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Smart Building Materials and the Mechanism of their use As an Entry Point to Create an Integrated Balance between Sustainable Building Technology and the Environmental Efficiency of the Building

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ABSTRACT :Smart materials are a relatively new term for materials and products that have variable properties and are able to change shape or color in response to physical or chemical influences, and we find that light, temperature, or the application of an electric field. A change in one property of smart materials may often be associated with a change in other properties. The past few years have been marked by a new generation of buildings: buildings of varying degrees of advanced technology, which are characterized by their extreme environmental behavior through the intelligent use of functionally adaptable materials, products and configurations which are able to respond to changes in their direct or indirect surroundings and adjust themselves to fit. This creates new tasks for the designers and planners of these buildings, who must know, the design process requires knowledge and integration of many information and these “smart” materials and technologies belong to solutions to long-standing problems in building design.

Therefore, smart materials and their different characteristics were presented, with the definition of sustainability and its principles in order to know how to achieve it. Then, each of the smart materials was mentioned separately, with an applied example for each of them, and results (percentages of achieving different sustainability principles) for each material separately. The results are at the end of the search. Then, several criteria for each material were studied, including (coefficient of thermal conductivity - thermal transition - thermal resistance) in order to calculate the criterion for the recovery period for each material in order to know the period that it takes for each material to achieve a gain equal to its price, as well as the amount of energy provided by each material of the smart materials. This is considered An guiding standard for the architect for the ease of use of the material used.

KEYWORDS: Smart Building Materials - Smart Buildings - Sustainability in Architecture - Relative Weights for a Group of Strategies - Sustainability Strategies Standard recovery period - thermal resistance - thermal transition

I. INTRODUCTION

The design requirements of buildings have changed over the past 25 years as a result of technological development in building systems and materials. It is not of a renewed visual impact, but it surpassed all changes in automated building technology through the development of building materials and the transition to providing buildings with more functions in addition to the desire to find new means of expression, and to bypass environmental and economic restrictions. Previous contracts in terms of shape, finishing materials, and dealing with the surrounding environment.

Therefore, we find that smart materials technologies are the key to the competitive advantage of the twenty-first century, and within the framework of the global trend to reduce energy consumption and reduce environmentally harmful practices and preserve them. Modern.

1.1. MAIN OBJECTIVE: Develop an assessment of smart materials Through the criterion of the payback period to be a guide for the use of smart building materials (finishing) to create a balance between smart buildings, sustainable building technology and environmental efficiency of the building. To reach a hypothesis between smart buildings and environmental efficiency

1-2- secondary objectives :

- 1- Developing a methodology for each of the smart building materials from determining the criterion of the recovery period for each of them to reach a specific approach to achieve the most environmentally efficient smart building materials.
- 2- Determine the relationship between smart building materials and environmental balance.
- 3- Studying and analyzing smart materials that are compatible with the environment and their impact on the local scale and their role in achieving environmental efficiency.

1.3. RESEARCH PROBLEM: Despite the technological development in construction, the use of smart building materials in buildings in Egypt has only been activated by a rate that does not exceed 5%, and this is an insufficient limit to benefit from the advantages granted by smart building materials.

Which requires an alternative to traditional building materials. And replacing them with smart building materials because with buildings consuming high energy that includes in its content lighting, cooling and thermal insulation. It resulted in a problem in increasing energy consumption, due to the annual increase in per capita energy to 17%.

1.4. RESEARCH HYPOTHESIS : The use of sustainable smart building materials achieves environmental efficiency by reducing the percentage of energy consumed in the building by up to more than 40%.

1.5. RESEARCH METHODOLOGY:

1-5-1-Inductive method:

By studying the concepts related to smart materials, their types, characteristics, and the mechanism of their use, in addition to identifying the applications of smart materials and how to overcome climate problems by using them. Also, mentioning the principles of sustainability in order to identify how to achieve them through smart materials

1-5-2-Analytical Method:

This is done through a study and analysis of some experiences (global, regional, Egyptian) in the use of smart materials and come up with guiding standards for the use of smart building materials in different buildings to reach a hypothesis between smart buildings and achieving environmental efficiency.

1-5-3-Evaluation of materials: Develop an evaluation for each material based on determining the criterion for the recovery period for each material, and then to evaluate each material on this basis and determine its role in achieving sustainability in architecture

II. THEORETICAL STUDY

2.1. INTRODUCTION SMART MATERIALS IN ARCHITECTURE

Buildings are among the highest energy-consuming fields, as they consume nearly 40% of global energy consumption, and are responsible for approximately the same percentage of greenhouse gas emissions, and also constitute about 70% of electricity consumption.

As a result, the interest in trying to find advanced and innovative solutions increased, so smart building materials appeared and became an important pattern in the current lifestyle, and the construction and building industry recognized the contribution of smart building materials in treating global energy problems, but it is not sufficiently exploited.

And with increasing countries' awareness of the problems facing the world in the future in providing the amount of energy required to meet the needs of the population, several initiatives have been taken to develop those systems that manage smart building materials as energy-saving buildings.









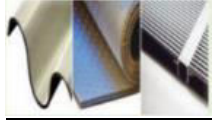
2-2-Definition of memorial materials:

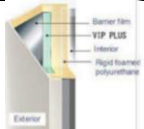
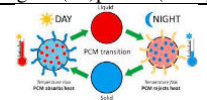



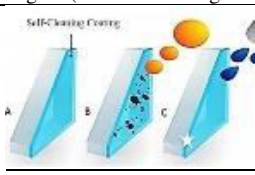


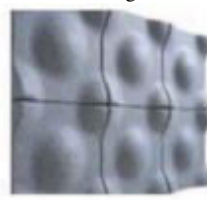
Smart materials are defined as smart formations that sense, analyze, store, and interact with surrounding events. They also respond to stimuli from the external environment. These materials also have the ability to perceive and feel different stimuli and adapt to them by integrating functions into their structures. These stimuli may be electrical, chemical, or magnetic.

2.3 TYPES OF SMART MATERIALS:

- Isotropic materials: (state-changing substances-Color changing materials-thixotropic materials)
- Energy reflective materials
- Energy generating materials

2-4-some applications of smart materials in finishes, which can be used in the field of sustainability and can be classified into:

2-4-1- Construction materials		
Smart Concrete	Adding short carbon fibers to the traditional concrete mixture in the building. This addition enables the concrete to detect stresses and deformations in the concrete.	 Figure (1): Smart Concrete
smart brick	Monitoring the construction condition of the building and protecting the personnel inside the building so that the thermistor inside can send temperature data	 Figure (2):smart brick
Light Transparent Concrete	A mixture of concrete with a matrix of optical fibers and gives permeability to the outside world surrounding the void and allows the passage of light through it	 Figure (3):Light Transparent
2-4-2- Thermal insulation materials		
Airgel	Good heat insulation, do not burn and reduce temperature equivalent to 10-20cm thick glass window	 Figure (4):Airgel
foam glass	In this glass, airgel is used to fill the space between the two layers of glass, which helped in good sound insulation and the ability to disperse light and glare.	 Figure (5):foam glass
Coagulate glass	The presence of a laminated layer between two panes of glass, when the sun's rays fall on it (Coagulated) to turn from a transparent state to a semi-transparent one, as the light transmission factor decreases by itself as the incident lighting increases directly. As its coagulation depends on the incident light and has nothing to do with the temperature, no matter how high it is	 Figure (6):Coagulate glass
insulating glass	This glass distributes the light evenly in the space without forming shadows. In addition to the insulation feature that it provides through the high reflectivity of the cell walls that it contains, and thus this glass provides solar control according to the time of year and day.	 Figure (7):insulating glass
Aluminum Coated Sheets	It absorbs excess heat in the interior space of the building and stores it until the temperature drops, and then releases heat into the interior space (radiation). Use these panels in addition to air conditioning. It can reduce heating bills in winter by 15%.	 Figure (8):Aluminum Coated
Aerofoamed Aluminum	Aluminum sheets are flexible and vary in thickness and designs, and are equipped with a layer that protects the surface from ultraviolet radiation, and it is considered one of the light materials that are easy to use.	 Figure (9):Aerofoamed Aluminum

<p><u>Thermal insulation vacuum insulation panels (VIPs)</u></p>	<p>They are flat panels in order to improve the temperature. Insulation based on the principle of a thermos flask. VIPs offers ten times more thermal insulation than conventional insulation materials. 2 cm of VIP insulation will replace 20 cm of fiber or foam insulation. Also, the service life is up to 50 years.</p>	 <p>Figure (10)panels (VIPs)</p>
<p><u>phase Change Material (PCMs)</u></p>	<p>PCM materials are materials that absorb and release heat by freezing and thawing at temperatures that store heat during the day and release it at night, which mainly helps in the energy saving process.</p>	 <p>Figure (11)(PCMs)</p>
<p><u>UV protection</u></p>	<p>Zinc oxide works with titanium dioxide and nitrogen grafted with titanium dioxide absorbs amounts of ultraviolet radiation and prevents its entry into the vacuum, which helps reduce the energy consumption used</p>	 <p>Figure (12)UV protection</p>
<p><u>Solar protectionVO2 based</u></p>	<p>The glass darkens automatically or can be switched without the need for static electricity</p>	 <p>Figure (13)Solar protection</p>
<p>2-4-3-External finishing materials</p>		
<p><u>Fire resistant glass</u></p>	<p>Preventing flames and toxic gases from moving into adjacent spaces, and this situation lasts from 45 to 120 minutes, where the protection is integrated</p>	 <p>Figure (14)Fire resistantglass</p>
<p><u>Self Clening Glass</u></p>	<p>A type of advanced glass coated with titanium dioxide (TiO2) to self-clean and get rid of contaminated materials on glass panels.</p>	 <p>Figure (15)Self Clening</p>
<p><u>Plastic Glass</u></p>	<p>Types of plastic glass have been available in abundance and with high specifications that made them stronger, lighter and less expensive than traditional glass.</p>	 <p>Figure (16) Plastic Glass</p>
<p>2-4-4-Interior finishing materials</p>		
<p><u>Reflective Indoor Coatings</u></p>	<p>It is a type of paint that reflects lighting better than regular paints, which increases the feeling of space and lighting, reduces the amount of energy used in artificial lighting, and increases the perception of natural lighting.</p>	 <p>Figure (17) Reflective Indoor Coatings</p>
<p><u>Polyester Acoustic Panels</u></p>	<p>They are solid closed-cell polystyrene sheets that are manufactured in different thicknesses, densities, and sizes upon request. It is used to insulate walls and ceilings or polystyrene hurdy blocks for ceilings and pipe insulation Polystyrene for ceilings and pipe insulation</p>	 <p>Figure (18) Polyester Acoustic Panels</p>



2-5-General definition of smart buildings:

A smart building is "one that provides productive efficiency, cost effectiveness, the internal and natural environment, optimal utilization of the structural structure, management systems, and coordination of mutual relations between them." We will explain the most important features of smart buildings in the following points:

2-5-1-Features and objectives of the smart building:

Achieves a set of essential objectives:

- The social dimension: It is represented in improving the internal environment for the occupants of the building and the quality of the internal environment
- The technological dimension: It is represented in the use of modern technologies and advanced technological systems to serve the building
- It integrates many heating and ventilation systems, lighting, communication systems, fire fighting....etc) to manage resources efficiently to increase the efficiency of occupants' performance and reduce operating costs.

2-5-2-Smart buildings have several characteristics and advantages that are limited to the following:

- 1- Providing comfort conditions and a healthy environment:By improving the type of indoor air, while increasing the possibility of controlling the internal environment, from a suitable temperature and relative humidity for the occupants of the building.
- 2- Energy Efficiency:In smart buildings, it means controlling the operational cost, and here achieving comfort in these buildings should not consume more energy than the necessary energy
- 3- Effectiveness:Knowing the right things to do when managing different aspects of a building such as control, energy management, maintenance management, communications management, fire protection and security systems, and other services
- 4- Flexibility:Smart buildings are buildings that are designed and constructed to be a flexible means capable of adapting to surrounding conditions according to requirements and needs
- 5- Adaptation:Intelligent Buildings systems adapt to the needs of their occupants
- 6- Comfort Physiological:Smart buildings enable occupants to program each space according to their desire, including temperature, humidity, and the type of ventilation required
- 7- The running cost of the building:Smart buildings reduce costs in the various stages of the mini, by automatically controlling building elements such as turning off unnecessary lights and not heating unoccupied rooms.

2-6-Sustainable Architecture:It is architecture that meets the needs of the present without compromising the ability of future generations to meet their own needs (self-sufficiency)

2-6-1-(sustainable):The concept of sustainability is the optimal exploitation of available resources and capabilities, whether human, material or natural, in an effective and balanced environmental and urban manner to ensure the continuity of sustainability without wasting the gains of future generations.

2-6-2-General principles of sustainability:There are three basic principles of sustainable architecture and sustainable architectural design, which are resource economy, life cycle design and humanistic design.

The first principle: energy and water conservation

The second principle: the life cycle of the building

The third principle: human design

2-6-3-Principles of sustainable design:

In order to reach a sustainable architecture, the principles of sustainability must be established in the design process and direct the attention of architects to the sustainable design process, which is concerned with the following elements:



1- Study the place	8- Studying human nature
2- Communication with nature	9-Environmentally friendly building materials.
3- Understanding the environmental impact	10-Methods of water conservation inside buildings
4- Reducing the use of new resources	11- Indoor air quality
5- Energy Management	12-The envelope of the building
6- Adapting to the climate	13- Comprehensive thermal insulation
7 - Integration of the design environment and support operations	14- Water and treated water management


III. ANALYTICAL STUDY

3-Model analysis of smart materials :


Many models of smart materials have appeared in the field of building and construction engineering, which have contributed to achieving many sustainable building strategies. They will be recognized and the role they play in achieving them, and they will be divided into:

3-1-Thermal insulation materials:



3-1-1-Aerogel :		
Example:	<p>University of San Francisco: Glass was used in the area of the external corridors of the university, which leads to the entry of natural lighting, ventilation, and good thermal insulation Glass was also used in the food court to enjoy natural lighting and ventilation, as well as a high percentage of thermal insulation</p>	
achieving sustainability	-Thermal insulation: 65% -Energy saving: 60% -Noise canceling: 80%	-UV resistance: 60% -Light transmittance: 50% -Providing natural lighting: 40%
3-1-2-Coagulate glass:		
Material features	Containing airgel gel between its layers, it responds to the sun's rays quickly and coagulates, changing its color to a semi-transparent state. When the sun's rays fall, the airgel gel coagulates inside the glass to change from a transparent state to a semi-transparent state, as the light transmission coefficient decreases by itself as the incident light level increases. and not It has to do with temperature, so its transparency depends on the intensity and angle of incidence of the light. It is also a good thermal insulation, providing privacy	
achieving sustainability	Thermal insulation: 70% Energy saving: 70% UV resistance: 60%	Light transmittance: 80% Providing natural lighting: 40%
3-1-3-Jelly glass:		
Material features	It contains aerated silica gel, and this layer works to reduce the thermal conductivity coefficient to a minimum, and it also raises the light transmission factor	
achieving sustainability	Thermal insulation: 600% Energy saving: 75%	UV resistance: 70% Light transmittance: 70% Providing natural lighting: 50%
3-1-4-Thermal insulation vacuum insulation panels (VIPs) :		
Example:	<p>sonnenschiffcenter: Vacuum insulation panels were used in the internal spaces, which work on thermal insulation, a percentage that may reach 80%, which leads to saving the energy used in the building by a rate that may reach 90%.</p>	
achieving sustainability	-energy saving 80% -heat insulation 80%	-UV resistance by itself 60%
3-1-5-Polyester Acoustic Panels:		






Example:	<p>Burj Khalifa in the United Arab Emirates: Its height is more than 800 meters, and the number of apartments is about 100, in addition to the hotel and the offices located in it. Burj Khalifa is distinguished by its energy consumption. At peak time, this huge building consumes 36 megawatts of electricity, which is the amount needed to light 4 million energy-saving 9-watt bulbs. The cooling devices drain the bulk of the electrical energy,</p>	 <p>Figure(21)Burj Khalifa</p>
achieving sustainability	Thermal Insulation:60% Energy saving: 40%	Noise suppression: 50% UV resistance: 55%

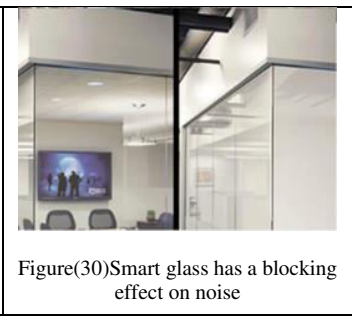
3-2-Energy materials :

3-2-1-Temperature Regulation Phase Change Material (PCMs)		
Example:	<p>Sur falveng housing for elderly people: Sur valve housing for elderly people: PCMS was used in the interior ceilings of the building, and it works to store energy during the day and release it at night. Which saves energy by a very large percentage and makes the building sustainable. They are panels that store the sun's rays during the day and release them at night to maintain the temperature and are also used for cooling</p>	 <p>Figure(22)pcm in the ceiling</p>
achieving sustainability	Thermal Insulation:30% Energy saving: 40%	UV resistance: 50%

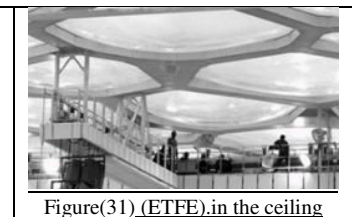
3-3- Glass Technology:

3-3-1-Self-Cleaning glass :		
Example:	<p>Cairo Land Port (Torgoman Station): The design idea of stained glass windows combines a group of modern technologies, namely: 1-Self-cleaning glass technology. 2-Transparent solar cell technology 3- The technique of etching on the glass</p>	 <p>Figure(23)stained glass</p>
achieving sustainability	Thermal Insulation:50% UV resistance: 70%	Light transmittance: 60% Providing natural lighting: 65%
3-2-2-insulating glass:		
Example:	<p>Qatar International Convention Center: High performance insulating glass was used in the facades of the building High PerformanaceInsulatingGlass, which is a type of smart glass to distribute light evenly in the space without forming a shadow. Curved vertical longitudinal walls, which are characterized by a low rate of heat emission, which works to limit the transfer of heat from the outside to the inside, which are electronically controlled There are solar panels on the roof of the buildingThrough which solar energy is generated, which contributes to saving the energy used in the building. Plastic glass was also used in some places in the building, which works on thermal insulation in the building</p>	 <p>Figure(24) Insulating glass</p>


		
	Figure(25) external interface	
<u>achieving sustainability</u>	Thermal Insulation:80% Energy saving: 50% Noise Reduction :40	UV resistance: 50% Providing natural lighting: 65%
3-2-3-plastic glass:		
<u>Example:</u>	China Cosmetics Storage Building: Plastic glass was used in the facades because of its advantages given to the building, which is unbreakable while preserving natural lighting, and it is also resistant to combustion. 1- A high percentage of natural lighting 2- High rates of heat and noise insulation 3- Resistant to combustion 4- It is not affected by climatic changes from -40 degrees below zero to 160 degrees Celsius	
	Figure(26) China Cosmetics Storage Building	
<u>achieving sustainability</u>	Thermal Insulation:80% Noise suppression: 50% UV resistance: 40%	Light transmittance: 70% Providing natural lighting: 80%
3-2-4-Fire resistant glass:		
<u>Example:</u>	uniqlo shops in Europe: Fire-resistant glass was used in the destinations, which led to preserving the building from fire It also led to protection from ultraviolet radiation	
	Figure(27)uniqlo shops in Europe:	
<u>achieving sustainability</u>	Thermal Insulation:30% Energy saving: 40% UV resistance: 70%	Light transmittance: 50% Providing natural lighting: 60%
3-2-5- Energy generating glass:		
<u>Example:</u>	Garston State Environmental Building: The southern façade of the building includes rotating, treated glass slides, and includes photoelectric cells to operate the building. By generating electrical energy from natural light in the atmosphere. Provide electric power for the complete operation of the building	
	Figure(28) Garston State Environmental Building:	
<u>achieving sustainability</u>	Energy saving: 90% UV resistance: 40%	Light transmittance: 60% Providing natural lighting: 70%
3-2-6-Electrochromic glass:		
<u>Example:</u>	Mandarin Oriental, Hong Kong: Glass works inside the building as follows: 1- As a privacy partition wall, you can change the state of this electromagnetic smart glass for office as you like.The response time from private state and open state ranges from 10ms to 50ms. When the power is on, the clear glass has extended visual effects. The office looks	
	Figure(29)Privacy partition wall	

	<p>more spacious</p> <p>2- Inner chips are EVA film and pdlc clear film. When the power is on, the light transmittance is 80.0%. When the power is off, the UV resistance is more than 98%. It has better heat insulation and sun protection</p> <p>3- It is explosion-proof. When the smart glass is hit, the inner EVA film will stick the glass pieces and prevent them from hurting people.</p> <p>4- To maximize its decorative effect, each cutomer can do a unique design for their desk. Here are some designs for their practical applications.</p>	 <p>Figure(30)Smart glass has a blocking effect on noise</p>
<p><u>achieving sustainability</u></p>	<p>Thermal Insulation:40%</p> <p>Energy saving: 40%</p> <p>Noise suppression: 20%</p>	<p>Light transmittance: 80%</p> <p>Providing natural lighting: 60%</p> <p>UV resistance: 90%</p>


3-4-lighting materials:


<p>3-4-1-Ethyltetrafluoroethylene (ETFE).</p>		
<p><u>Example:</u></p>	<p>Beijing National Swimming Complex Building in 2006: ETFE material was used in the roofing of the building of the National Swimming Complex in Beijing. It achieved natural lighting inside the building, and it also has an aesthetic shape and light weight.</p>	 <p>Figure(31) (ETFE) in the ceiling</p>
<p><u>achieving sustainability</u></p>	<p>Providing natural lighting 80%</p> <p>UV resistance: 70%</p>	<p>Light transmittance: 50%</p> <p>Noise Reduction :40%</p>

3-5-External finishing materials :

<p>3-5-1- Areo Foamed Aluminum:</p>		
<p><u>Example:</u></p>	<p>Gleichenberg Gallery, Australia: Aluminum panels were used in the facade of the building, which led to</p> <ol style="list-style-type: none"> 1- Built-in protection from ultraviolet rays 2- Electrical and magnetic protection 3- It also acts as a strong sound insulator 	 <p>Figure(32)Gleichenberg Gallery, Australia</p>
<p><u>achieving sustainability</u></p>	<p>Thermal Insulation:50%</p> <p>Energy saving: 30%</p> <p>Noise Reduction :40%</p>	<p>UV resistance: 50%</p> <p>Light transmittance: 20%</p>

3-6- Interior finishing materials:

<p>3-6-1-Luminous glass bricks:</p>		
<p><u>Example:</u></p>	<p>Chanel in Amsterdam, the Netherlands: The bricks were inspected visually on site for any defects, the surfaces were cleaned, and an amount of adhesive was spread to prevent any capillary effect along the faces of the glass bricks. A light beam is used to harden the liquid adhesive. If it appears on vertical seams, it is initially exposed to low intensity UV light for 5 seconds while the bricks are kept under pressure. This step was made the beginning of processing for practical reasons. The glass brick stabilizes while still allowing for unevenness and escaping any adhesive overruns. After cleaning and finishing, the pre-prepared panels are placed and prepared to be combined to build the glass wall. It has also been proven that glass bricks work on natural lighting inside the void</p>	 <p>Figure(33)Chanel in Amsterdam</p>

		
achieving sustainability	Thermal Insulation:40% Energy saving: 20% UV resistance: 40%	Light transmittance: 50% Provide natural lighting: 90%

IV. EVALUATION STUDY

3- Calculate the standard payback period for smart materials

Category	Smart materials	element thermal resistance (R-value)	Energy available per meter in kilowatts per day	The price of available energy per meter per day	Price per square meter of material	standard payback period	
Thermal insulation materials	Airgel material	Coagulateglass	0.138m ² *k/w	124.4 kw	0.62 LE	640 LE	400 Day
		Jelly glass	0.286m ² *k/w	60.4 kw	0.3 LE	800 LE	2640Day
		Aeragel Glazing	0.125m ² *k/w	138.4 kw	0.69 LE	400 LE	578Day
	Thermal insulation vacuum insulation panels (VIPs)		0.042m ² *k/w	402.2 kw	2 LE	960 LE	480Day
	Polyester Acoustic Panels		0.61m ² *k/w	28.4 kw	0.14 LE	43 LE	303Day
power materials	PCMs	0.025m ² *k/w	691.2kw	3.5 LE	1750 LE	500Day	
glass technology	Electrochromic glass	0.127m ² *k/w	136.3 kw	0.68 LE	4800 LE	7058Day	
	Photochromic glass	0.035m ² *k/w	489.4kw	2.4 LE	470 LE	196Day	
	The glass is self-cleaning	0.069m ² *k/w	248.8kw	1.2 LE	2000 LE	1607Day	
	insulating glass	0.35m ² *k/w	49.2kw	0.25 LE	400 LE	1600Day	
	plastic glass	0.016m ² *k/w	1088.6kw	5.4 LE	1280 LE	237Day	
	Fire resistant glass	0.44m ² *k/w	38.9 kw	0.19 LE	600 LE	3086Day	
	Glass is a generator of electrical energy	0.022m ² *k/w	799.2 kw	3.9 LE	3000 LE	769Day	
lighting materials	ETFE	0.004m ² *k/w	4112.6 kw	20.5 LE	5080 LE	248Day	
exterior finishing materials	foamed aluminium	0.131m ² *k/w	131.3 kw	0.66 LE	9500 LE	14393Day	
	Aerofoamed Aluminum	0.059m ² *k/w	290.3 kw	1.5 LE	500 LE	333Day	



	Aluminum Coated Sheets	0.333m ² *k/w	51.8 kw	0.3 LE	300	1000Day
Interior finishing materials	Reflective interior paint	0.039m ² *k/w	447.5 kw	2.2 LE	230	104Day
	dark paint	0.02m ² *k/w	864 kw	4.32 LE	659	153Day
	Luminous glass bricks	0.65m ² *k/w	26.6 kw	0.133 LE	250	1879Day

3-1-Method for calculating the item's payback period criterion:

-Since the thermal conductivity of the element (watts / square meters / Kelvin)

So $w=(w*k/m^2)*(m^2/k)=w$

- By standardizing the temperature of 27 degrees Celsius, it equals $27 + 273.15 = 300.15$ Kelvin.

-So to find the energy in watts available in one meter of material = $u*(m^2/300.15)$

-So $w=u/300.15$

-And to calculate w per day = $(u/300.15)*60*60*60*24$

-To find power in kilowatts, divide w/1000

-Then find the price per square meter of the material

-Then calculate the recovery period for the element = price per meter of material / price of available energy per meter per day

Results: We conclude from the above that:

The least material in terms of achieving the recovery period is the reflective interior coating material, which indicates that it achieves sustainability and environmental efficiency in a way that is cheaper than other materials and achieves a more economic return. Through the previous table, it is possible to choose the appropriate material for different projects. Then comes the dark coating material, as its recovery period is 153, which encourages many engineers to activate its use in many projects. Then, photochromic glass material, as its recovery period is 196, which is also a small period, which is preferable to replacing traditional glass with photochromic glass. Then it is followed by the plastic glass material, where the standard of recovery period is 237, which is still a short period and must be replaced by traditional glass in projects. Then it is followed by ETFE material, where the recovery period standard is 248, and it is still a small period and must be activated within the projects. Then it is followed by the material of polystyrene panels, where the recovery period is 303, then followed by moldable aluminum, the recovery period is 333, and they are still a short period of less than a year. Then the end comes in the foamed aluminum material, where the recovery period for it reaches 14393, that is, approximately 39 years, and it is also still a short period, which indicates that all materials have a short recovery period,

Thus, the rest of the materials, and through these materials, we can prove the research hypothesis, which is that the use of smart materials provides a very large percentage that almost exceeds 40% of the energy used in semen.

as Each of the smart materials contributes to achieving a good percentage of sustainability strategies (thermal insulation - energy saving - noise control - resistance to ultraviolet rays - light transmittance - provision of natural lighting) as shown in the previous analysis, and we conclude from this analysis that the use of smart materials contributes to Achieving sustainability in the long run. Smart materials are the best solution to face the upcoming energy shortage. Therefore, architects must be educated to employ them in large projects so that the return is as large as possible.

Recommendations:

- 1- Activate the use of smart materials at a greater rate to achieve environmental efficiency
- 2- Use the previous table as a guide for the use of smart materials
- 3- Awareness of the importance of smart materials for architects to achieve the lowest economic cost
- 4- And in comparison between the price of the material and the criterion of the recovery period, we find that it is not necessary that the material with a short recovery period be of a low price, but this is due to the energy available per day through the material. Therefore, the materials can be arranged in another order in terms of energy, and this is due to the nature of the project.
- 5- It is also possible to arrange the priority of the materials in terms of the thermal resistance of the material, in projects with hot areas, in which the priority is to save energy through materials with high resistance and thermal insulation.

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