



# The Impact of the use of Smart Materials on the Facades of Contemporary Buildings

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## Abstract

The impact of the development of smart materials after the third millennium on the design process in order to produce more responsive architectural buildings adapted to the internal and external environment and the performance and comfort of its users, adding the tremendous potential for the level of architectural facades in contemporary buildings. The problem of research in the lack of clarity of the impact of the use of smart materials in the facades of contemporary buildings, so the importance of it in studying the impact of these materials on the production of contemporary architectural facades. The research aims at preparing a theoretical framework that deals with the definition, types, and importance of smart materials in architecture through studies related to this aspect of the smart materials used. Of the smart materials in the facades of contemporary buildings, it dealt with the analysis of a series of facades of contemporary buildings where smart materials are used, The research found a range of formal, climatic and technological influences.

**Keywords:** Smart Materials - Architecture- Contemporary Buildings- Smart Facades.

## 1. Introduction

Contemporary architecture has used the latest developments and techniques that have reached the modern building materials and their techniques, including the smart materials, which gave enormous architectural possibilities for the buildings. The various studies dealt with the definition of these materials and how they are used and their potentials, but if they give a full picture of the effects of their use in the facades of contemporary buildings, Therefore, The problem of research in the lack of clarity of the impact of the use of smart materials in the facades of contemporary buildings ,and the aim of this research is to discover the effect of using smart materials on the facades of contemporary buildings ,The research assumes that the use of smart materials in building facades creates a range of different influences on these buildings ,The research chose to be the scope of research is the façades of contemporary buildings of the Arabian Gulf region because of the similarity of climate and social in this region, and followed the research descriptive and analytical approach to those projects and their interfaces and then the statistical analysis of the variables to reach the most important and most frequently repeated effects which is dealt with research in the practical study.

## 2. Previous Literature

### 2.1 Study Aggour, M & Soliman, O, (2010)

The study considered that the development of smart materials helped to improve its function and increased the response to the sense of environment surrounding the building and added a new function. [1]

### 2.2 Study Rubnicu, Alin(2012)

The study examined the function of the smart materials and their importance in the environment by discussing their relationship with the environmental elements, which include natural ventilation, solar radiation, rain and acoustic insulation[2]

### 2.3 Study Saidam and Others (2017)

The study addressed the definition of smart materials and their importance when used on the cover of buildings, including physical and structural as well as adaptation to the external environment and gave the study classification of smart materials and the most important applications in architecture, which helped to enhance the performance of the building [3].Most of the previous studies have limited the discussion of some of the effects, most of them climatically, but they have not discussed the formal and technological effects that smart materials can effect on building facades.Smart materials:

## 3. Smart Materials

Are materials have change properties and are to reversibly change their shape or color in response to physical and –or chemical influences. [4]. They are materials and configurations that have the ability to respond to and adapt to external and internal environmental stimuli by integrating functions into their structures. These catalysts may be chemical, electrical or magnetic. [5] Schodek has characterized the characteristics of smart materials as; (Immediacy, Transiency, Self-actuation, Selectivity and Directness.)[6]

### 3.1 Types of Smart Materials

#### 3.1.1 Property-changing

- **Electrostrictive Materials:** Electrostrictive materials, like piezo electrics produce electrical charge when mechanically stressed and generate strain when subjected to an electric field.
- **Magnetostrictive Materials:** change shape when subjected to a magnetic field.[11]
- **Electrochromic Materials :** change color upon application of an electrical voltage [14]
- **Thermochromic Materials:**[6]

#### 3.1.2 Phase Change Materials

These are substances whose condition changes as a result of change in temperature or pressure and is similar to the behavior of thick walls, which reduces heat fluctuations and energy availability. [13]



**Fig. 1:** a) Façade with holographic glazing Augenfeuer in Bonn. b) Sensitiles system light reflective polymer panels[14]

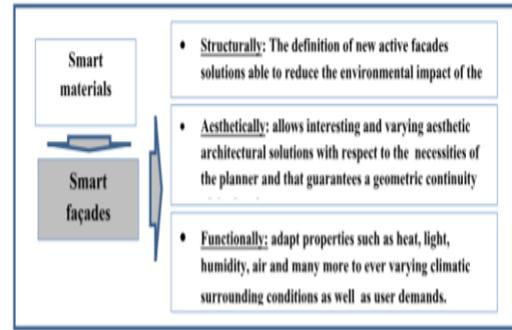
#### 3.1.3 Energy Exchanging

These are convert energy from one form to another directly like (Photovoltaic, Thermoelectric, Piezoelectric, Photoluminescent, Electrostrictive and Magnetostrictive)[6]

## 4. Smart Facades in Architecture

Many modern studies, envelope construction and building façades have been examined, where different terms are used to designate the exterior elements of the building [20] it's the most strategic part in a requalification plan because it is the most visible part of the building[15]The façade is always bi-directional because transfers energy in both directions simultaneously. Heat may be conducting to the outside while radiating to the interior, and light entering the building must be balanced with the view to the exterior.[7] The introduction of architectural technology helped to provide their intellectual and creative needs in the design of building facades with the beginning of the twenty-first century, in which architecture faced technological challenges [8], There are many functions of smart façade system for a building such as enhancement of natural light, protection from glare, sound and noise insulation, provision of inside and outside view, enhancement of ventilation, heat or cold collection, protection from pollution, safety protection, protection from rain solar gain, and solar protection.[10] The application of smart materials in architecture may bring real benefits. As scientists claim, the use of smart materials optimizes energy and matter flows [12] contributes to extending lifespan of building materials, and makes possible the creation of high-strength ultra-light structures[10]Its

one of the most spectacular and aesthetic smart solutions in architecture.



**Fig. 2:** The impact of smart materials on smart facades (researchers)

## 5. Types of Smart Facades

### 5.1. Double Skin Facades

This Façade created the ability for developing the conventional curtain walls so it will works against energy loss and sun reflection through using double glazing walls and this construction consists of: outer glazed façade to provide weather protection and sound insulation, intermediate space (air cavity) (fig 3) which is used to protect thermal impacts on the interior[17]

### 5.2. Interactive Facades

This façade emits light either by reacting to external stimuli or from physical movement, (fig 4 )The first group are often called media façade because they display various refined animations or low resolution patterns both during the day or night. The second group are kinetic structures: dimensional, textural building envelopes [15]

### 5.3. Kinetic Façade

The Kinetic Façade are designed as alternative building envelopes, providing convenience to building users by reducing energy consumption and cost efficiency. This concept is described in many ways, from the use of innovative components to highly complex designs and advanced technological applications.[16]



**Fig. 3:** Double skin façade system[18]



**Fig. 4:** Interactive façade [19]

We conclude from the previous studies and studies that dealt with the relationship of smart materials with architecture and building facades where there can be three impacts of smart materials when

used in the facades of contemporary buildings are Formal impacts - environmental impacts - technological impacts As shown in table No. 1:

**Table 1:** The impact of smart materials on facades (researchers)

<b>Formal impacts</b>	The structural level	Type of facade	Double skin Facades	<b>Environmental impacts</b>	Self-adaptive	Control of solar radiation	<b>Technology Impacts</b>	Smart material quality	Property -changing
			Interactive Facade			Ventilation Control			Energy exchanging
			Kinetic Façade			Heat control		One type	
		Modulation	traditional		Protection of	energy saving		Material diversity	More than kind
			Modern			Save materials			
			Color			Save water			
		possibility of change	Texture		continuity	Permanence		Using material	The facade as a whole
			Formation			Durability and hardness			
			Scale			Resistance to natural factors			
			Relationship with neighbors		Connected	Function of materials		environmental	structural
	Source format	Separated	Field of Architecture		Aesthetic				
		Nature			Other				
	Form Indication	Local	Science						
		Technique			Other				

### 6. Practical Study

After the paper put the theoretical framework and the variables included in the theoretical framework, including Table 1, the study moved to the practical study and included the selection of a series of architectural projects, including the various projects located within the Gulf region, which is similar in hot climate and similar

in the environment . The paper was done in tables (3-A, 3-B, 4,5) And then adopt the statistical analysis of the result

#### 6.1. Case Study of Architectural Projects

Includes a variety of architectural projects shown in the table 2

**Table 2:** Architectural projects – case study

No	Project s	Image detail of project
A	<p><b>Al Bahar Towers/ Abu Dhabi</b></p> <p>The building responds to solar radiation through a series of fiberglass screens to control the thermal gain of the sun by controlling the closure and opening of the grills used in the front of the building. The screens used in the facade are 2 meters away and are installed on an external frame At sunrise the Mashrabiya will begin along the east of the building. The vertical strip will move completely with the sun [21]</p>	
B	<p><b>Qatar National Convention Center</b></p> <p>The building is located in a sunny and warm climatic area, It uses 3700 square meters of solar panels to invest in solar energy. One of the most important features of the building is its massive construction system, which represents the Sidra tree. Reduce resource use, improve internal environment and reduce CO2 emissions[22]</p>	

<p>C</p>	<p><b>Zayed National Museum/Abu Dhabi UAE</b>                  The building, located in the city of Abu Dhabi, consists of five towers up to 124 meters in green spaces characterized by its appearance and the form of the towers derived from the Falcon wings known in the region. The building used photovoltaic panels and heat exchangers in addition to the exploitation of solar radiation in the water heating process. Of environmental sustainability concepts in reducing energy consumption.[23]</p>		
<p>D</p>	<p><b>Lighthouse tower/ Dubai UAE</b>                  The facade of Lighthouse was a response to the best use of daylight and passive cooling. The facade contained solar panels and wind turbines, reducing the energy consumption by 65% and reducing the water consumption [24]</p>		

**Table 2:** Architectural projects – case study

No	Project s	Image detail of project
<p>E</p>	<p><b>Yas Hotel/ Abu Dhabi UAE</b>                  The building is located on Elias Island, a 500-room hotel complex that represents a curved building with a network of steel panels controlled by the RDM system. Its illumination is based on the LED system by controlling the network brightness and thus controlling the amount of heat and the intensity of the lighting of the lamps [25]</p>	
<p>F</p>	<p><b>medical center planned for Al Ain UAE</b>                  The project was designed to be a recreation and recreation complex at the same time and the project designer used an innovative approach to adopt a unique and innovative structural system of inflating textile systems that enabled the building to provide adequate temperatures inside the building [26]</p>	
<p>G</p>	<p><b>Louvre Abu Dhabi/ Abu Dhabi UAE</b>                  This building, located in Abu Dhabi, is designed in close proximity to the local environment of the Arab region. The museum's facades were designed using 3,900 high-performance concrete panels (UHPC). The four outer layers of the dome were covered with stainless steel, while the interior was covered with aluminum panels separated by a steel frame Five meters [27]</p>	

H	<p><b>Doha Institute/Qatar</b>                  The basic design of the building in Doha is inspired by the environment and the traditional urban fabric in a contemporary style. The Arabic calligraphy was used in its facades, which are characterized by being environmentally friendly, specifically in terms of thermal gain, the use of shaded areas and the internal screens of windows. [28]</p>	
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**6.2. Project Analysis**

In this paragraph, the variables presented in the theoretical framework and the statistical analysis of the selected projects will

be analyzed to reach the conclusions and recommendations that indicated in tables 3 , 4

**Table 3-A:** The impact of smart materials on facades

No .	Formal impacts										
	structural level										
	Type of facade			Modulation		possibility of change				Relationship with neighbors	
	Double skin Facades	Interactive Façade	Kinetic Façade	Traditional	Modern	Color	Texture	Formation	Scale	Connected	Separated
A	1	0	0	0	1	0	1	0	0	0	1
B	1	0	1	0	0	0	0	0	1	0	1
C		0	1	0	1	0	0	1	0	0	1
D	1	0	0	1	0	0	0	1	0	0	1
E	1	0	1	0	1	1	0	0	0	0	1
F	1	0	1	0	0	0	0	1	0	0	1
G	0	1	0	1	0	0	1	0	0	1	0
H	0	1	0	1	0	1	0	0	1	0	0

**Table 3-B:** The impact of smart materials on facades

No .	Formal impacts						
	Semantic level						
	Source format				Form Indication		
	Field of Architecture	Nature	Science	Other	Local	Technique	
A	0	0	0	0	0	1	
B	1	0	0	0	0	1	
C	0	1	0	0	0	1	
D	1	0	0	0	0	1	
E	0	0	1	0	0	1	
F	0	1	0	0	0	1	
G	0	0	0	0	0	1	
H	1	0	0	0	0	1	

**Table 4:** The impact of smart materials on facades

No .	Environmental impacts								
	Self-adaptive			Protection of sources			Continuity		
	Control of solar radiation	Ventilation Control	Heat control	energy saving	Save materials	Save water	Permanence	Durability and hardness	Resistance to natural factors
A	1	0	0	1	0	0	0	0	1
B	1		0	1	0	0	0	0	1
C	0	1	0	1	0	0	0	0	1
D	0	1	1	1	0	0	0	1	1
E	1	0	1	1	0	0	0	0	1
F	1	0	1	1	0	0	0	0	1
G	1	0	0	1	0	0	0	0	1
H	1	0	0	1	0	0	0	1	1

**Table 5:** The impact of smart materials on facades

No .	Technology Impacts			
	Smart material	Material diversity	Using material	Function of materials

	quality								
	Property -changing	Energy Exchanging	One type	More than kind	The facade as a whole	Parts of Facades	Structural	Aesthetic	Environmental
A	0	1	0	1	1	0	0	0	1
B	0	1	0	1	1	0	0	0	1
C	0	1	0	1	0	1	1	0	0
D	0	1	0	0	0	1	1	0	0
E	0	1	0	1	1	0	0	0	1
F	1	1	0	1	1	0	0	0	1
G	1	1	1	0	0	1	0	1	1
H	0	1	0	1	1	0	1	1	0

**6.3 Discuss the results of the analysis of frequency ratios according to the architectural examples analyzed**

The graphical analysis of the criteria has been done by dividing the number achieved by the one standard on the total number that is supposed to be multiplied by the percentage ... in order to obtain a percentage of the repetition of the single criterion in the selected examples of the practical study

**1. Formal recurrence rates:**The results of the analysis of recurrences at the level of the form were shown as follows:(fig 6)

- To achieve a smart cover ideally must have a separate layer and secondary coated to the core layer of the facade of the building Double skin Facades 63%
- To achieve a smart cover, ideally the building should be isolated from neighbors. Relationship with neighbors (Separated) 75%
- In terms of modern or traditional composition showed ratios equal to the index by 50% evidence, that the formation depends on the self-designer in the formation of elements of smart cover
- The results showed that the design should go to the technique Form Indication (Technique) 100%
- As for the field of metaphor in the composition, the results showed that the metaphor of the metaphor of the fields of architecture 38%-

**2. Environmental recurrence rate:** (fig 7)

- The ratios indicated that the smart cover works to control the amount of solar beam inside the home and reduce it, as indicated by the index of Control of solar radiation75%
- Smart Cover works to conserve energy inside the building as indicated by the 100% energy saving index
- The smart cover works to resist the natural weather conditions surrounding the building as stated by the resistance to natural factors100%

**3. Technical recurrence ratios:**(fig 8)

- Materials in the manufacture of the smart envelope must be technology that allows control of energy Energy100%
- Be two layers to achieve the optimal state of the work of the smart envelope, and surround the basic facade of the building
- Materials included in the manufacture of the smart envelope usually have a better environmental efficiency than being internal as a building element of the building.

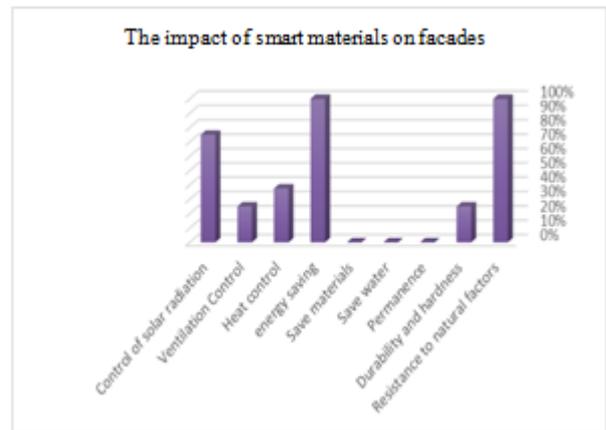


Fig. 7: Environmental recurrence rates

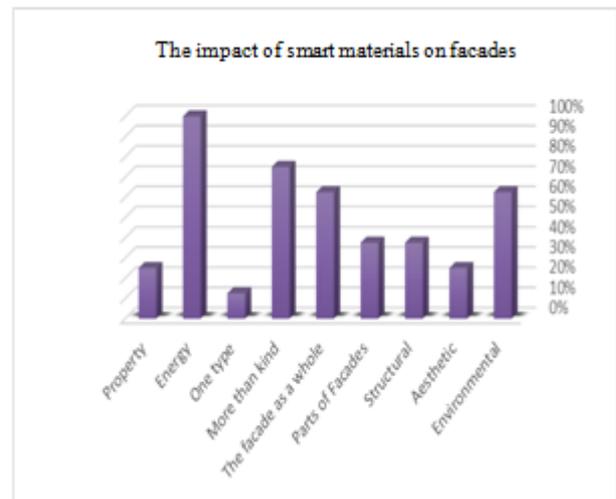


Fig. 8: Technical recurrence rates

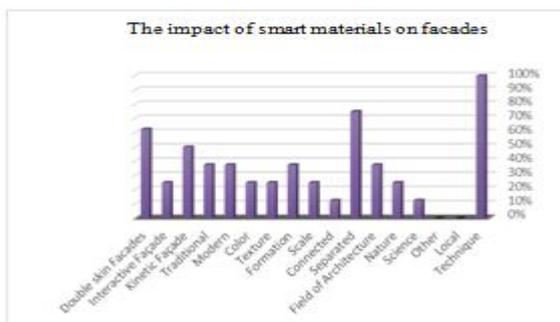


Fig. 6: Formal recurrence rates

**7. Conclusions and Recommendations**

It has become necessary for architecture and architectural design to take advantage of the modern technology of the potential in various fields, including the vast potential created by the technology of smart materials on the design process and the dramatic changes in the design of the architectural facades of the buildings and thus on the building as a whole and its users is discussed in the theoretical framework And tested it on the side of the practical study of a group of buildings.

The research recommends that architects seek to adopt the use of smart materials in their interfaces because of the large formal, environmental and technical impacts that can be employed in the design process

## References

- [1] Aggour , M. & Soliman, O.,(2010),Smart Materials – Toward A New Architecture.( Conference Of Smart Materials.No. Bue-Fisc – 13).
- [2] Rubnicu , A.(2012). Intelligent Systems In Architecture Façade Systems.Gheorghe Asachi, Technical University of Iași, Faculty of Architecture .G.M.Cantacuzino
- [3] Saidam,m,& Other,(2017).The application of smart materials in building facades,Eco. Env. & Cons. 23 (Nov. Suppl. Issue) : 2017; pp. (S8-S11).
- [4] Axel Ritter,(2007), Smart Materials In Architecture, Interior Architecture And Design, Birkhäuser, Publishers For Architecture, Switzerland
- [5] El Attar, S. (2013).Smart Structures And Material Technologies In Architectureapplications. Academic Journals, 8(31),1512-1521.
- [6] Addington, M. &Schodek; D.,(2005), Smart Materials And Technologies, For The Architecture And Design Professions, Oxford, United Kingdom.
- [7] AlinRubnicu,( 2012), Intelligent Systems In Architecture Façade Systems
- [8] Rafeeq,Alla,(2017),Mechanisms For Applying Smart Architecture Requirements To Administrative Buildings,(Palestinian Pension Authority Building - A Case Study)
- [9] A. Ritter, (2007), Smart Materials In Architecture, Interior Architecture And Design, Birkhauser Publisher For Architecture, Pp.7
- [10] Www.Materia,(2017)Nl/Article/Homeostatic-Facade-System/ Access 05/2017
- [11] José Daveiga1, Paulo Ferreira2, Smart And Nano Materials In Architecture, Acadia05: Smart Architecture
- [12] Hardaker, S.S., Gregory, R.(2003) Mrs Bulletin. Aug. 564-567
- [13] Sadeghi, M., Masudifar, D.,&Faizi, F.(2011).The Function of Smart Materials Behavior In Architecture. Paper Presented At Intelligent Building And Management International Conference. Retrieved 15 Sep.2016,Fromtp://Www.Ipcsit.Com/Vol5/57-Icccm2011-B2002.Pdf
- [14] Zennaro P.,(2009),ArchitetturaSenza. Micro Esegisi Della RiduzioneNegliEdificiContemporanei, Francoangeli, Milan.
- [15] Konarzewska, B , (2017)Smart Materials In Architecture: Useful Tools With Practical Applications Or Fascinating Inventions For Experimental Design?Iop Conf. Ser.: Mater. Sci. Eng. 245 052098
- [16] Sharaidin,K.(2014),KineticFacades,Towards Design For Environmental Performance ,An Exegesis Submitted In Fulfilment Of The Requirements For The Degree Of Doctor Of Philosophy
- [17] Knaack, U., Klein, T., Bilow, M., & Auer, T. (2007). Facades Principles Of Construction. Berlin, Germany: BirkhouserVerlag Ag
- [18] R itcher ,J, & Others,(2014),Double façades: comfort and ventilationaspects at an extremely complex casestudy,International Journal of SustainableEnergy
- [19] Pasternack, A.(2008). In Beijing, World's Largest Led Display Uses Solar Power Retrieved 21 November, 2016, From: Http://Www.Treehugger.Com/Interior Design/In-Beijing-Worlds-Largest-Led-Display-Uses-Solar-Power.Html
- [20] Kelbaugh, “The Building Envelope”, Solar Heat Technologies: Fundamentals And Applications”, Chapter Co-Author With Don Prowler, Mit Press, 1990
- [21] <https://www.archdaily.com/270592/al-bahar-towers-responsive-facade-aedas>
- [22] <https://www.archdaily.com/425521/qatar-national-convention-centre-arata-isoza>
- [23] [network.com/projects/zayednationalmuseum/](http://network.com/projects/zayednationalmuseum/)
- [24] <https://www.lafargeholcim-foundation.org/projects/lighthouse-tower-with-low-carbon-footprint-dubai-uae>
- [25] <https://architizer.com/projects/yas-hotel-abu-dhabi-uae/>
- [26] <https://www.philippebarrierecollective.com/project/al-ain-oasis-world-class-medical-clinic-with-bungalows-residence/>
- [27] <https://www.archdaily.com/883157/louvre-abu-dhabi-atelier-jean-nouvel>
- [28] <https://bharchitects.com/en/project/arab-centre-research-policy-studies/>