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The Role of Nanomaterials in Sustainable Architecture

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ABSTRACT

The study of the impact of nanotechnology applications in architecture, its role in the development of building performance and its impact on the formation of sustainable architecture, is the result of decades of research and development of nanotechnology and its applications for buildings. Sustainable development has been of great interest in recent decades and has always been considered as one of the important topics in new sciences and technologies. Nowadays, various technologies are used to create more comfort and save costs, especially in the consumption of energy resources, on the other hand, by using nanotechnology, logical and appropriate solutions can be invented and presented in the construction industry to provide human comfort conditions. Therefore, this research focuses on investigating the different types and shapes of nanomaterials and their applications in construction and various supplementary materials. In addition to the study of the foundations and factors that determine their application in architecture and their impact on the overall shape and development of the building's performance. This includes understanding the functional and economic aspects and the aesthetic and environmental enhancement of buildings. It also sheds light on the role of nanotechnology applications in saving and rationalizing energy consumption, preserving it, increasing the effectiveness of fire resistance, reducing costs, and maintaining and extending the life of buildings. The benefits of using nanomaterials in architecture and their impact on them were discussed. It mainly affects buildings in terms of performance, performance, operation, formation, and the interior and surrounding environment of the building. It helps to achieve buildings with appropriate architectural figures, high performance, and low costs to achieve distinctive architectural designs with a unique aesthetic appearance. Finally, the architectural designer should pay attention to the selection of nanomaterials used in buildings and their places of application to create distinctive forms and facades. In general, the results showed that increasing awareness of modern technologies and nanotechnology leads to improved building efficiency.

Introduction

Nanotechnology is one of the minor standard units that humanity has been able to measure and produce something tangible that serves humanity. The advent of this technology and composite materials, through its impact on architecture, which led to developments in the formation of the architecture of buildings – the creation of new means of expression and consideration of environmental and economic constraints changed our perception of the present and the future.
. By rearranging matter particles together, nanotechnology has contributed to a huge leap in all branches of science and engineering, especially in building, construction, and architecture. Unique methods of microscale, and most countries have upgraded scientists and their abilities to produce those materials and products that they cannot produce. All of them are due to rapid development.
Due to its unique and new characteristics, nanotechnology is one of the essential areas in the present era that will change the concept of construction, have a positive impact on buildings in the future, and contribute to the development of architecture and urban planning.

Nanotechnology began with the American physicist Richard Feynman with the idea of controlling objects at a microscopic level whose size does not exceed the size of a bacterial cell. For the house building materials are used with it, new designs, features, features, house buildings or the use of building materials.
In fact, materials form the core of a building, and their impact on the environment cannot be ignored. "Nanotechnology research and the use of nanoparticles in the field of materials such as concrete, steel, glass, wood, or coatings have become needs such as strength, resistance, durability in building structures, and helping to conserve resources (Pourjafari & Asadi, 2007). On the other hand, the issue of modern architecture in the world is the use of the selection and use of products that have the least environmental impact. Therefore, the importance of studying the impact of nanotechnology and its use in architecture can be concluded.
Nanotechnology can improve production capacities in the field of building materials. This technology has the potential to make it stronger, lighter, cheaper, safer, more durable, and easier and more sustainable maintenance. Sev and Ezel report that there are two ways to improve structural materials, one by reinforcing existing materials such as concrete and steel, and the second by adding nanoparticles to improve the properties of bulk materials. Or it is technically and economically feasible by supplying all structures that are mainly made with new materials, such as carbon nanotubes (CNTs).
In general, the traditional building methods and materials used in their conventional and repetitive form in many buildings have not had an impact on the architectural and aesthetic formation, as well as the determination of these materials and their impact on human comfort. The low quality of the surfaces and the efficiency of the buildings, the increase in maintenance costs, and the short life of the buildings also do not help to save energy, and through the research, the importance of using nanomaterials and the technology used in buildings is confirmed. That they are highly efficient buildings that can avoid defects and problems caused by it. Therefore, increasing the efficiency of buildings using nanomaterials technologies and determining the impact of nanotechnology on them led to this study with the aim of identifying the effective components of nanomaterials on building materials and how to use them in architecture.
It was done sustainably. .This study presents the latest nanomaterials used in construction and some of their emerging capabilities at the end of the 20th century and how nanotechnology has

developed traditional building materials and improved their performance, as well as the emergence of new materials.

2- Theoretical foundations

2.1. The Concept of Sustainability

Nowadays, the term sustainability along with sustainable development is widely used in economic, environmental, and even social development
(Fang et al., 2009). The term sustainability expresses the fact that no man-created environment can survive and continue to exist without the participation of the natural environment or ecosystem (Azerbaijani & Mofidi, 2003). Sustainable architecture pays attention to architecture as a living organ rather than the environment It should provide a suitable environment for human life as a living organism , and in this regard, it values the environmental identity of the built space, and although it has the most advanced design and implementation techniques on the surface
, it is closely related to the principles of traditional architecture.

2.2. Nano and Nanoscale

Nano means something very small or precise in size (infinitely small things). The word Nano appeared at the beginning of the Greek period, as it derives from the word Nanos in Ancient Greek and means midget in English. In science it refers to nano one billionth of a meter (i.e., the lion of a thousandth of a throne) and in numbers (9-10 meters) or one millionth of a millimeter (Schroderchodek et al., 2009).
A nanometer is a unit of longitudinal measurement like other known units of measurement. It measures small things that can only be seen under an electron microscope and cannot be seen with the naked eye. It is a science that studies and deals with materials at their atomic and molecular levels at a scale of more than 100 nanometers, and deals with the classification of molecules and atoms and the study of Their distinctive properties in nanomaterials as well as the study of the phenomena associated with their size reduction to explain them for different properties and characteristics (Ayshin and Meltem, 2014).

2.3. Nanotechnology

It is the technology that gives us the ability to control matter directly. Its concept also depends on particles that are less than a hundred nanometers in size, which give matter new properties and behaviors, and this is because these particles (which are smaller than the characteristic length related to some phenomena), by constructing, monitoring, measuring and investigating its properties, and to atomic assemblies of five. Atoms are up to 1,000 bits, because nanotechnology has much smaller dimensions than those of living bacteria and cells (Ward Jand, 1988).

2-4- Nanomaterials

Nanotechnology has influenced architecture in terms of building methods and finishing materials, so many types of nanotechnology have been integrated with the architecture of Table 1. Nanotechnology has an impact on the properties of materials and energy, which caused a noticeable difference in architectural thinking and design, and nanotechnology was used in construction and building to reduce construction costs, conserve building material resources, and open up modern areas for energy conservation and environmental protection (Thwe and Liao, 2002).
The savings in the use of these technologies reached 25%, in addition to the endurance capacity and distinctive characteristics of building materials and their superior ability to withstand unusual weather, which contributes to the deployment of these materials in desert locations and places with high temperatures, humidity or frosts or other various environmental characteristics.

Table 1. Shapes of nanomaterials

Different types and shapes of nanomaterials	
Hollow tubes are less than 100 nanometers in diameter and perhaps thousands of nanometers	Nanotubes

long. Examples include carbon nanotubes, silicon tubes, and titanium	
They are like nanotubes, except that they are solid and shorter than them, such as gold and platinum bars	Nanorods
It is the result of the distribution or diffusion of nanomaterials within ordinary materials. For example, carbon nanotubes are dispersed and spread inside some plastic materials to obtain nanocomposites with superior properties.	Nanocomposites
This thin layer is made of a special material with a thickness of less than 100 nanometers, and these thin layers are used in the field of semiconductors such as silicon and gold alloys.	Thin Films
It has several forms. One dimension is less than 100 nanometers and may be cubic, spherical, or oval.	Nanoparticles

2-5-Composite Materials

Recently, there has been an increase in interest in composite materials as engineering metamaterials due to their unique properties. This interest was shown in the construction facility requirement (). Composite materials consist of the integration of materials with different properties, and the purpose of this merger is to create new properties that were not available in the raw materials. Figure (1) shows composite materials and these materials have been successful in different types of composite materials that affect architecture (Yasser et al., 2013).

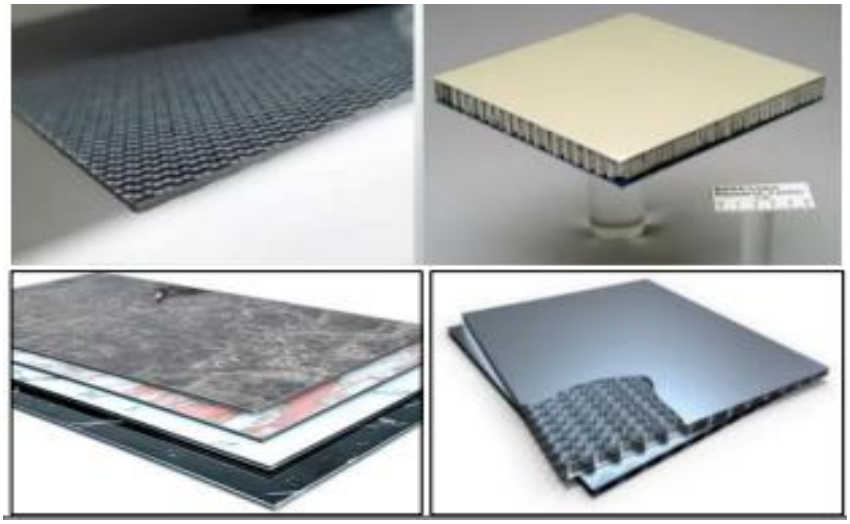

Figure 1- Composite materials used in construction and finishing (aluminum, marble, wood).

2.5.1-Glass Fiber Reinforced Polymer (GFRP)

Composite materials are materials that are made up of a mixture of materials that share the required properties there. It is a mixture of polymers and other materials with high strength (Stiffness) such as glass or boron fibers, examples of which are: Represented Polymers, Glass Fibers, Plastics (GFRP), and Glass Fiber-Reinforced Concrete (GFRC) are panels that are architecturally used in the façade. They are.It is composed of layers of high-performance white cement concrete grains, characterized by durable and thin materials from (mm to cm). It can also be poured separately to form the curved shapes required by the design. Figure (2) shows the glass fiber reinforced polymer and its applications, and the Heydar Aliyev Cultural Center in Baku, which In it a polymer reinforced with glass fibers is applied (Whatmore et al., 2006).

Figure 2- Glass Fiber Reinforced Polymer and Its Applications

2.5.2-Carbon nanotubes

The discovery of carbon nanotubes in 1991 is more vital in industrial and scientific applications due to their symmetrical structure and extensive properties (Taha Kamal et al., 2015). Carbon-shaped tubes (3) and tube walls may be single-atomic, double, or weighted with greater resistance to optical loads and are called multi-walled MWNT tubes (nanotubes) and the diameter of the tube ranges from less than one nanometer to less. 100 nm and the most famous examples are carbon nanotubes.

One of its most important features is its very high hardness, which is 30 to 100 times greater than that of steel (steel), although the carbon density of these pipes is six times lower than that of steel (Adawy et al., 2015).

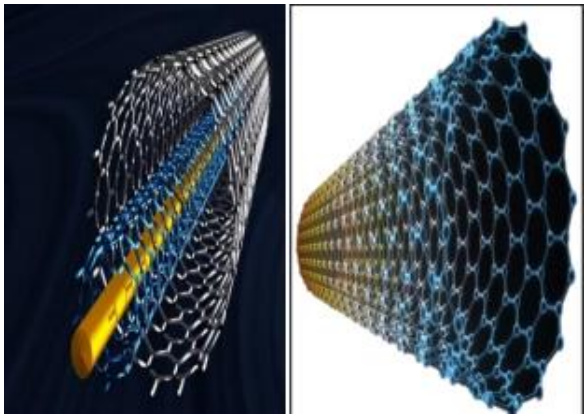

Figure 3- Different types of carbon nanotubes based on chirality

Objectives of Nanoarchitecture

- Improving environmental and economic performance, achieving a self-cleaning building, and Table 2 classification shows the impact of some nanomaterials on the properties of materials and improving performance in buildings (Abdullah, 2017).
- Increasing human comfort in indoor spaces by reaching optimal temperatures by rationalizing energy consumption.
- Maintaining ecosystem integrity by reducing carbon dioxide emissions.
- Obtain a building that controls temperature and humidity according to climatic conditions.
- Achieving a building that is lightweight, sturdier and durable, resistant to cracks and cracks, monitoring work and damage and self-repairing work.

Table 2 - Classification of the Effects of Nanomaterials on the Properties of Materials in Buildings

Classification of the Effect of Some Nanomaterials on Material Properties and Performance Improvement in Buildings		
Characteristics (their effect on building elements)	Places of Use	Nanomaterials
Self-cleaning breaks down carbon and organic compounds into hydrocarbons, which are eco-friendly,	Various roofs of the building (exposed to sunlight).	Titanium Dioxide

anti-UV, antibacterial, and antifungal.		
Increasing the mechanical strength of various elements	Structural and non-structural elements	Carbon Nanotubes
We are increasing the mechanical strength of various elements and improving the ductility, flexibility and shrinkage of concrete and cement.	Structural and non-structural elements	Nano Silica
Increase wear resistance and rust resistance	Structural and non-structural elements	Nano Aluminum
Self-healing of concrete, deep and superficial cracks and microbial cracks.	Structural elements (concrete), non-structural elements	Carbon Fiber Nanotubes

Nanotechnology in the Architecture Industry

In recent years, the rapid progress of sciences, especially in nanotechnology, has led to great developments in the construction industry and the environment
. Organic architecture is defined as the adaptation of the structure of buildings based on their location in nature, and today
nanotechnology is studied in the form of sustainable architecture and its new horizon, nanotechnology (Mahmoudi & Sedigh Ziabari, 2008).
The architectural profession and the construction industry are faced with a huge range of materials and materials. In fact, materials form the core of the building
and their impact on the environment cannot be ignored (Mahmoudi et al., 2008).
Nanotechnology has created nanocoatings
that reduce energy consumption and increase the life span of the building. In general, nanotechnology has been developed by making
the devices and tools used in the sector more efficient. Various factors as well as reducing the consumption of raw materials and energy have made it possible to take effective measures to protect natural resources and the environment.

Applications of nanomaterials in architecture

The study of the behavior of materials at the nanoscale enables building builders to produce new materials with unique properties and helps to reduce the environmental impact of the production of cement and concrete mixtures, reduce the volume of carbon dioxide emissions in the building materials industry, as well as in waste recycling systems. And its environmental importance, which is part of modern global trends that aim to save electricity and The energy used in cooling is lighting, and heating water, which reduces harmful carbon emissions, maintains the integrity of the ecosystem, and thereby extends the life of the building (Mahmoud, 2023). Additives for materials used in construction such as silica, alumina, titanium dioxide, shale metals and carbon pipes, and from them in coatings, nanocomposites, additives for concrete and cement mixtures and adhesives, the production of building glass coatings and concrete mixtures itself, which are characterized by their thin shape, high transparency, increased protection and reduced maintenance costs, as well as thermal insulation materials such as "aerogel". The gel material is very light weight, made of silica and carbon. Nano Ceramic Films for Glass Thermal Insulation show a very light weight solid transparent gel material, made of silica and carbon. It is described as a material with high thermal resistance.

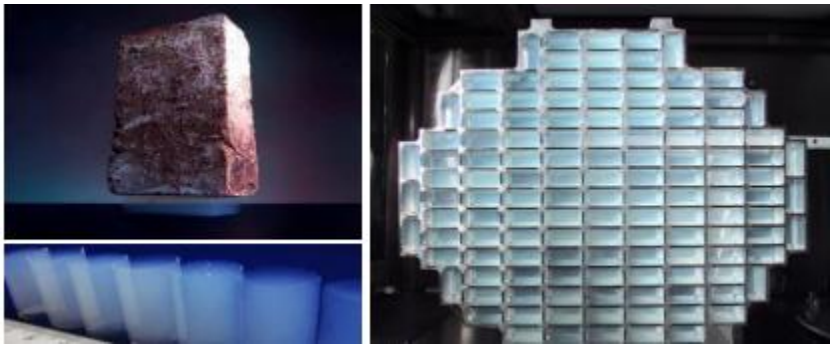

Figure 4-Nanoceramic Films for Glass Thermal Insulation - Aerogel

Advantages of using nanotechnology in the field of construction

Most countries in the world have recently moved towards the use of nanotechnology in the field of construction by replacing traditional building materials with "modern building materials that are cheaper, smarter, and environmentally friendly", which has led to the use of nanomaterials. The advantages of using nanotechnology in the field of construction include clean, healthy, low-cost, then controlling the temperature and humidity of spaces according to climatic conditions, resistance Against high temperatures and harmful radiation, as well as reducing greenhouse gas emissions from carbon dioxide and nearby buildings, fire protection, etc.,..Self-cleaning capability through self-cleaning glass, resistance to UV rays, moisture and fog caused by glass, thermal insulation of the building, and also has the ability to reduce maintenance by handling any cracks and cracks early, and directly and automatically repair it on its own, making it lighter in weight and more robust. Nanotechnology has also opened up a new world for the use of new materials and capabilities in construction, which has led to the use of the best natural resources (Treacyeacy et al., 1996).

The development of structural and non-structural materials and coatings used influenced the exterior formation of buildings, which significantly led to the introduction of new architecture. Table (3) shows the classification of Accor nanomaterials and how they are used in architecture, to what extent these materials affect the development of their function, and change the exterior configuration of buildings to access unconventional buildings They give.

Nanomaterials have slip technology of several elements, and nanotechnology is widely used in building materials to improve building materials as follows. Nano-additives were also used in terms of places of use and techniques affecting building materials and their properties, which made them a material that interacted with climatic factors, and then their effect on the exterior created a distinct and unique aesthetic appearance. Nanotechnology provided many of the materials used in the construction and completion of buildings, which helped to develop their functionality and It helped to achieve the required level from an aesthetic point of view and interaction with atmospheric factors to make the building environmentally friendly.

Table 3 - Classification of Nanotechnology Applications

Building Materials	Finishing Materials		
New Structural Materials - New Finishing Materials - Coatings		Applications of Nanotechnology in Architecture	Type of use of nanotechnology
Self-cleaning (lotus effect-photo stimulation), easy to clean, anti-bacterial, anti-graffiti, anti-fog, anti-reflective			
Energy Saving	Insulation Materials		
Sustainable Energy	Thermal Insulation (Vacuum Insulation Boards, Aerogels, Nanogels, Thin Layers, PCMS) (Phase Change Materials)		
Nanotechnology Cement	Use of glass	Nanomaterials	

Nano-iron	Processed Aluminum Nanotechnology		
Nano Refined Wood			

Results

The application of nanotechnology in architecture has many benefits, including achieving the functional and aesthetic aspects of buildings, achieving the rationalization of energy consumption and energy saving – cleaning the buildings by themselves, the building's fire resistance, and increasing the lifespan of buildings, which has had a good impact on buildings in terms of performance.

The use of nanotechnology materials has the greatest impact on reducing the total cost of buildings, as well as reducing maintenance costs and finding architectural solutions in buildings and construction, because it is achieved for the architect's unique and distinctive designs with a specific aesthetic appearance. Resistance to environmental factors is done efficiently and with the required quality, helping to preserve raw materials and their resources, and being able to meet needs.

Nanotechnology has helped to solve some of the energy-related problems in architecture and construction by using nanomaterials in the exterior of buildings to achieve buildings with new architectural structures that are energy saving, high efficiency, low cost, long life, and reduced.

The application of nanotechnology led to the emergence of smart architecture in the operation, operation, and maintenance of buildings. Nanotechnology in the field of construction has led to the emergence of paint systems with unique properties that reduce the accumulation and adhesion of dust and pollutants on the exterior surfaces of buildings and act as anti-moisture, heat, oxidation, and UV cracking. rays and constant change in shades of colors. The use of colors with a lower cost and higher quality than other colors that do not take into account the characteristics and environmental conditions will extend the life of buildings and roofs.

Nanotechnology provided materials that helped the architect to think and coordinate the choice of materials in buildings to balance the outdoor space with the surrounding environment. It also presented distinctive engineering thinking related to nanotechnology through materials that affected the exterior appearance of buildings and improved the efficiency of structures by applying nanotechnology materials in the exteriors of buildings and determining the extent of the impact of their application on architecture.

Discussion and conclusion

Global trends show that nanotechnology is advancing rapidly, and one of the most important features of this technology
is its ubiquity. Nanotechnology can change architecture in ways that are hard to imagine. This technology is
further influencing architecture, design, and even design ideas in the world by introducing new materials and how energy is used.

According to the theoretical foundations of nanomaterials and the type of selection of these materials in buildings, their scope of use, and the benefits of using
this technology in buildings in the studied projects, we achieve the importance that materials and materials at the nanoscale have
high performance and multi-purpose. For example, as mentioned in the designs, benefits such as increased strength-to-weight ratio, greater durability and reliability, increased energy efficiency, environmentally friendly recycling capability, etc. They have.

With the results of the present study, it is possible to use the analyzes and studied examples of

such materials in all areas of architecture that has a close relationship with the environment so that we can witness more peace in today's architecture and the environment that is being destroyed. Also, the use of nanotechnology is a smart solution to achieve sustainable architecture.

According to what has been presented and based on the results obtained about the role of nanomaterials technology in buildings in order to improve their efficiency accordingly, the research suggests the following:

1) Increasing awareness and publicity of nanotechnology at the level of media and publications by posting in specialized scientific and architectural journals, research and architectural studies, and holding conferences and symposiums that discuss the thesis of applied buildings in nanotechnology. It is necessary to encourage businessmen to contribute to nanotechnology research expenditures and to allocate the art of financial resources to carry out the architectural and scientific research required to achieve outstanding results.
2) Shakeel is an integrated research team covering all disciplines related to nanotechnology in architecture to conduct a series of specialized research and studies and to conduct integrated studies of environmental, economic, maintenance and operation aspects in order to extract new materials that help solve building problems in terms of cost and energy consumption.
3) The government should adopt the development of scientific research and the use of the nanotechnology approach and its study in the early stages of university education. He presented the curricula of nanotechnology and its applications in architecture to find solutions to building problems (exchange of the latest and most prominent research and projects with the global and Arab benefits of nanotechnology).
4) The architect designer should pay attention to the selection of nanomaterials used in exterior facades and the place where they are used to create distinctive forms and make unconventional facades by working to increase the awareness of architects about modern technologies in general and nanotechnology.

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