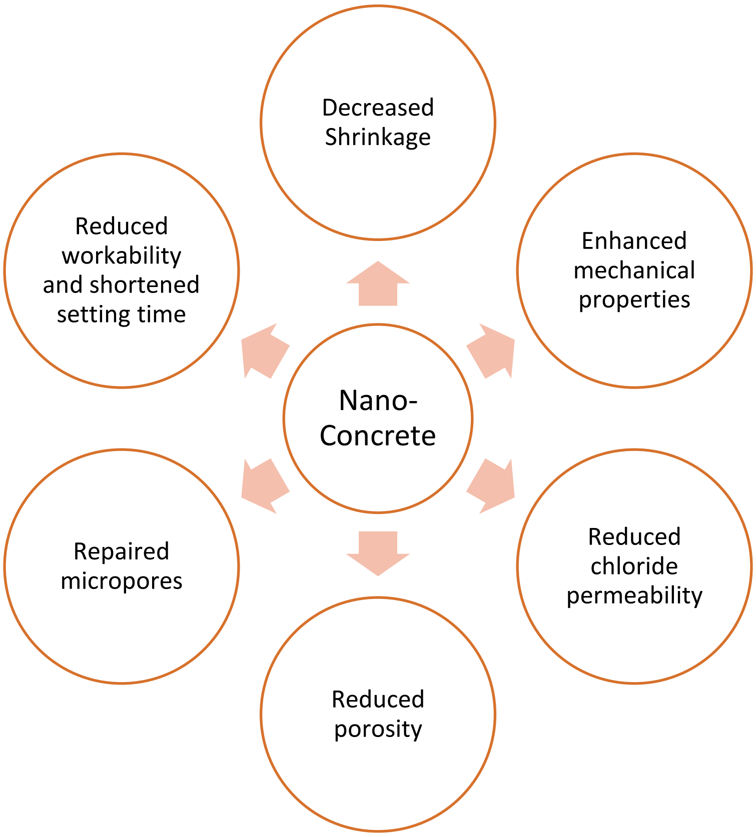
5. Why should we adopt nanotechnology for concrete?

- Enhances the bulk characteristics of the substance
- Capability to handle or control materials on an atomic scale.
- To achieve thinner goods and a faster setting time.
- The cost-effectiveness.
- Environmental pollution has been reduced.

6. Properties of Nano-concrete

- Increased durability as a result of fewer water-filled pores.
- decreased shrinking and drying shrinkage
- Concrete with high compressive strength (15 & 75MPa at 1 day, 40 & 90MPa at 28 days & 48 & 120 MPa at 120 days)
- High workability and a low w/c ratio.
- The addition of superplasticizers is unnecessary.
- Fills all of the micropores and micro spaces.
- Savings on cement might range between 35 and 45 percent.





7. Conclusion

Nanofibers are among the most important materials being researched for nanotechnology applications. Their distinct features, ranging from ultra-high strength to peculiar electrical behaviour and good thermal conductivity, as well as the capacity to store nanoparticles within the tubes themselves, have indicated prospective applications in a wide range of scientific and technical endeavours. Reinforcing concrete with nanofibers results in tougher concretes by halting fracture formation as soon as it begins.

There are three key roadblocks to the widespread adoption of nanotech:

(1) lack of awareness to discern the qualities that might be influenced by its use,

(2) scarcity of qualified staff, and

(3) lack of resources and funding.

Nanotechnology has the potential to improve concrete performance and lead to the improvement of new, environmentally friendly, advanced mixture made from cement with superior mechanical, thermal, and electrical properties, and numerous prospects are expected to emerge in the coming years. But even so, present problems such as proper dispersion, nanomaterial compatibility with cement, processing, production, safety, and management concerns, scale-up, and affordability must be dealt with before the complete prospective of nanotech in concrete applications can be realised.

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