International Journal of Structural Civil Engineering and Management
Volume 1, Issue 03, 2025

Applying Nanotechnology to Civil Engineering Projects

Ahmed A. Ali Rasool

Research Article
Received: 19-05-2025 Revised:22-06-2025 Accepted:05-07-2025 Published:15-07-2025

***Abstract*—** The mechanical behaviour of a material, which is effective on a micro and nano-scale, determines the performance of a structure once its structural components have been installed. Having the capacity to develop materials at the nano-structural level ensures that they will exhibit the creative behaviour and performance that is required to increase their mechanical performance, volume change characteristics, durability, and sustainability. One of the most obvious demands of the exploration network is the study of nanotechnology's use in building development and structures. The research reviewed the literature on the use of nanotechnology in the building industry, with a focus on its use in the production of concrete, steel, wood, and glass, and provided an overview of the technology as a whole. There has been very little planning for the use of nanotechnology in civil engineering so far. In order to apply nanotechnology in the building industry, we must address the following issues: generation processes, contaminations caused to human wellness, fabrication problems, and execution.

***Index Terms*—nano-materials, nanotechnology, construction, civil engineering, nanoconcrete**

I. INTRODUCTION

The incorporation of nanoparticles into our everyday lives has greatly increased the research precedence of nanotechnology programs. It goes without saying that every single scientific field has been affected by the conversion process, what with all the ongoing flooding and subsidies. The most important areas of study for nanotechnology are the basic sciences, including chemistry, biology, computer science, engineering, and physics, but other disciplines contribute more practically to the field's advancement. The humanities and sociologies have also seen a surge in study proposals and suggestions, mainly in the areas of ethics and policy management.

In the construction industry, nanotechnology has significant effects. There are a number of applications tailored to this industry that aim to increase the durability and functionality of building components, boost energy efficiency and structural safety, promote ease of support, and provide greater living comfort. Given the above, it should come as no surprise that nanotechnology was a major focus of the UNESCO Science Report: towards 2030 [1]. This was provided in response to the concerns and demands of the countries that will, in the future, determine how the 2030 Agenda for Sustainable Development is implemented and evaluated. Nanotechnology was highlighted in this research as a key area for most countries' science, innovation, and development plans and administrations. Nanotechnology, according to surveys conducted in the United Kingdom and Sweden, is the most promising innovation in the building sector, particularly in concrete goods [2]. Materials used in civil engineering projects may be enhanced with the help of nanotechnology. The use of nanotechnology has greatly improved civil engineering's design and building processes. In the building industry, this method has led to the creation of lightweight buildings, long-lasting structural composites, low-maintenance coating goods, glass with higher reflectivity, and cementitious materials with improved characteristics [3]. The effects of nanotechnology on civil engineering and, more specifically, on construction materials including wood, glass, steel, and concrete will be the primary topics of this literature review. Engineering matter at the atomic level is known as nanotechnology [4]. It involves manipulating atoms and molecules. Data on a nanometre scale may be understood and manipulated in this way [5]. Because of its many potential uses, nanotechnology has recently garnered a lot of attention and is having an impact on civil engineering. New methods of building materials needed in civil engineering have been made possible by nanotechnology, according to Hossain and Rameeja (2015) [4]. Materials that are resistant to fire, such steel and durable concrete, have been developed thanks to nanotechnology.

The overarching objective is to provide the pursuer with an opportunity to learn about the developments in nanotechnology as they pertain to the construction industry, the areas that still require attention, the aspects that are enabling of this revolutionary process, and the aspects that are limiting or potentially harmful. This paper's reminder structure is as follows. Section 2 focuses on the effects of nanotechnology on concrete preparations, the building industry's most used material. part 3 delves into nanotechnology and steel, whereas this part explores the applications of this new developments in the glass and wood industries were addressed in sections 4 and 5, respectively. Section 6 presents the results and potential for the future.

II. EFFECT OF NANOTCHNOLOGY APPLICATION ON CONCRETE

When it comes to civil engineering, concrete is among the most used construction materials. Innumerable ways had nanotechnology impacted the production of concrete. Cement, interfacial, and surface impact physical and chemical characteristics have all been improved because to nanotechnology's remarkable qualities [6]. Nanoconcrete is the end result of adding

nanomaterials to concrete in order to make it more stable. An example of nanoconcrete, Self-Compacting Concrete (SCC) improves the long-term stability of Portland cement while simultaneously making concrete that looks better and lasts longer. Because it is already present in concrete, less of it is required for construction projects [7]. Another kind of nanoconcrete, Nano-Silica, enhances both the mechanical qualities and the nanostructure of concrete. Nano-Silica also minimises the quantity of water needed for construction and the amount of concrete needed on site. Wang et al. (2016) [6] also discovered that Nano-Silica decreased concrete porosity, enhanced cement paste hydration heat, and strengthened Portland cement's compressive strength when added to concrete. When compared to conventional concrete without Nano-Silica, the compressive strength was significantly higher after adding Nano-Silica in wet circumstances (Mohammed 2014, [8]). And as it became wet, the cement's flexure strength went up, too. Saloma et al. (2015) [9] discovered that Nano-Silica enhanced cement performance and increased cement resistance to sulphate attack; it also revealed that the compressive strength of concrete with Nano-Silica rose with time. By using nano-Titanium Dioxide TiO2, the concrete was able to prolong the preservation of its aesthetic qualities. The component's ability to make the surface self-cleaning makes it a vital one [7]. Glenn (2013) [10] used the homogenisation model to determine that adding more Nano-Silica to a cement sample made it stronger and stiffer. Similar conclusions about the effect of Nano-Silica on concrete's strength and stiffness were also drawn from the study's computational results. The research also discovered that the air-entrained cement had a denser cement matrix, less permeability, and stronger concrete because of the nanomaterial components [10].

III. Effect of Nanotchnology Applications on Steel

The building industry could not function without steel. It predates the second industrial revolution by a long shot [11]. Although nanotechnology has had substantial impacts on steel, the material still has a number of drawbacks that make it unsuitable for building, such as corrosion and weak strength. Steel goods' power may be affected by nanotechnology, which can reduce the use of materials [12]. Nanoparticles not only make steel more robust, but they also make it more resistant to corrosion. One of the elements that limits steel is the stress riser, which is equally essential. Products like oil steel pipes are protected from corrosion by nanotechnology's capacity to resist it. Saurav (2015) found that copper nanoparticles may smooth up steel's surface, which in turn reduces the amount of stress risers. Better, more efficient building materials that need less supervision are the result of this technology's advancements in safety. Nanoparticles of magnesium and calcium improve plate steel's welds and reduce the size of grains in the heat-affected zones (HAZ).

An anti-corrosion coating made of smart pigment that inhibits corrosion in powder form was developed with the use of nanotechnology, according to research by Wansah et al. (2014) [13]. Pigment particles that prevent corrosion also serve as nanoscale repositories for that inhibitor. In the past, steel oil pipelines were insulated using materials that allowed moisture to be trapped within, which led to corrosion. The use of nanotechnology in insulation and corrosion prevention helps keep steel oil pipelines in good condition. Also, when it comes to steel metallurgy, nanotechnology is key. Russian metallurgists have reduced Ural steel using nanotechnology.

A combination of plastic-deformation nanotechnologies and microalloying with nitride phases helps reinforce the steel [14]. Steel also becomes resistant to cold and rust. The frequent loading and unloading caused fatigue, which is a prevalent issue in steel constructions like bridges. Steel is able to retain its structural integrity even when subjected to high temperatures, like 540 degrees Celsius, because copper nanoparticles are present [12].

IV. Effect on Nanotchnology on Wood

Wood is an essential material in the field of construction. Wood has been in existent for many years despite its drawbacks such as fire, decay, dimensional instability, and degradation because of weathering [15]. Different means to extend the durability of wood have been applied for many years, but have proven futile. Nanotechnology proves to have a significant impact on protecting timber and increasing longevity. Nano-based treatments using nanoxides such as TiO_2, ZnO, SiO_2, and CeO_2 minimize reaction to fire and hygroscopic properties, block ultraviolet radiation, and improve scratch and abrasion resistance [15]. Oke, Aigbavboa and Semenya (2017) [16] argue that nanotechnology will bring about a durable type of wood that will have hyper- performance when used in severe environmental conditions. Additional nanotechnology techniques are under research, and once they become applicable, they will have a significant impact on the quality of wood for construction. For instance, researchers are trying to exploit the Nano scale properties of wood to produce a new material that would be light, bio based, and multifunctional to compete with steel and concrete [17]. Researchers believe that the extraction of Nano fibrils will make wood cheaper than manufacturing carbon nanotubes. Although critics argue that the technological advancements might affect the environment, it is evident that thorough research will yield results that will transform the field of construction.

V. Effect of Nanotchnology Application on Glass

Glass is another material that is used in the construction industry. Glass is frequently positioned in the exterior surface of buildings for the penetration of light. Glass is also susceptible to corrosion and decay. The combination of water and atmospheric gases causes weathering, which is detrimental to the sustainability of the glass [18]. Nanotechnology can influence the structure of glass materials and increase longevity as well as the reduction in corrosion.

Nanotechnological solutions such as thin coatings are being developed for window glass. The coat has a significant impact of filtering out unwanted infrared frequencies of light; hence, reducing the heat in

buildings [19]. Additionally, thermo chromic technologies are under study and can provide thermal insulation, minimize heat in the room, and provide the required lighting. The presence of Titanium dioxide (TiO_2) nanoparticle in glass has a significant impact on the sustainability of glass. The particles can break down pollutants, volatile organic compounds, and are attracted to water, which assists in washing off the contaminants from the glass. Furthermore, the coating of glass with silica (SiO_2) nanoparticles makes the glass rigid and opaque to fire [20]. Jones et al. (2015) [21] also found that Nano-silica intumescent layers influence the properties of the glass by making it a high-grade fire safety for thirty years.

Altavila (2006) [18] found that nano-coatings with alkylsilanes (OTS) and fluoroalkylsilanes (FAS) significantly modify the glass wetting properties without changing the visible appearance of the glass. The technology played a crucial role in protecting the glass from water and atmospheric gases that cause weathering and decay. In this case, it can be said that nanotechnology significantly influences the sustainability of glass products making them suitable for construction purposes.

VI. Conclusion

The construction business is one of several that has seen a surge in interest in nanotechnology. Thanks to nanotechnology, civil engineering has advanced tremendously. When applied to materials including concrete, glass, wood, and steel, nanotechnology has shown promising results. The development of efficient, long-lasting, and resilient building materials has been aided by nanotechnology.
The following findings are taken from the reviewed literature: nanotechnology is a rapidly expanding area of study that has the potential to revolutionise civil engineering via the use of materials with unique features produced at the nano scale. Although the current state of the construction sector is hindered by the high cost of nanotechnology-engaged materials and devices, this is expected to change shortly. The benefits of using nanotechnology may also justify the higher price tag. It is important for designers to have a clear vision and give careful consideration to the possible uses of nanotechnology in the building sector so that the industry can make the most of the positive improvements that nanotechnology may bring.

References

The UNESCO Science Report: Looking forward to 2030. This sentence is paraphrased from an article published in 2015 in the Procedia Materials Science that discusses the effect and impact of nanotechnology on material characteristics and how it will affect civil engineering in the future.
[3] in "Nanotechnology in civil engineering," A. A. Firoozi, M. R. Taha, and A. A. Firoozi, 2014, EJGE, vol. 19, pp. 4673-4682.
The article "Importance of nanotechnology in civil engineering" was published in the European Journal of Sustainable Development in 2015 and was written by K. Hossain and S. Rameeja.
The article "Nanotechnology in civil engineering" was published in the European Scientific Journal in 2012 and can be found in volume 8, issue 27, pages 96-109.
The impact of nano-SiO2 on the hydration and microstructure of Portland cement was examined in a 2016 article by L. Wang, D. Zheng, S. Zhang, H. Cui, and D. Li published in the journal Nanomaterials, volume 6, issue 12, pages 1–15.
[7] H. Kahachi and W. Jalil, “The impact of nano-concrete in contemporary architecture,” Wasit Journal of Engineering Science, vol. 5, no. 2, pp. 89-98, 2017.
[8] In a 2016 article published in the HBRC Journal, A. M. Mohamed discussed the effects of nanomaterials on the flexural behaviour and compressive strength of concrete. The reference is page 212-225 of the journal.
[9] Saloma, A. Nasution, I. Imran, and M. Abdullah, “Improvement of concrete durability by nanomaterials,” Procedia Engineering, vol. 125, pp. 608-612, 2015.
[10] J. Glenn, “Nanotechnology in concrete: Critical review and statistical analysis,” MSc. dissertation, The College of Engineering and Computer Science, Atlantic Univ., Florida, 2013.
"Application of nanotechnology in building materials," Saurav wrote in 2012 for the International Journal of Engineering Research and Applications (IJERA), volume 2, issue 5, pages 1077–1082.
The article "Material follows function: nanotechnology and sustainability in steel building constructions" was published in 2013 in the International Journal of Scientific Research (IJSR), volume 2, issue 12, pages 2319-7064.
By J. F. Wansah, A. E. Udounwa, A. D. Ahmed, A. A. Essiett, and E., the number thirteen is referenced. U. Jackson, “Application of nanotechnology in the corrosion protection of steel oil pipes,” in Proc. the 1st African International Conference/Workshop on Applications of Nanotechnology to Energy, Health and Environment, UNN, March 23 – 29, 2014.
[14] "Nanotechnology in the metallurgy of steel," Steel in Translation, 37(8), pp. 716–721, 2007, by S. V. Kolpakov, V. A. Parshin, and A. N. Chekhovoi.
[15] S. M. Fufa and P. J. Hovde, “Nano-based modifications of wood and their environmental impact,” in Proc. World Conference on Timber Engineering (WCTE), June 2010.
[16] A. E. Oke, C. O. Aigbavboa, and K. Semenya, “Impacts of nanotechnology adoption on sustainable construction,” Advances in Engineering Research (AER), vol. 102, pp. 364-369, July 20