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THE CONCEPT OF APPLICATION OF NANOMATERIALS ON THE ENVELOPE FACADE OF BUILDINGS IN EGYPT

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ABSTRACT

Egypt has suffered several problems for applying the traditional building materials on building envelopes, which results in degradation of building quality and failure to stimulate environmental factors. Accordingly, this paper presents innovative nanomaterials and their effect on envelopes in order to improve the performance, efficiency of building envelopes, and reduce the total energy consumption of new or existing buildings. Furthermore, nanomaterials are considered one of the most promising high-performance materials in construction applications as they possess great features against environmental factors compared to traditional paints. This research also demonstrates high performance in the adaptation and the response of buildings to external factors. The paper also discusses the concept of nanomaterial application on building envelopes in Egypt in order to enhance the knowledge about adaptive envelopes area and innovative technologies. Nanomaterials are capable of saving energy, reducing costs, extending the life span of buildings and reducing maintenance if new technologies are considered to be a crucial factor in the innovative architecture. The innovation in materials will be affected by nanotechnology, which will have an impact on architecture and its concept.

KEYWORDS: Nanomaterials, Responsive, Nano coatings, Innovative envelopes, Energy consumption.

1. INTRODUCTION

At present, the technological developments have a direct impact on architecture, as nanotechnology is considered as one of the most interesting research areas to innovate unique features, which have the capability to be used on an atomic and molecular scales. This revolutionary technology has many possibilities to change the design process of building envelopes. In addition, the recent researches suggest that the nanomaterials

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used in the built environments have such many advantages that they can fix current problems in construction as well as provide the building requirements [1]. Therefore, this methodology explains the change of thinking through the use of nanomaterials in order to achieve innovative forms in building envelopes. It also clarifies how nanotechnology continues to offer a lot in all areas of life, especially in architecture, with global trends towards energy conservation, production of eco-friendly materials, and contribution to the low cost of operating in the long term. Unfortunately, some architects are unaware of the dimensions and importance of nanotechnology besides how these materials can be practically applied to the building envelopes. So, we will highlight this technique through introducing it with identifying its uses, as well as its classification and applicability in architecture. Consequently, this research discusses the uses of these materials in addition to their applications on the building envelopes [2].

Global market size rates for nanomaterials are constantly increasing due to the continuous innovation in architecture, gradual development of construction technology, continuous reduction in costs for producing nanomaterials and new application areas. Global and Chinese market standards for nanomaterials which appear in the past, present and future are shown in Figs. 1 and 2 [3].

The application of nanomaterials in construction, especially in the building envelopes, leads to the preservation of energy, environment and resources. Consequently, the market demand continues to grow.

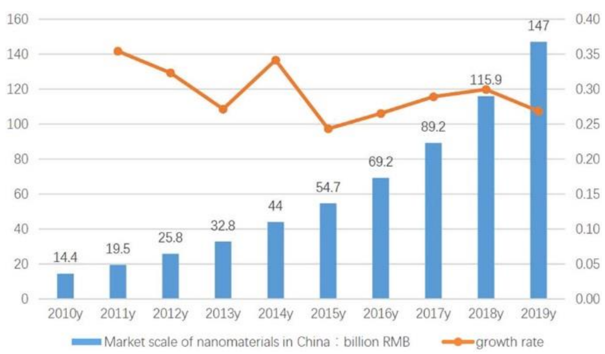


Fig. 1. Nanomaterials market rate: past-present 2010 to 2019 [3].

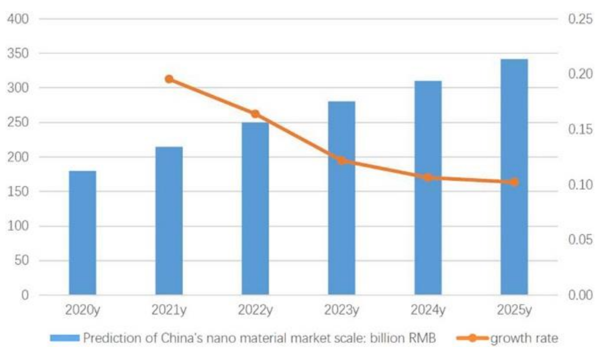


Fig. 2. Nanomaterials market rate: future 2020 to 2025 [3].

2. STATEMENT OF THE PROBLEM

The main problem discussed in this paper is that many buildings are still using traditional materials in the building envelopes whether in their conventional or refined forms. Consequently, buildings with the traditional materials increase the energy consumption, maximize initial and operational costs as well. Furthermore, this paper demonstrates the value of adding nanomaterials to building envelopes and its effect on the interactive performance of these envelopes. However, the question that researchers need to answer is twofold: firstly, what is the role of nanomaterials in exploring innovative envelopes? Secondly, what are the main obstacles to implementing nanotechnology projects in Egypt?

3. RESEARCH SCOPE AND PURPOSE

The research purpose is to improve the performance of buildings by applying nanomaterials to building envelopes and to assess the degree to which the use of nanomaterials influences them through the following points: reduction of energy consumption, reduction of maintenance, self-cleaning, aesthetic requirements, extended life span, and being eco-friendly materials. Thus, this paper aims to identify responsive nanomaterials, which affect the architectural development, aesthetic and functional appearance of the building. In addition, it shows how to improve both quality, efficiency of the buildings as well.

4. RESEARCH METHODOLOGY

4.1 Theoretical Approach

This is based on the inductive method of studying the concept of nanomaterials and their evolution, classification according to their innovative applications in the building envelopes, besides the role of nanomaterials and their applications in architecture.

4.2 Analytical Approach

This is based on analyzing the applications of nanomaterials on building envelopes in order to use lower-cost, more eco-friendly and adaptive materials as a performance-based methodology for controlling thermal comfort and moisture within the internal spaces of buildings according to the changing climate conditions.

4.3 Deductive Approach

This is based on applying nanomaterials to the building envelopes of two different models of buildings in Egypt, deducing the effectiveness of these materials and their impact on the building envelopes, then evaluating each one of them through the points specified above.

5. THEORETICAL APPROACH

The theoretical approach provides a brief overview of nanomaterial role in scientific and technological development through the concept of nanotechnology, the discovery of these nanoparticles that are measured by nanometer unit and concentration on applying the nanomaterials to building envelopes.

5.1 Nanotechnology Revolution

Scientists confirm that nanotechnology will revolutionize science because its applications and inventions are used in various fields of life, the materials used in processing the building envelopes can be classified into six main categories as follows: nanomaterials for heat insulation, regulate temperature, heat absorbent windows, intelligent Nano-techniques to control light and heat, air purification coatings, and self-cleaning coatings. Hence, this paper will explore the innovative qualities and characteristics of these materials, the potential advantages of using them in the building envelopes.

5.2 Nanotechnology Definitions

Nanotechnology is a technique that gives us the ability to directly control materials, which grants the material new properties and behaviors. In addition, this point refers to the concepts of nano, nanotechnology in architecture, and the effect of nanomaterials on the building envelopes [4, 5].

5.2.1 Nano and nanotechnology

Nano means extremely small or minute object, the word nano first appeared at the beginning of Greek age as it is derived from the Greek word "Nanos" meaning in English "dwarf ", the specifications of nano scale is shown in Fig. 3, where in science, it means a part of a billion of meters (that is a part of thousands of a million) and in numbers (10^{-9} m) or equal to one-millionth of a millimeter [6].

Nanotechnology has the ability to rearrange atoms and molecules for innovative materials, which play a major role in architecture, particularly its applications to envelopes along with its interaction in face of external influences. Thus, we can employ these materials on structural or non-structural materials to improve the quality of construction and raise its efficiency [4, 7, 8]. The plans for the future of envelopes technology are shown in Fig. 4.

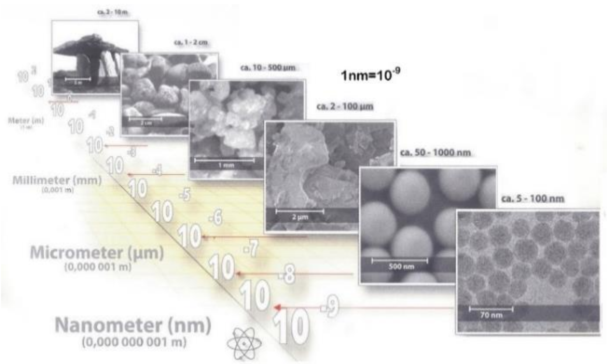


Fig. 3. Nano scale from the meter to the nanometer [4].

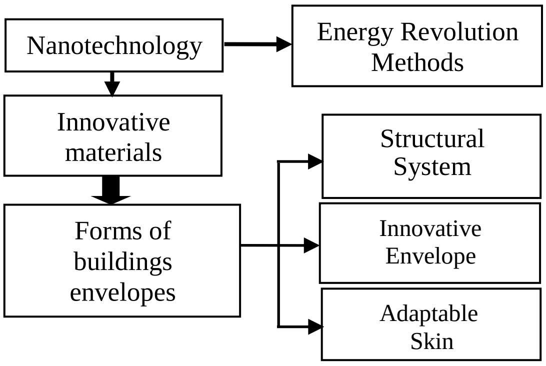


Fig. 4. Plans for the future of envelopes technology [7].

Nano architecture is between nanotechnology and architecture, which contributes to a new generation of architectural designs that will affect the building envelopes in the built environment [7, 9]. The outline of nanotechnologies in architecture is shown in Fig. 5.

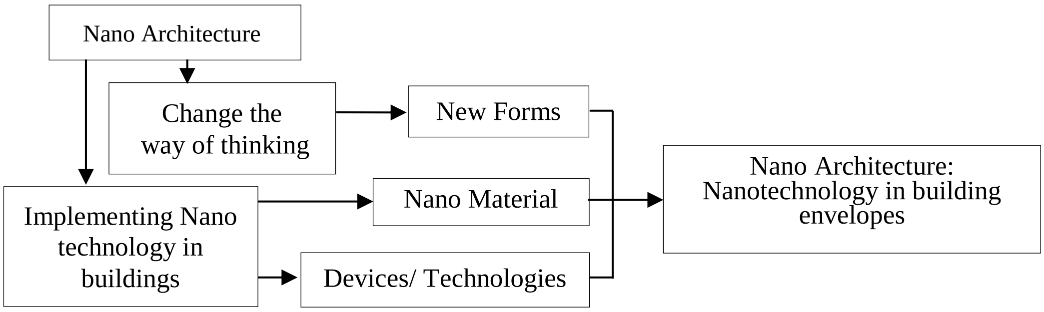


Fig. 5. Nanotechnologies in architecture [7].

5.4 Nanomaterials in Architecture

As stated earlier, nanotechnology deals with the properties of the materials. Architects started to search for the use of this technology in their designs so that the traditional materials could have different features, which result in a beneficial impact on external building envelopes [9-11]. The methodology of nanotechnology illustrates the shift in the way of thinking through the use of nanomaterials. The technological progression of nanomaterials is illustrated in Fig. 6 [12]. Basically, this can be implemented through the exploration of nanomaterials for developing new and creative forms in interactive envelopes of building. With global trends towards energy conservation and the production of environmentally friendly materials, nanomaterials still provide a great deal in all areas of life. An example of the global trends, US nanotechnology federal funding from 2001 to 2018, is identified in Fig. 7, which deduced that the usage rate of nanomaterials reached 15.4% in 2018, and the rate of application of materials in building envelopes increases [13, 14].

It is to be noted that in addition to building materials performance, distinct characteristics and their superior ability to interact with changing factors, the amount of savings in using this technology has reached (25%).

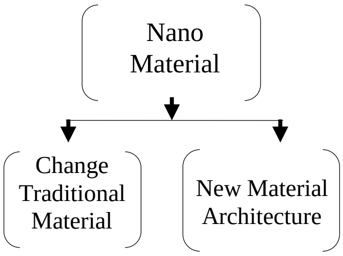


Fig. 6. The technological progression of nanomaterials [12].

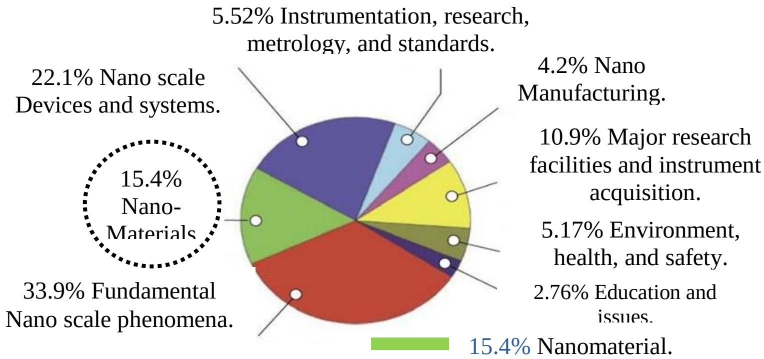


Fig. 7. Trends in US nanotechnology federal funding, 2001–2018 [13].

6. ANALYTICAL APPROACH

6.1 Nanomaterial Applications and Functions

Nanomaterials have created an innovative world of functionality for materials and innovative construction capabilities. Therefore, the use of nanomaterials in building envelopes assess in resolving several energy related problems. Nano engineering uses both materials and techniques for the purpose of producing multifunctional composite materials of superior properties and durability. The Innovation of sustainable nanomaterials is shown in Table 1 [15].

Table 1. Nanotechnology axes enable innovation of sustainable nanomaterials [15].

Classification of Nanotechnology Applications	Nanomaterial		Structural materials	Non-structural materials
			Nanotech cement /Concrete	Nano Glass
			Nano Steel	Plastic and polymers
			Nano-Wood	Nano Aluminum
			New structure materials	Drywall
	The Architectural Applications of Nanotechnology	Coating Material	"Self-cleaning (Louts Effect-Photo Catalytic), Easy to Cleaning (ETC), Anti finger print, Anti-Scratching, Anti-Reflection, UV protection, Anti-Graffiti, and Anti-Bacteria"	
		Reducing Energy consumption	Application of Nano Material Insulation "Thermal Insulation Panels, Vacuum Insulation Panels (VIPs), Aerogel (Nano Gel), Thin-Film Insulation, and PCMS (Phase change materials).	
			"Energy Production"	

Nanomaterials are used in building envelopes to enhance the efficiency of traditional building materials such as concrete, steel, and glass. Furthermore, increased strength and reliability are also a part of the drive to reduce the environmental footprint of the built environment which minimize energy consumption [15].

6.2 Structural Materials

6.2.1 Nanotech cement/concrete

Concrete is the most widespread and even used building material in the construction sector, as it is used to establish the structural framework of the building, where many studies have been carried out on concrete to develop its properties [16]. Conventional concrete combined with the ratio of silica (SiO_2) that make up the concrete [17, 20]. In concrete, nanotechnology was used to enhance its properties by adding materials (e.g. nano-silica, carbon nano tubes, and nano titanium dioxide) that gave it new properties, which have the ability to feature durability, high efficiency, and increase strength [17].

6.2.2 Nano-wood

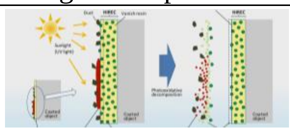
In general, wood is one of the most often-used structural materials, whereas wood to some extent is considered as simple materials, so nanotechnology has been used in the wood material in order to make it more coherent and stronger than the natural material, where wood particles are gathered and rearranged with nano materials. In addition, nano sensors are also created by nano materials in order to identify fungi and corrosive points which help in self-treatment process [18]. However, the high cost accompanied with nano-wood materials restrain their propagation in Egypt.

6.3 Non-Structure Material

6.3.1 Application of nano coatings on glass

The non-structure material is based on analyzing the applications of nano coatings on glass for self-cleaning (Louts Effect - Photo Catalytic - Easy to cleaning (ETC), and disinfection properties of Nano-treated glass are addressed in Table 2 [19].

Table 2. Applications of nano coatings on glass [19].

Non-structural materials	Properties		
	Self-Cleaning (Lotus –Effect)	Self-Cleaning Photo catalytic) (	Easy to Cleaning (ETC)
Utilization	The Self-Cleaning (Lotus -Effect) is used in buildings to minimize maintenance and save costs. There by allowing the building envelopes to be self-cleaned.	The photo catalysis is used in building air technology systems. As well as, Fujishimai used oxidation properties of (TiO_2) in light.	Lotus leaf has fine hairs that reduce stress on the surface and prevent water absorption.
Application	Building Envelopes		
Application forms			
Technique used	TiO_2, Granule coating applied at fabrication.	TiO_2, Glass coating with titanium dioxide.	
Critical Comments	- Excellent water-flushing capability. As well as Buildings would be able to maintain themselves automatically and directly. - The lotus effect has resulted in a highly water-repellent surface.	- This eliminates dust and contaminants from the glass surface to enhance illumination and light indoors, thus reducing the energy use used in lighting. - Its reduces maintenance costs.	- Easy-to-clean property does not allow ultraviolet light to enable its role in such surfaces that use water to clean.

6.3.2 Nano aluminum

Aluminum is considered to be one of the lightest weight building materials relative to thickness; aluminum density (2,7 kg/cm^3) is equal to one third of iron and copper density [20]. It has other important properties, including (high rust resistance, fire resistance, and corrosion resistance) which is deemed to be Eco-friendly. A strip for composite panel of aluminum which displays the component layers is shown in Fig. 8 [21].

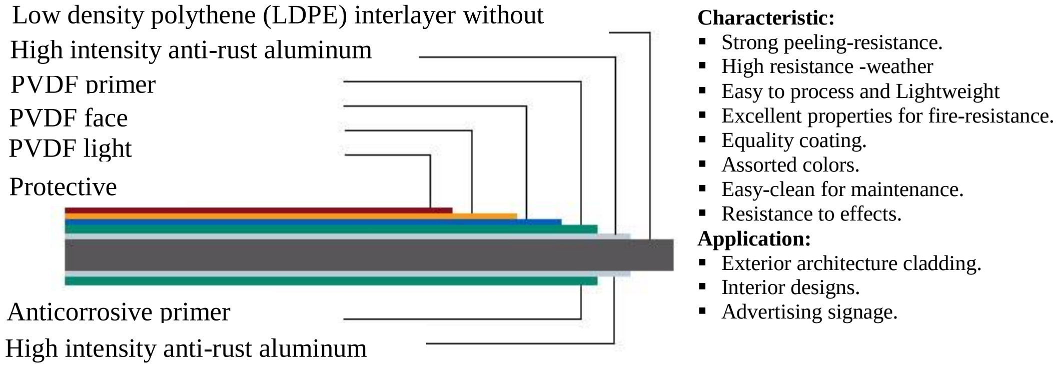


Fig. 8. Strip of aluminum composite panel and its component layers [21].

6.4 Application Nano Materials in Building Envelopes

6.4.1 Ecological nanomaterial

"Off the Grid" initiative design offers practical solutions to the energy crisis, lack of clean water, as well as global warming and environmental pollution. The description of Philips sustainable habitat project that established in China is illustrated in Table 3.

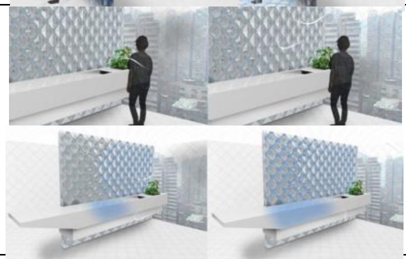
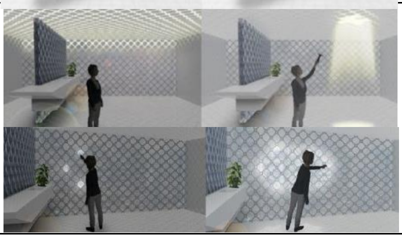
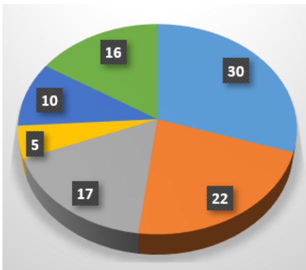
Table 3. Off the grid: Philips sustainable habitat 2020-China [22, 23].

Project	Off the grid: Philips sustainable habitat 2020-China
Architect	Philips's Design Probes
Location	China.
Date	Proposal 2020
Style/ Type	Proposal skyscraper/ Adaptive and Intelligent Nano Architecture
Nanomaterial's used	Nano Sensors – Nano envelope (alive skin)
Emissions of CO_2	Zero carbon emissions
Achievement sustainability (LEED points)	Location (the effect on ecosystem) - Water (rain water collection-collection Humidity) Environment (CO_2 absorb) - Energy (wind - solar - biogas) - Materials (Nano envelope) Recycling waste (the water grey - Bio- and human waste - No energy consumption sensors) internal (fresh air - daylight)

Eco-systems can also help in formulating strategies for a sustainable urban future, in which an example of a sustainable eco-system with the envelope interact strategy are shown in Fig. 9. Table 4 discusses the inclusion of inert materials of electronics and biochemical functionalities (Nano sensors) in the built environment.

Fig. 9. Membranes used in the envelope of the building to carry water, air and light [22].

Table 4. Interactive nano sensors sustainable skin features [23].

<table>
<tr><th>Features</th><th colspan="2">Key Potential Factors</th></tr>
<tr><td>Water</td><td>▪ The active envelope response to rain, and collecting rain water.
▪ Attracting humidity from the rain, and the exterior absorbs water even dry times.
▪ Water is employed in a closed loop and freshwater is optimized.</td><td></td></tr>
<tr><td>Air</td><td>▪ The active building envelope response to the wind.
▪ Direct wind and air across the envelope, to produce energy and purify the indoor air to provide clean air.
▪ Air cooled, compressed and dissipated into natural air conditioning cones.</td><td></td></tr>
<tr><td>Light</td><td>▪ The active envelope response to sun rays, and then automatically moves to the building to direct light and produce energy.
▪ The natural light collection and channeling, as electricity will be not required for lighting throughout the day.</td><td></td></tr>
<tr><td>Performance Results</td><td>The innovative envelope functions as a membrane for carries in air, light and water from outside. As the membrane is moving around to be in the better possible to produce as much energy.</td><td>

Energy Efficiency.
Efficiency of the Internal Environment.
Material and Recourse.
Water Efficiency.
Site Sustainability.
Smart Technology.</td></tr>
</table>

6.4.2 Biological nanomaterial

The Nano Vent-Skin (NVS) project summarized in Table 5 includes different types of micro-organisms that work together to consume and convert natural energy from the environment. The skin consumes two of the most abundant natural energy sources on earth: sunlight and wind. The advantages of the absorption of CO_2 from air are shown in Fig.10 and Table 6.

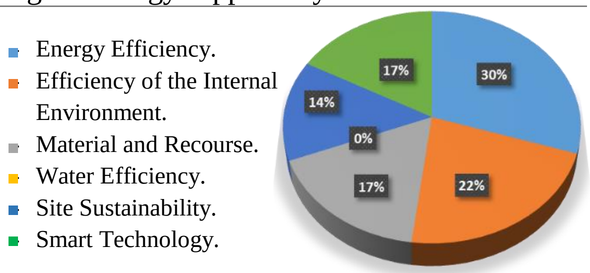
It is to be noted that nanomaterials assist in achieving environmentally friendly buildings by applying nanomaterials to conventional (structural or non-structural) materials according to the following points (self-cleaning external surfaces and thus reduce the cost of maintenance after operation, as well as in the treatment of cracks and consequently prolong life span, and achieved energy savings in buildings). It has also achieved interaction with nature to obtain responsive and interactive buildings.

Table. 5. Nano vent-skin of micro-wind turbines [23].

EX	Nano vent-skin of micro-wind turbines
Architect	Designer Agustin Otegui
Site	Mexico
Date	Proposal 2010
Type	Nano-Nano Architecture / Bioengineering
Nano materials applied	Photovoltaic envelope, Nano fiber, and solar Nano technology
Emissions CO_2	Strategy is to achieve null emissions
Performance (LEED metrics)	Energy saving (wind - solar - storage units) - Atmosphere (CO_2 absorption) - material (Nano bio-organisms - CO_2 emissions) - internal (Natural illumination)

Fig. 10. Nano vent-skin (NVS) [23].

Table. 6. Features of nano vent-skin (NVS) [23].

Scale Model	To check the wind turbines and do changes that could improve the design, a scale model was created. Every wind turbine is 10.8 mm wide and is 25 mm tall.
Supply Units and Storage	Each panel is equipped with Four round distribution units (one at each corner). These groups are responsible for: supplying fuel for regeneration to damaged or disabled turbines, and then collecting and storing the energy supplied by turbines.
Studying Wind Contact	The ideal result on energy. If the wind direction changes, each turbine adjusts, depending on the situation, by rotating in the clockwise or anti-clockwise direction. 

7. DEDUCTIVE APPROACH

7.1 Nanomaterial Evaluation Points

What has been drawn from the theoretical and analytical part is that nanomaterials play an active role on building envelopes. Therefore, several evaluation points are analyzed in Table 7 in order to determine the extent to which the proportions of these points are achieved in the building envelopes. Moreover, how they are applied to nanomaterials, through the following: economic standards, energy saving, maintenance, self-cleaning, functional standards, aesthetic standards, life span, fire resistance, and being eco-friendly. Adding to the full utilization of nanomaterials in architecture, applying nanomaterials to building envelopes can help in achieving the aesthetic and visual aspects, as they are one of the most important elements affecting both quality and efficiency of buildings.

Table 7. Evaluation points for nanomaterials.

	Economic Norms						Parameters Studied			Performance Consideration					
Evaluation Points	Energy saving	maintenance	Photo catalytic Self-Cleaning	Aesthetic Norms	Functional Norms	Life span	windows design/ ratio	Nano vent skin	Nano material	wind turbines	Thermal performance	Day light	Simulation analysis	Performance metric	Percentage %
Evaluation metrics															
Metrics	Very Good			Good			Weak			Not Available					100%
Code	10%		●	7.5%		◒	5%		◉	zero		○			
Rating	10	10	7.5	5	5	7.5	5	5	10	5	5	10	5	10	
Number of criteria: 14 criteria															

7.2 Analytical Case Study

The analytical study aims to shed light on the role of nanotechnology, so two buildings under study have been selected in Cairo. One is under construction and the other is a virtual building, where the purpose is to apply nanomaterials to each one of them, besides studying the impact of these nanomaterials on building envelopes. As well as that, the two buildings will be assessed through the proposed evaluation points, along with to which extent they respond to nanomaterials and their interaction with the environment. Also, to which extent they affect the reduction of maintenance and the prolongation of the life of building, and the role of nanomaterials in saving costs during operation.

7.2.1 Case Study 1: Eastown District, New Cairo (EDNC) commercial project, Egypt, Cairo, Mearaj city.

As long as over 50% of the construction work has been established, the current Eastown District New Cairo commercial project in Egypt is on target to be released starting from next year. This is according to Magued Sherif, the managing director of the projects developing company acknowledged as SODIC development, one of Egypt largest real estate developers, contributing to the ever-growing need for high quality residential, commercial and retail properties in the North African countries. The case study specifications will be clarified in Table 8.

Table 8. Case study specifications.

Project Title	Eastown District New Cairo (EDNC) commercial project.
Project main consultant	Sodic .design and engineering.
location	Egypt, Mearaj City, Cairo Ring Road, Bldg. No: 2075 To 2078
Drawing title	Building 02 - All floor plan.
Area	199144 m^2
Status	Under construction
Type	Office Building, B2
Year	Started in 2019, with completion Slated for 2021.

EDNC [24].

EDNC perspective [24].

The EDNC commercial project is the commercial portion of Eastown, SODIC mixed-use development on the same road directly adjacent to the American University in Cairo (AUC), situated on route 90. It brings 90,000 m^2 of prime commercial and trade space. Its trade space contains a total of nearly 22,250 m^2 of built-up space including a combination of highly creative ground floor and single-story buildings. Some of Cairo optimum restaurants, entertainment concepts and fashion brands will be located in this location, along a vibrant walkway with access to a beautiful 13,631 m^2 park with an amphitheater.

The improvements also involve approximately 63,000 m^2 of built-up area, which comprises office complex constructed with 4-storey cantilevered buildings. As shown in Fig. 11 a sustainably developed with facades of high-performance curtain wall double-glazing with high-quality precast concrete insulated panels to promote a healthy productive environment with a reduced environmental impact. On a glass base intersected by geometric cut-outs. Table 9 identifies the material used and the proposed Nanomaterial in project EDNC.

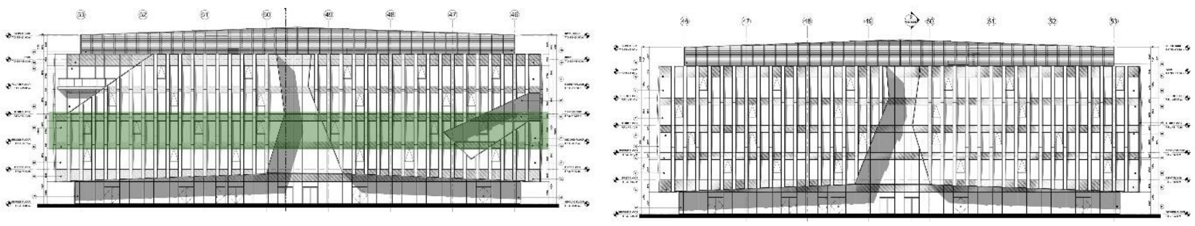


Fig. 11. Buildings facades featuring high-performance curtain wall.

Table 9. Materials used and the proposed nanomaterials applied in EDNC.

No.	Material used	Proposed Nanomaterial Applied
01	Vision Panel: 24mm THK (6-12-6) double TEMPERED GLASS Curtain wall, clear inside, reflective outside, on thermal break silver anodized satin finish aluminum sections, (Dark Blue).	Nano panel: Nano Glass coating Self-Cleaning-Lotus –Effect and Fire-Proof, clear inside, reflective outside, on aluminum composite panel and its layers.
02	Spandrel Panel: 6mm THK tempered glass (external pane) insulated spandrel panel, with color coating, on thermal break silver anodized satin finish aluminum sections, (Dark Blue).	Nano panel: Nano Glass coating Self-Cleaning-Lotus –Effect, insulated, on thermal break silver anodized satin finish aluminum sections.
03	Vision Panel: 24mm THK (6-12-6) double tempered glass curtain wall, clear both sides, on thermal break silver anodized satin finish aluminum sections, (Light Blue).	Nano Panel: 24mm THK (6-12-6) double tempered Nano glass curtain wall, Anti-Reflective Coating, on thermal break silver anodized satin finish aluminum sections.
04	Spandrel Panel: 6mm THK tempered glass (external panel) insulated spandrel panel, with color coating, on thermal break silver anodized satin finish aluminum sections, (Light Blue).	Nano Panel Nano Glass Coating Self-Cleaning-Lotus –Effect, insulated, on thermal break silver anodized satin finish aluminum sections.
05	Precast Concrete Louvers, (Light Grey).	Precast nano concrete louvers, Added to it self-healing concrete and titanium dioxide (TiO_2).
06	Powered Coated Aluminum Louvers, (Dark Color).	Powder Coated Aluminum Louvers, with Poly Vinylidene Di-fluoride (PVDF).
07	Aluminum Composite Panel, (Dark Color).	Aluminum Composite Panel, Added to it Poly Vinylidene Di-fluoride material (PVDF).

The proposed nanomaterials affected the building envelope, resulting in energy savings, which could improve the buildings efficiency and quality. In addition to obtaining the aesthetic and functional elements. This is shown in Table 10.

Table 10. Performing nanomaterials on the EDNC project.

Evaluation metrics	Case study		Economic Norms						Parameters studies			Performance consideration					
Building function	Real	Hypothetical	Energy saving	maintenance	Self-Cleaning-Lotus -Effect	Aesthetic Norms	Functional Norms	Life span	windows design/ ratio	Nano vent skin	Nano material	wind turbines	Thermal performance	Day light	Simulation analysis	Performance metric	Percentage %
Style	✓		●	●	◒	◉	◉	◒	●	○	●	○	◉	◒	◉	●	92.5%

- Performance results, after applying nanomaterial, it was found that it can help simulate changing climate factors, completely treat thermal conditions and humidity, save energy, and reduce operating costs. The EDNC project reflects the achievement of measurement points in relation to the building performance, besides the buildings energy saving has enhanced the project metrics to a rate of up to 92.5 %, illustrating the need to use nanomaterials in Egypt for their positive effect on the building and the great interaction with nature. This is shown in Table 11.

Table 11. The main factors affecting cost recovery of nano coatings and the conventional coating in project.

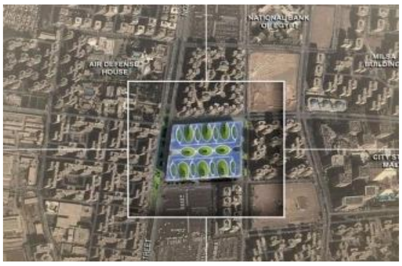
Main Factors	Conventional Coating	Nano coating
Value of money	Constant Factor.	
Labor	Fixed Factor	
Finishing Time		
Initial Cost	50%	80%
Running Cost	Higher 30%	Less 30%-40%
Maintenance	Each 7- 10 year.	Each 15- 25 year.
Building quality	Erosion of the building over time.	Preserving building paints extend the life span.
Energy Conservation	20-30%.	Up to 80%.

7.2.2 Case Study 2: Vincent callebaut designs sustainable mixed-use complex for Cairo, Egypt

The French company Vincent Callebaut Architectures (VCA) has unveiled a new multi-use complex for Nasr City in Cairo. The building was built to receive standing LEED Gold Plus featuring a solar roof, green terraces, sky villas, vertical system of gardens, and solar heating pipes. The case study specifications are listed in Table 12.

Table 12. Case study specifications.

Project	THE GATE RESIDENCE
Location	Heliopolis District, Cairo, Egypt
Architects	Vincent Callebaut Architectures
Local Architect	K&A Design, Injaz Development.
Program	1000 Apartments, Offices and Shopping Mall.
Surface Area	450000 m².
Budget	EGP 4,5 bn.
Current Phase	Schematic Design / Building Permit.
Client	Abraj Misr, Cairo, Egypt: Urban Development.
VCA's Team	Agnes Martin, Jiaoyang Huang, Fabrice Zaini, Maguy Delrieu, Vincent Callebaut.
Green Certification	LEED Gold Plus.
Year	Started in March 2015, with completion slated for 2019.



General location [25].

Gate residence [25].

The residential levels are wrapped by layers of E-low Nano glass and polished white stone, accompanied in the courtyard by suspended balconies with two different facades on the commercial floors. A Voronoi panel is inspired by the architecture of coral reefs. It points to the patio areas and the inner street between the offices and housing. This panel offers additional protection for the climbing plants to grow along its foundation. The materials used in building envelopes can be seen in Fig. 12.

Fig. 12. Materials used in building envelopes [25].

The architects designed the mega trees structural to serve as passive cooling systems inspired by the wind catching tower technology, or Nano vent skin, or “Malqaf,” originally developed in medieval Cairo. Simultaneously, photovoltaic cells can cover the solar roof to generate most of the energy required for the building. This is shown in Table 13.

Table 13. Performance nanomaterial after applying it on project.

Evaluation metrics / Building function	Case study		Economic Norms			Aesthetic Norms	Functional Norms	Life span	Parameters studies			Performance consideration			Simulation analysis	Performance metric	Percentage %
	Real	Hypothetical	Energy saving	maintenance	Self-Cleaning-Lotus -Effect				windows design/ ratio	Nano vent skin	Nano material	wind turbines	Thermal performance	Day light			
Style	✓		●	◉	◉	◒	◉	◒	○	◒	●	●	◒	◉	◉	◉	90%

This project applied nanomaterials, which helps to simulate changing climate factors, fully treat temperature and humidity conditions, save energy and interact with reduced operating costs. This has resulted in energy saving in buildings, the needs and specifications of the project by up to 90%, which illustrates the necessity for the use of nanomaterials in Egypt.

8. IMPACT OF NANOMATERIALS ON BUILDING ENVELOPES

The impact of nanotechnology on the two buildings under study is analyzed and evaluated in Table 14. It provides many technologies in every building, including economically saving for the following: energy, maintenance, self-cleaning, and life span.

Table 14. Evaluation of the case studies applied to nanomaterials.

Evaluation metrics / Building function	Case study		Economic Norms			Aesthetic Norms	Functional Norms	Life span	Parameters studies			Performance consideration			Simulation analysis	Performance metric	Percentage %
	Real	Hypothetical	Energy saving	maintenance	Self-Cleaning-Lotus -Effect				windows design/ ratio	Nano vent skin	Nano material	wind turbines	Thermal performance	Day light			
Case 1	✓		●	●	◒	◉	◉	◒	●	○	●	○	◉	◒	◉	●	92.5%
Case 2	✓		●	◉	◉	◒	◉	◒	○	◒	●	●	◒	◉	◉	◉	90%

Nanotechnology has a great influence in the two case studies. According to the evaluation points and the natural effect of nanotechnology materials that have been applied to the building envelopes, it can be concluded that (EDNC) project provide the best features compared to the other project. It is seen that by adding nanomaterials to the envelopes of existing buildings in Egypt, it has raised the efficiency of buildings, improve their quality and adaptation to changing climatic factors. In addition to its ability to save energy and fulfill the requirements of the building itself, thus achieving buildings that mimic the environment and provides a unique appearance to improve the architecture.

9. CONCLUSIONS

Based on the above observations, we have found out that nanotechnology works to improve building envelopes. Since materials with special properties tend to change the general concept of using building materials, some of the benefits of nanotechnology are as follows:

A. Improving the properties of construction materials.
B. Nano technique allows the facade to be self-cleaned, thus reduces maintenance costs and uses more environmentally friendly materials.
C. In nanotechnology, measurement points have been defined to assess the degree of Efficiency of buildings. Furthermore, in terms of economics, in particular, the initial cost of using materials in buildings would be comparatively large because of their unavailability, thereby increasing the economic cost by 80%. In the meantime, running costs are lowered by 30% due to a decrease in repairs, energy savings and building life.

Finally, Table 14 compares two projects, one is built by applying nanomaterials while the other is built by using different materials. It is worth noticing that the EDNC Building has saved energy by applying nano glass and saving energy. Therefore, the building has saved 66% of energy, using self-cleaning nano glass curtain walls to block out sunlight. Thus, the necessary degree of thermal comfort is achieved and this results in energy savings through in the southern facade.

DECLARATION OF CONFLICT OF INTERESTS

The authors have declared no conflict of interests.

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مفهوم تطبيق المواد النانوية على الأغلفة الخارجية للمباني في مصر

واجهت مصر من عدة مشاكل في تطبيق مواد البناء التقليدية على أغلفة المبانى، مما أدى إلى تدهور جودة البناء وعدم القدرة على محاكاة العوامل البيئية، وبالتالي تقدم هذه الورقة مواد النانو المبتكرة وتأثيرها على الأغلفة لرفع كفاءة المبانى، وتقليل إستهلاك الطاقة للمبانى الجديدة أو القائمة. علاوة على ذلك، تعتبر مواد النانو من أكثر المواد القائمة على الأداء، فإنها تمثل خصائص فريدة تتفاعل مع العوامل البيئية مقارنة بالمواد التقليدية، كما أنها تظهر أداءً عاليًا فى تكييف وإستجابة المبنى للتأثيرات الخارجية. بالإضافه إلى ذلك، يناقش البحث أيضاً مفهوم تطبيق مواد النانو على أغلفة المباني في مصر، بهدف تحسين المعرفة في مجال الأغلفة التكيفية والتقنيات المبتكرة، القادرة على توفير الطاقة، والراحة الحرارية، وانخفاض تكلفة التشغيل، وإطالة العمر الافتراضي، وتقليل الصيانة. وإذا أخذنا في الاعتبار التقنيات الجديدة كعامل حاسم لهندسة معمارية مبتكرة، فإن ابتكارات مواد النانو ستؤثر على مفهوم العمارة.