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Aplicaciones de la nanotecnología en arquitectura e inspirándose en ella en diseños innovadores. Applications of nanotechnology in architecture and inspiring by it in innovative designs.

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Resumen— **A principios del tercer milenio dC, se prometió a la nanotecnología otra Revolución Industrial, conocida como la cuarta ola de la Revolución Industrial. Muchos investigadores, como John MacLane Johansen, Calatrava…, creen que en un futuro cercano, todos los objetos se fabricarán sobre la base de la nano escala y sus propiedades se formarán en esa escala, y la producción de todos los objetos hechos a mano cambiará. Por lo tanto, la transformación de los materiales de construcción y la tecnología de la construcción parece posible y sus efectos en la arquitectura deben examinarse a partir de ahora. Este artículo pretende estudiar los efectos de la nanotecnología en el campo de la arquitectura mediante el estudio del uso de nanomateriales y el cambio de la estructura de las células y la forma arquitectónica. La nano arquitectura puede inspirarse en la nanotecnología, que produce una variedad de efectos. La nanotecnología tendrá un gran impacto en los materiales de construcción y sus propiedades, pero la inspiración de los arquitectos en las estructuras de nanopartículas también es importante porque es una gran fuente de conceptos para inspirar el diseño arquitectónico que puede mostrar una arquitectura extraordinaria. Por lo tanto, nano puede considerarse como un elemento en la evolución de la arquitectura en términos de función y forma que puede moverse en línea con la última tecnología en el mundo.**

Palabras clave: arquitectura sostenible, nano arquitectura, nano materiales, biónica, morfología de la nano.

***Abstract*— At the beginning of the third millennium AD, nanotechnology has been promised another Industrial Revolution, known as the fourth wave of the Industrial Revolution. Many researchers same John MacLane Johansen, Calatrava…, believe that soon, all objects will be made on the basis of the nanoscale and their properties will be formed on that scale, and the production of all handmade objects will change. Therefore, the transformation of building materials and construction technology seems possible and its effects on architecture should be examined from now on. This article intends to study the effects of nanotechnology in the field of architecture by studying the use of nano-based materials and changing the structure of cells and architectural form. Nano architecture can be inspired by nanotechnology, which produces a variety of effects. Nanotechnology will have a great impact on building materials and their properties, but architects' inspiration from nanoparticle structures is also important because it is a huge source of concepts in inspiring architectural design that can display extraordinary architecture. Therefore, nano can be considered as an element in the evolution of architecture in terms of function and form that can move in line with the latest technology in the world.**

Index Terms— sustainable architecture, nano architecture, nano materials, bionics, morphological of nano.

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I. INTRODUCTION

NANOTECHNOLOGY is a name, which has been given to a type of manufacturing technology. As the name of Nanotechnology implies, it will be happened when there is a capability to make objects from atoms and in this case the ability to rearrange materials with atomic precision will be achieved (Fazeli et al., 2005). During the past decade, new technology has done the gradual evolution of design and production.

This new technology will remove some limitations such as standards, irreversible compounds like concrete and brick, steel, nails, fittings, etc. from designers' route and will alter the architectural concepts (Olson, 2000). In nowadays' world, the alarm about the depletion of oil and fossil reserves has been sounded from a long time ago, so it is issue to find new sources of cheap energy and preserving reserves and resources for future generations and this is the key to the nations to be success about not being independent on others.

On the other hand, some characteristics like reducing environmental pollution, preventing the loss of work force, and reducing huge costs are among which are defined for any successful and sustainable project or activity to preserve the natural and non-renewable resources with needed resources supplying for the next generation, reducing pollution and finally preserving the ecosystem.

According to the current needs of society, some questions arise: will the nanotechnology be able to alter the architecture and the field of construction fundamentally and operationally to guide the construction process in line with sustainability of resources and ecology? Will the use of Nano-based materials bring about buildings with high resistance to earthquakes and natural disasters? Will the use of building nanotechnology increase the useful life of the buildings? and more important, will this technology be able to create a responsive and ideal environment and prevent form-based buildings' design and construction?

Firmitas , Utilitas and Venustas are the three principles of Vitruvius, which have been questioned at various period of times by the emergence of various schools, but still beautifully and completely express the characteristics of a building. Therefore, with the appearance of this nanotechnology, spatial geometry in the form of molecules and atoms will provide stability, usefulness, and beauty of the building. "This is not a science fiction dream, because Nano-science will happen much faster than a reality" (Quatman et al., 2003).

In other words, "the biggest plans for building the environment will be very, very small in the future" (Limt, 2001). Persuasive and immediate evidence of encountering nanotechnology with architecture are materials (physical products) which generally grant different uses to buildings. Such materials create new facilities for completing and improving the architectural thing and thinking about a new form of life (Rennie, 2000).

If we want to name the new features of nanotechnology in architecture, we can mention the following: sunscreens, invisible walls, and copying of reproductive structures. In addition; social, moral, and environmental developments; will not be separated from this evolutionary course (Quatman et al., 2003).

Therefore, the use of Nano according to molecular arrangement, structural structure (such as bionic) and modern materials is a logical solution to solve the challenges of today's form-based architecture (Like what Johanson has been doing during consecutive years).

On the other hand, the adaptation of structure and architecture along with architecture and structure forming as a single construction and reducing energy crisis, sustainability of the building against unexpected events (economical) and conservation of energy resources for future generations accompanied with finding new energy sources will provide new horizons in architecture and urban planning. As this study aims to investigate the role of nanotechnology in of architecture, the research method "applied research" with "descriptive approach" according to the specificity of the subject.

For this reason, we have pointed to this technology's application in various fields with a comprehensive definition of Nano and overviewing its history; then analyzed the subject and rendered the results with emphasizing on the field of architecture and urban planning along with mentioning to some examples of nanotechnology's application in the subject of architecture and construction industry based on case-by-case approach

II. NANOTECHNOLOGY AND NANO PREFIX

The term nano comes from Greek nano meaning little old man or dwarf (undersized). Like other prefixes, nano comes at the beginning of units of measurement such as seconds, meters, etc. One nanometre is one billionth of a meter or 10 angstroms that is equal to the dimensions of five atoms. While the nanotechnology has many definitions; the "National Nanotechnology Initiative" (NNI) offers a three-part definition of nanotechnology: Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometre range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size.

Nanotechnology research and development include manipulation under control of the nanoscale structures and their integration into larger material components, systems, and architectures . In addition, the German Federal Ministry of Education and Research (BMBF) describes nanotechnology as follows: Nanotechnology refers to all the activities of research and study, creation, and application of molecular structures, in the intra-material range and outer surface of materials that at least one of its dimensions has a tolerance of less than 100 nanometres.

Obviously, the manipulation of the components of a system in nanoscale leads to the creation of applications and

characteristics in materials, so that we can create new materials for previous materials with new applications.

III. NANOTECHNOLOGY BACKGROUND OVERVIEWING.

Throughout human history since ancient Greece, people, especially scientists of the time, believed that each matter could be broken down into small pieces repeatedly to have particles that cannot be broken more, so these particles formed the basis of that matter. Around 400 BC, the Greek philosopher Democritus for describing the particles that make up matter, used the word atom, which means indivisible in Greek language. Many consider him the father of nanotechnology and Nano science. The exact starting point of Nano Technology is unknown. Maybe we should consider the medieval glassmakers as the first nanotechnologists. The glassmakers used Medial Forges to shape the glass, but they did not know why the glass colour changes because of gold addition. At that time, nanometre gold particles were used to make medieval church glass, resulting in very attractive coloured glass (Leydecker, 2008). Totally, the process of (Nano) technology development can be considered as follows:

Nanotechnology has been able to establish its position among various sciences and disciplines for two decades and has revolutionized in some disciplines or products, which we will mention to some of them here.

TABLE I
NANOTECHNOLOGY DEVELOPMENT PROCEDURE

1959	**Lecture by Richard Phillips Feynman, Founder of Nanoscience, entitled as: "There is a lot of space on a micro scale"**
1974	The term “Nanotechnology” was coined by “Norio Taniguchi” a professor at Tokyo University of Science
1981	STM[1] Microscope Invention
1985	Buckyball[1] (Pure carbon sphere shaped and hollow)
1986	AFM[1] Microscope Invention
1989	The term “IBM” was written with separate atoms
1990	Artificial production of Buckyball on a scale visible to the naked eye
1990	Starting investment in research and development of nanotechnology in different countries
1990	entering the first nanotechnology product into market
1991	Nanotubes’ Discovering
2000	Bill Joy's article "Why Does the Future Need Us?" - The beginning of disputes over nanotechnology
2007	Introduction of the first global certification in the field of risk management and monitoring of nanotechnology systems in Germany and Switzerland

IV. NANOTECHNOLOGY APPLICATIONS.

As mentioned earlier, nanotechnology, despite its new-fangled, is expected to change the lives of human society and make human dreams come true. Therefore, this new-fangled technology has entered into many widely used sciences and disciplines and researchers have achieved significant results (Daryoush et al., 2013). These achievements are:

TABLE II
NANOTECHNOLOGY APPLICATIONS

Field or Branch	Description
Environmental Protection	– Reduce raw material and energy consumption, thereby reducing CO2 emissions and conserving resources, – Solar energy production (photovoltaic cells) and fuel cells,
Marine Industries	Vessels Manufacturing with purpose of: – Creating suitable coatings against corrosion and increasing strength, – Avoid carrying multiple tons of fuel and multiple stops with the production of new fuels and batteries with high energy storage
Nano Medicine	– Production of intelligent systems for detection of diseases and treat the damaged biological tissues at the molecular level – To aim and deliver medicine to inaccessible parts of the body with Nanometers’ equipment - Production of artificial tissues compatible with the body, – Treatment of some incurable diseases such as cancer, AIDS, and hepatitis. – Better health care via using nanometer equipment in vivo
Computer & Electronics Science	– Increase data storage capacity – Simulator machines’ manufacturing with the Nano-computer and Nano-assembler, – Potential application of nanotubes as field emitting components in flat panel displays etc.
Biotechnology Or Nano-Biotechnology	– Manufacturing systems for release drugs into the body, – Making compatible parts to replace with body organs, – Simultaneous diagnosis of several diseases from a single drop of blood (based on DNA) – DNA-based nano metric instruments’ manufacturing, including nanotechnology applications in biotechnology

V. NANOTECHNOLOGY IN ARCHITECTURE URBAN PLANNING.

The application of nanotechnology in architecture can be divided into two groups: The first group is bionic architecture (or application of geometry and Cretan structure in the architecture of various buildings) and the second group is utilization of nanomaterials’ made materials. For the first group, mean the case of bionic architecture, special attention can be paid to its roots for proper exploitation, about 3 billion years have passed since the creation of the earth, and during this period, nature itself has been proposed as a capable and creative architecture.

For example, plants and animals have been able to overcome their environmental problems with the necessary decorations and designs, and humans throughout their lives have always tried to build and design the needed places and equipment from their around nature and the environment and inspire them.

Architecture has not been exception in this trend, and has often been inspired by natural structures, natural shapes and the nature itself, which recently, this trend is seen more in the internal logic and morphology of natural processes or structural cells, instead of imitating the nature and being directly influenced by it, and follows its constituents' rules, such as flexibility and resistance, in the best possible way. From such a perspective, the bionic architecture movement rejects the regular quadrangular shape of traditional buildings to create biological buildings and the natural world.

Fig. 1. Similarities between Buckyball and a soccer ball.

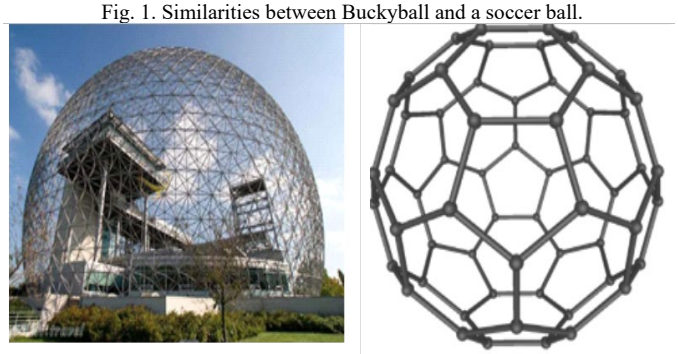

Fig. 2. America's Booth at the 1976 Montreal Exhibition.

The result of this view will be a collection of unique buildings with biological and mathematical forms. Utilizing the geometric structure of basic elements (nanostructures) and their behavioural properties (Bionic architecture), has long been in the model of many architects such as Calatrava. "Nanotechnology" is not part of the future but the whole future.

One of these structures is carbonic structure, in which hard elements such as diamonds are the result of this behaviour and chemical bonding, and the Buckyball is a clear example of this hard structure. Buckyball is the most well-known Fullerene that looks like a soccer ball (Figure 1) and is made of 20 hexagons and 12 pentagons. Fullerene was discovered by Cibal, which was also called Buckminsterfullerene because of its resemblance to Buckminster Fuller's geodetic dome (Figure 1).

The Buckyball molecule consists of 60 carbon atoms (C60) resembling a soccer ball, in which the molecules being arranged in interconnected hexagons and pentagons.

Carbon Nanotube, which is made of tubular graphite plates with a hexagonal arrangement, is considered a close relative of fullerene carbon nanotubes if their ends are closed (Figure 3). In fact, they are like fullerenes that become tubular by placing carbon in their meridian. However, the word fullerenes do not include nanotubes here.

As mentioned earlier, in addition to the use of nanometre carbon geometry and structure in the architecture of various buildings, the use of materials made using nanomaterials is another application of nano in architecture. Nanotechnology is the science of making materials with atom by atom, and by controlling materials at the molecular scale, it is possible to produce suitable materials with unique properties such as stability and durability of materials and buildings, high impact resistance and low fragility.

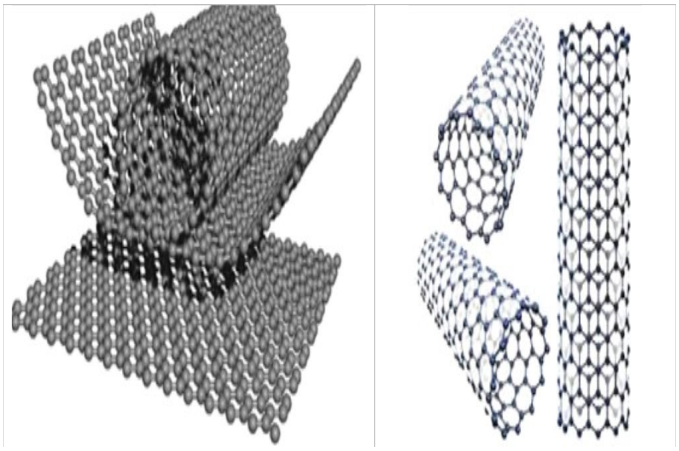

Fig. 3. Carbon nanotube.

In general, the results of the nanotechnology's application in the construction industry include the following: providing lighter and more durable structures, making highly resistant materials that can be used in the construction of building installations, improving the performance of water pipe connections, increasing the electrical and mechanical efficiency of building installations, reinforcing materials, reducing heat loss and insulation needless. All these features are among the physical properties of materials that will be produced in the construction industry using nanotechnology. In the construction sector, in addition to preventing energy loss in various sectors and the optimal use of energy in the building, it is possible to maintain the building for a long time and make it resilient even for force majeure or unexpected (economically viable) events. Reduction of effluents and pollution due to energy consumption, as well as the possibility of recycling and reuse of materials, energy, and water are other results of using nanotechnology. Although the contents mentioned here are about the field of construction industry and production of products that have the least environmental impact, other aspects such as beauty, visual quality, reparability, easy access and also the same three principles of Vitruvius are considered too. It is worthy to say that these three principles which are Firmitas, Utilitas and Venustas; have been mentioned in "Ten Books on Architecture ". Totally, what can be mentioned in the field of architecture and construction industry are as follow:

TABLE IV
DIFFERENT SHAPES AND FORMS OF USING NANO PRODUCTS

Self-Cleaning and Easy-To-Clean Materials	– Lotus Effect[1] – Water friendly and easy to clean – Self-cleaning, Photo Catalysis
Nano Coatings	– Anti-Reflective[1] – Anti-Fingerprint[1] – UV Protection (*blocking* the *ultraviolet* light from reaching your eyes) – Solar Protection – Anti-Fogging[1] – Air-Purifying (removing the contaminants from the air in a room to improve indoor air quality)
Nano Insulators	– Thermal Insulation – Fire-Proof – Temperature Regulation
Self-Healing Elements	– Scratch Proof and Abrasion
Antibacterial and Antimicrobial Surfaces	- Such surfaces inhibit the ability of microorganisms to grow on them.
Nanotechnology in Steel and Concrete production	– Adding silicon dioxide nanoparticles and polymer additives to ordinary construction materials such as cement, steel, and concrete makes them denser, more stable, and more resistant to corrosion, among others. These additives include carbon nanofibers (CNFs), carbon nanotubes (CNTs), and nanostructured metals. Nanoparticles may improve properties such as self-healing and fire-resistance.

There are many nanomaterials in the field of architecture that can be classified them as follows:

VI. NANOTECHNOLOGY OUTLOOK IN ARCHITECTURE.

According to the abovementioned matters, a question arises now: how the architecture can blend in with emerging science and technology such as nanotechnology? John M. Johansen who is author of the book, "Nano Architecture, a New Species of Architecture" fully addresses this issue. He believes that the use of nano will transform the future of architecture and lead it in a special direction. In other words, nano-architecture allows designers to interact better and closer with users. In fact, this type of architecture has been shaped based on nature and closeness to it. In addition, if the man uses this type of architecture, he uses not only advanced technology, but also this type of architecture will provide a more familiar and assimilated design for him and his human needs. On the other hand, designing materials with the desired characteristics and in accordance with the needs of the project and the audience is another advantage that is predicted for the future of nano and architecture. It should be remembered that the use of nanotechnology will cause special properties in materials and will change them in a wonderful way; For example, self-healing property or returning to the environment are among the features that should be mentioned (Johansen, 2002).

A. Nano-architecture: the architecture compatible with nature.

Organic Architecture, which has been defined by "Frank Lloyd Wright" as the adaptation of the structure of buildings based on location in nature, is today discussed in the form of sustainable architecture and its new horizon, nanotechnology. According to Wright, designing should be harmonized with humanity and the environment, nature. He called this a philosophy organic architecture. He believed each object in turn has a specific language for speaking and expressing emotion. In bionic architecture and in the works of architects such as Santiago Calatrava, the use of the structure and mechanism of nature can be seen well, and designers have created ideal and responsive collections by modelling what nature has moved in a long time to its evolution and has removed everything that has not been compatible with. Nanoparticles follow the molecular structure of diamond, which is a stable structure and for this reason, the diamond is one of the hardest materials in the world. Now, the use of this structure in the structural system and architecture of a building, makes it strong and flexible. Of course, modelling the morphological structure of nanoparticles is not very widespread and is still in its infancy.

B. Nano-Tower

Nano Towers in Dubai have been proposed by Allard Architecture as the new headquarters for the DuBiotech Research Park in Dubai. This combination includes 160,000 square meters of office space, hotel, laboratories, residential and along with facilities in a tower with a height of 262 meters. A cover near the ground provides shade, while providing a

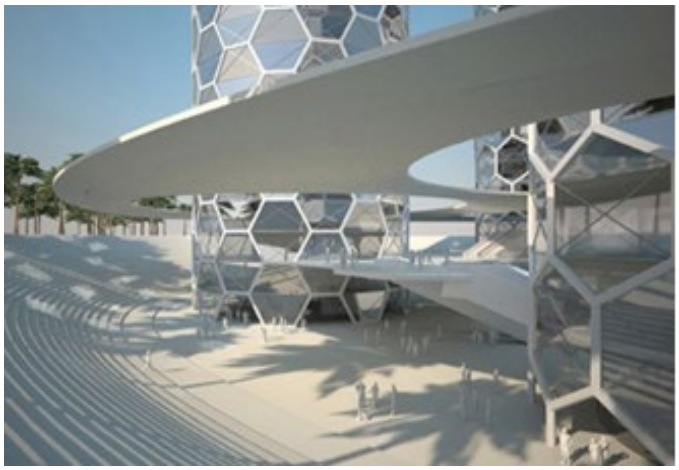

Fig. 4. Nano-towers and its concept plane.

striking entrance to the towers: a concept terrain from which the towers grow (Figure 4).

Its interesting architecture is a repetitive network is a structure of the external protective covering of the building, which has non-curved beams but of equal lengths. The overall appearance of the tower is multifaceted - inspired by the nanoscale carbon tube - and the structure provides connections to change the engineering direction from vertical to horizontal, providing numerous opportunities to divide interior spaces along junction lines (Figure 5). The form created as repetitive grid of hexagonal structure, while a nano scale carbon tube inspires the entire facade of the tower. If the designer, only copy forms discovering at nano scale, this will make the biomimicry

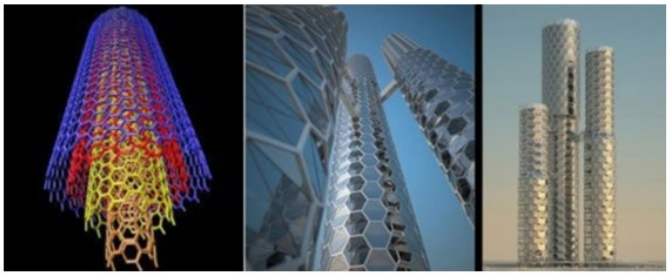

Fig. 5. Similarities between nano towers and carbon pipes.

level is the least unless using the other levels of materials, function, etc.

As can be seen in the picture, the structure of diamond molecules - which is a very stable structure – has been used in the exterior of the building. In this project, structure and architecture are intertwined and are not separate from each other. Therefore, it is the product of an ideal and responsive architecture and has provided the characteristics of a building according to Vitrovius.

C. Nano and futuristic architecture.

Johansen, a prominent American architect, was one of the pioneers of futuristic architecture. He has spent years to build and present designs in the field of futuristic architecture based on the characteristics of nanostructure and Magnetic Levitation. In his book entitled “Nano Architecture”, he has presented eleven works in this field and considers it as an antidote to today's Form-Driven Practice and the realization of futuristic dreams [8]. In Johansen's works, the emphasis is on function rather than form. His designs are in accordance with social, anthropological, and urban environment and megastructures are discouraged. He first turned his attention to “box,” the single style to accompany the modern movement. In addition to its being economical, the box, as a coherent stabilizer both in organizational and aesthetical contexts, could easily be constructed. The following pictures are some examples of Johansen designs.

Fig. 6. Floating Shaped conference center.

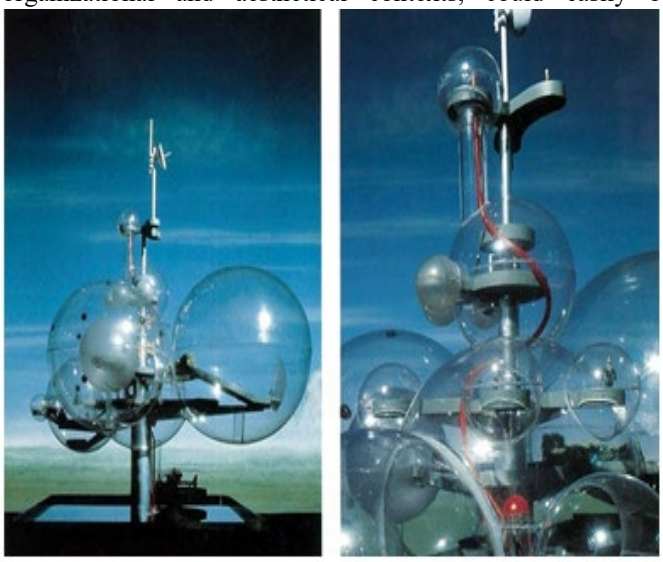

Fig. 7. Four bubbles shapes.

Of course, the use of nanostructure in the above presented designs is not only formal, but also nanostructure has been considered too, and in addition to providing building stability, will provide a different and attractive environment with a new spatial experience for the user (Figures 6 and 7).

D. Nanomaterials in architecture.

Since using the advances in nanotechnology, an object - a building - can exhibit different behaviours at different times and places, hard and inflexible or soft and fluid, so the theories of material recognition are altered totally. In fact, materials lose their fixed identity and architecture no longer has a limited definition in time and space.

On the other hand, the behaviour of structures and buildings becomes completely functional and context-oriented (Abbas, 2007). Self-Cleaning nano coatings (Lotus Effect) are another example of the application of nano in architecture. These coatings are one of the best tools for designing nanomaterial surfaces. The design idea of this type of cover is taken from lotus leaves. Lotus is an aquatic plant that grows in muddy water. By studying this plant, scientists have discovered the secret of its purity and based on this, they have experimented with making a kind of coating with nanotechnology.

Their experiments showed that the lotus leaf has a rough surface and very hydrophobic or superhydrophobic. The surface of these coatings is similar to lotus leaves with micrometre and nanometre protrusions, which makes the surface adhesion force between water and pollution more than the adhesion force between contamination and surface (Figure 8). As rain falls on lotus leaves, water droplets take the form of beads with a contact angle in the superhydrophobic range of

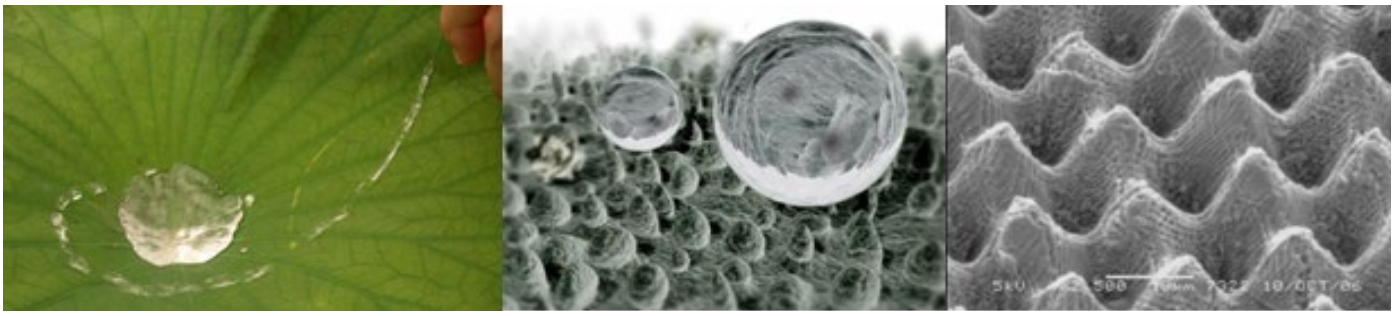

Fig. 8. Lotus' flower leaf structure.

approximately 160°. °.

It therefore appears that, depending on how water falls on the lotus leaves, they can have either a hydrophobic or hydrophilic surface, The lotus effect is thus defined as the ability of self-cleaning as a result of ultra-hydrophobicity, e.g., that of by the leaves of Nelumbo or "lotus flower". The micro- and nanoscopic architecture on the Surface causes water droplets to absorb dirt particles, which minimizes the droplet's adhesion to that surface.

In this way, the contact of water with the surface of the coating removes the contamination with it and removes it from the surface (Figure 9). These types of coatings are more suitable for surfaces that are exposed to enough rain and water, because otherwise the nano-coating will not have a good performance surface and traces of droplets will remain on it and it will look dirtier. The use of these coatings on surfaces that are not subject to mechanical wear is associated with a significant reduction in the need for cleaning, and the surfaces that are exposed to enough water no longer need to be cleaned but significantly reduce the need for care and maintenance (Leydecker, 2008).

Fig. 9. Similarities between nano towers and carbon pipes.

E. Ara-Pacis Museum.

The "Ara Pacis Museum" is an example of a lotus effect which has been designed and executed by Richard Meier & Partners. The Pacis Museum is currently the most prominent Archaeological Museum in Rome. This three-part building consisted of three sections as entrance gallery, the square in front of it, and the main building of the exhibition. The glass enclosure that forms part of the building surrounds the historic Pax Augusta statue to protect it from environmental damage. The rest of the building is made of large blocks of white travertine, common in Rome, with a white surface (Figure 10), (Rome, 2020).

To ensure the cleanliness and durability of the white paint, self-cleaning coatings are applied to the white surfaces. Due to the pollution of this city (Rome), it seems that the use of these coatings has been an efficient and appropriate way to keep the

Fig. 10. Exterior of the museum with self-cleaning technology.

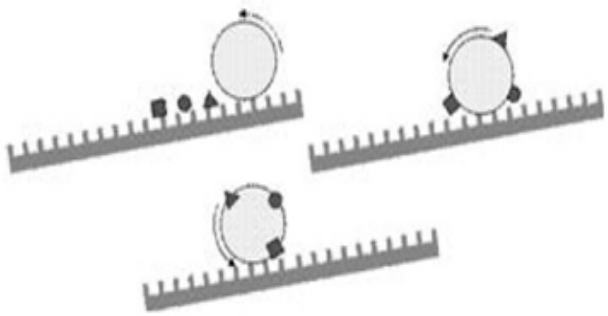

Fig. 11. Lotus effect in Ara Pacis Museum.

TABLE V
DIFFERENT SHAPES AND FORMS OF USING NANO PRODUCTS

Project Name	Place	Architect	Type of Nanomaterial and Result
Disable-access Housing for Elderly People[1]	Frick, Switzerland	Walker Architekten AG	Since "skyworkers" need to clean the outside façade, self-cleaning coating helps extend the cleaning intervals and reduce the building's running expenses [6]. The outer windowpanes use photocatalysis to protect against the sun and self-clean. The inner panes of the glazing are made of laminated safety glass.
Commercial Building	Pula, Croatia	Rusan Architectura, Andrija Rusan[1]	Nano facade coating with lotus effect, white colour of this building is far from pollution, daily and when it rains, all the surface pollution of the facade is easily washed away. This cover does not need to be renovated or repaired for a period of 5 years and will save on building maintenance costs [6].
Seitzstrasse Mixed – Use Building	Munich, Germany	Pool Architeckten, Martin Pool	In this building, Vertical insulation panels (VIP), many openings and glass surfaces have been used. To reduce energy loss, the ultra-thin insulation was used, which not only leads to less energy consumption, but also increases the useful space inside by 10% with the thickness of the walls.

building white for a long time (Ragesh et al., 2014).

F. Toxicity of Nanomaterials.

G. The dangers of producing and using nanomaterials to human health are not yet fully understood. It is predicted that fine nanoparticles that have lower solubility properties will have more destructive effects than larger particles. These particles can penetrate the human body in three ways and cause pollution: breathe in, swallowing, and penetrate to the skin (Tervonen T. et al., 2009). Nanomaterials embedded in building materials with nanomaterials used in other construction applications and facilities can cause cell poisoning through various mechanisms. Such products must first undergo nanotoxicology or toxicity assessment to discover their possible adverse effects and their effects on the human body.

VII. CONCLUSIONS.

Nanomaterials are a new type of high-performance, multi-purpose building materials. Multipurpose function means the emergence of new and different properties than the properties of conventional materials; in such a way that the materials can offer various applications and meet the demands and goals of the product applicant. In this article, various applications of nano-based materials were studied, and some plans based on the use of form-based structure and nano cells were rendered, in addition, the advantages and disadvantages of using this new technology were presented. The results of using nanotechnology in the field of architecture are:

- Reduction of construction waste and debris caused by the traditional construction system (due to a kind of industrialization of products)
- Reducing the weight of building materials and elements and increasing earthquake resistance,
- Improving the quality of materials to reduce the consumption of fossil fuels
- Improving the quality of materials in line with the structural and mechanical behaviours of the building and earthquake resistance
- Reduce maintenance costs due to the prevention of natural or mechanical damage and -Reduce the need for maintenance
- Preservation of natural resources

TABLE VI
TOXICITY OF NANOMATERIALS TO VARIOUS ORGANISM (NĚMEČEK, J. ET AL., 2009)

Nanomaterials	Organism	Toxic Effect
Carbon Nano tubes	Bacteria	– Having antibacterial properties against some bacteria – Damaging cell membrane
	mice	– Interruption of respiratory performance – Damaging mitochondrial DNA
Silica Nanoparticles	Bacteria	– Mild Poisoning in Reactive Oxygen (ROS 67)
	Rats	– Cell poisoning, premature cell death, disruption of the glandular regulatory process, premature death of alpha genes,
Quantum Dots	Bacteria	– Bar Bacteria
	Human Cells	– Release of toxic substances from metals, absorption of pollutant particles, oxidative damage to DNA
Quantum Dots	Mice	– Accumulation of metals in the kidneys
	Rats	– Cytotoxic damage because of oxidative damage to several cell organs,
Copper Nanoparticles or Copper Oxide Nanoparticles	Mice	– Severe poisoning of the liver, kidneys, and spleen
Titania Nanoparticles (Tio2)	Bacteria, seaweed, small crabs, and fishes	– Severe mortality, pregnancy tumour, inhibition of photosynthetic activity, injury

- Dynamic economy and returning on the investment
- Creating a responsive and ideal environment and preventing the design and construction of form-based buildings
- Nature Friendly
- Creating more stable structures based on nano form structure

Therefore, the use of nanotechnology is an inevitable process that will bring a huge change in the world of construction due to the listed benefits. In other words, nanotechnology can be introduced into the field of architecture in two ways:

- Utilizing nano-based materials such as nano coatings, nano-insulators and ...
- Utilization of form-based structure and structure of nano instruments

The first method affects the structure and physical body of the building, and the second method overshadows the architecture of the building, thus providing beauty, strength, and stability, the three characteristics that Vitruvius considers for a building.

REFERENCES

Fazeli, A.Z.-k., Nanotechnology Mirror of Creation. Tehran: Atena Press, 2005.

Olson, G.B., Designing a new material world. Science, 2000. 288(5468): p. 993-998.

G William Quatman, I. and R.R. Dhar, The Architect's Guide to Design-Build Services. 2003: John Wiley & Sons.

Lymt, S.A., lobal Technology Revolution: Global Trends in Biotechnology, Nanotechnology, Materials Technology & Information Technology Nanotechnology Policy Studies Committee Publications, 2001.

Rennie, J., Nanotech Reality. Science, 2000.

Leydecker, S., Nano materials: in architecture, interior architecture and design. 2008: Walter de Gruyter.

Daryoush, B. and A. Darvish, A case study and review of nanotechnology and nanomaterials in green architecture. Res J Environ Earth Sci, 2013. 5(2): p. 78-84.

Johansen, J.M., Nanoarchitecture: a new species of architecture. 2002: Princeton Architectural Press.

ABBAS, A.S., NANO HOUSES, FUTURE HOMES. 2007.

Rome, A.P.M., Retrieved from Ara Pacis Museum Rome, in http://www.arapacis.it/en. 2020.

Ragesh, P., et al., A review on 'self-cleaning and multifunctional materials'. Journal of Materials chemistry A, 2014. 2(36): p. 14773-14797.

Tervonen, T., et al., Risk-based classification system of nanomaterials. Journal of Nanoparticle Research, 2009. 11(4): p. 757-766.

Němeček, J., V. Šmilauer, and L. Kopecký, Characterization of alkali-activated fly-ash by nanoindentation, in Nanotechnology in Construction 3. 2009, Springer. p. 337-343.ArchDaily. (9 de Diciembre de 2020).