The role of Sustainable transparent materials in smart architecture

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Abstract:
These days, sustainable building materials are becoming increasingly popular due to the increasing interest of people and organizations in preserving the environment. Architects and builders continue to look for ways to improve their practices by creating materials that contribute to the sustainable construction process and are an effective option to reduce their environmental impact. Therefore, specialists resorted to some materials such as recycled wood, clay, and other materials that save energy, reduce waste, and preserve natural resources. The production of sustainable materials also aims to improve people's quality of life while protecting the environment from carbon emissions and saving energy consumption. These materials can be classified into two categories: the first seeks to contribute to nature as biomaterials, and the second seeks to achieve economic efficiency as low-cost, recyclable materials. These two materials were developed to meet the challenges of dealing with environmental issues.
This paper seeks to identify sustainable transparent materials and focuses on studying three advanced materials: transparent wood, rock salt crystals, and polycarbonate. The research also seeks to emphasize cooperation between industry and technology in producing sustainable, transparent materials that can be used efficiently in smart architecture. On the other hand, the research aims to identify the characteristics of these sustainable, transparent materials. For the paper to reach its goals, an analytical methodology is conducted on transparent wood and rock salt crystals, as they are vital and sustainable materials, in addition to polycarbonate; as a sustainable recyclable material. The results showed a major industrial shift in the trend towards manufacturing these architectural materials to keep pace with the needs of the times and to be compatible with the needs of smart architecture. The study suggests developing codes and standards to make it easier for architects and specialists to benefit from these sustainable materials and integrate them with smart architecture.

Keywords: transparent sustainable materials, bio-based materials, recyclable materials, efficiency, transparent wood, polycarbonate, rock salt.

Introduction:

Nowadays, the current situation of the earth is very alarming, especially with the issue of global warming caused by human activities such as industry and the use of non-environmental materials. All of this affects the phenomenon of global warming, which poses a threat to the Earth. The solution to reduce the impact of global warming is to apply the concept of sustainability in all aspects of life, especially in buildings and construction. If buildings do not take environmental standards into account, they will have negative impacts on the environment. It will also have a bad impact on the health of users and reduce the efficiency of vital activities for humans and the environment. Moreover, when construction begins, it also contributes to a lot of harmful impacts on the environment, ranging from waste, noise, smoke, dust, etc.

To reduce these problems, many architects and other experts have proposed and put forward solutions, starting with how to make recycled materials, green buildings, and environmentally friendly materials. Adopting the concept of green architecture has become the main solution capable of making the environment balanced. It has also been shown that making sustainable materials is necessary and can reduce the impact of environmental damage. Therefore, it is necessary to conduct research aimed at developing sustainable materials.

Hence, the paper will seek to identify three of the latest sustainable natural materials, namely transparent wood, which has begun to be widely used on facades in cases where sunlight is necessary to illuminate the interior space of buildings. Some other natural materials have also been developed and used for years, such as rock salt crystals, which are used in the construction process in Siwa, Egypt, but have recently been modified to challenge the surrounding weather. The study will also seek to identify one of the most important sustainable industrial materials that are widely exploited in industry and construction: transparent polycarbonate.

The term sustainable transparent materials can be applied to transparent or semi-transparent materials because they can keep interior spaces light without glare and respond to thermal comfort. Today's technology seeks to develop these materials to improve light transmittance and visibility through architectural screens. Since the integration between these materials and smart architecture is the main goal of this paper, the paper included some analysis and detail on the relationship between sustainable transparent materials and architecture to monitor their impact on achieving aspects of smart architecture.

The paper covers the following points:

- The general overview of both transparency and Smart Architecture.
- Displaying transparent sustainable materials.
- Evaluating the role of transparent sustainable materials in smart architecture.
- Estimating the concept and main features of Smart and sustainable transparent materials.

1. Transparency:

The use of transparent materials in architecture has appeared since the beginning of the twentieth century and has begun to spread throughout the world. Especially with the beginning of the call for preserving the environment, adopting the concepts of sustainability, green architecture, using environmentally friendly materials, and calling for design strategies that aim to preserve the natural environment and improve the quality of life. Despite the clear view that glass can provide while used on the building's outer shell, humans cannot achieve both thermal and visual comfort, because glass needs different applications and systems as a treatment for the problems posed by sunlight falling on the building. These applications cost a lot. Transparency also conflicts with human security. Therefore, scientists and industry are taking advantage of contemporary technology to develop materials that can achieve intelligent transparency, and these optically transparent materials used in architecture combine mechanical performance with optical functions to respond to sustainability. [48], [49]

2. Smart architecture:

The concept of smart architecture appeared at the end of the twentieth century through the addition of integrated technical systems in buildings to help control the modification of the internal environment of the building and achieve compatibility with the surrounding environment through smart external facades that allow responding to the needs of users and providing them with biological comfort. These smart buildings try to react to modern conditions and environmental problems by saving energy and making efficient use of resources. [6], [7], [16], [25], [39], therefore These buildings sought to achieve the following characteristics:

- Adaptability, as; simulating the actions and responding with intelligence.
- decision efficiently: it does more with less
- Offer the users a suitable and comfortable climate.
- The building responds to the needs of the users.
- The efficiency of energy and resources.
- Valuable and has aesthetic features.
- The optimum safety and security of the building.
- Forming database and communication systems.
- interface between its users and the surroundings

Both intelligence and sustainability seek to achieve the optimal combination of human biological comfort and saving energy and natural resources. It also seeks to provide sustainable materials that contribute to increasing the intelligence of buildings and their ability to adapt to environmental conditions. . [16], [18] Therefore, a number of architects and researchers have sought to take advantage of contemporary technology to develop materials that can achieve these smart properties. Hence, the paper will focus its study on three transparent materials characterized by flexible response and dynamic efficiency. These materials also combine mechanical performance with optical properties to respond to surrounding environmental conditions

3. Transparent sustainable materials:

3.1 transparent wood:

Transparent wood is one of these new materials that the German scientist Siegfried Fink produced in the lab in 1992, and his method of production has been improved by later research in 2015 and 2016; As to create transparent wood, the lignin in wood can be replaced with transparent plastic materials as polyvinyl alcohol (PVA) which is usually used to give wood higher strength while having 90% transparency. [19] This material is proposed to be more biodegradable than plastic or glass in the future. As it gained interesting physical, mechanical, and optical characteristics, it weighs less and is stronger than regular timber. [48]

3.2 rock salt crystals:

Salt rocks are formed by the deposition of salt layers after water has dried. They are in the shape of slabs retrieved from dried-up lakes; these rocks have been cut with extreme accuracy, rather than by the pressure of salt to get salt bricks, but a group of scientists who used technological progress produced these bricks. To avoid the misuse of salt and follow the eco-efficiency aspects as the recyclability. Recently, salt Waste generated by the desalination, and potash mining sectors

has begun to be encouraged for re-use in various applications. Resource efficiency has been recognized as an essential issue in the construction industry, and utilizing salt waste in general is a viable approach for three reasons which are: 1st reducing dependence on conventional materials such as gypsum or cement, 2nd creating more effective interior environments, 3rd reducing pollution. [46]

3.3 Polycarbonate:

In 1953, Dr. Hermann Schell and his team discovered a new material, polycarbonate or Lexan. It is a condensation product of bisphenol A and a carbonate donor such as phosgene or di-phenyl carbonate. Industrially it is manufactured by; Interfacial polymerization (Bisphenol-A+Phosgene). (Bisphenol-A+ Di-Phenyl carbonate) and be processed by Extrusion or Injection molding. Polycarbonate plays a very important role in the environmental, social, and economic dimensions of sustainable development. It could be a highly durable plastic that contributes significantly to the assembly of eco-efficient and sustainable use of many important products. These products include lightweight parts for vehicles and construction materials, cellular communications, high-quality clothing and plant architecture, medical devices, multi-use packaging, and modern virtual data storage. [57], [58], [59]

Polycarbonate sheets especially are used in roofing systems and are produced in India and Malaysia, and the common Polycarbonate sheets used in architecture are Corrugated Polycarbonate, Glossy Polycarbonate Solid Sheets, and Multiwall polycarbonate sheets. [55], [56]

4. the role of transparent sustainable materials in smart architecture:

The Features of the smartness can be drawn as shown in diagram (1)

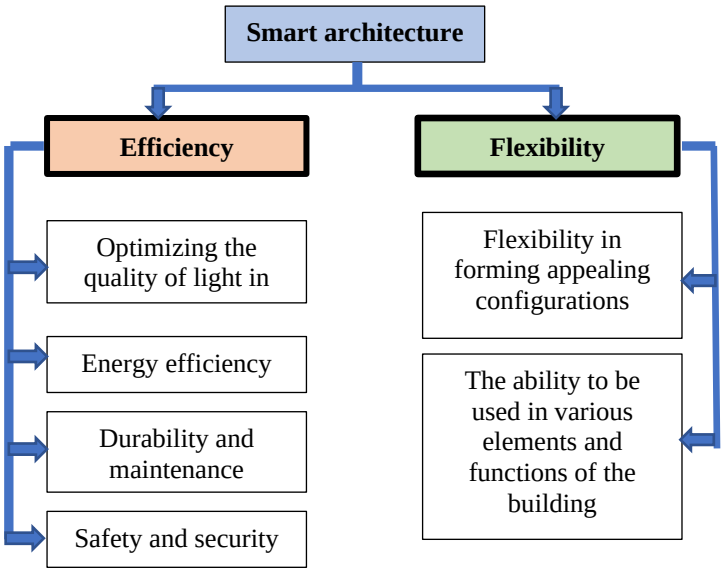

Diagram (1) The features of the smartness drawn to estimate the role of sustainable transparent materials in smart architecture. (The author)

4.1 Estimating the efficiency of transparent sustainable materials:

4.1.1 Optimizing the quality of light in the indoor space:

Architecture is seeing a growing demand for responsive designs that increase user comfort through the use of smart systems, applications, and sustainable materials. The paper focuses its study on sustainable transparent materials and also focuses on how to improve the properties of

these materials and how to increase their efficiency. It also aims to improve the quality of daylight that penetrates the interior space from visual facades, as it works to reduce glare and reduce heat absorption. This improvement keeps the facade free without adding shading systems and insulators to adapt to the sunlight used in natural lighting and reduce its damage. The goal of daylight diffraction is to adjust the intensity, direction, and dispersion of light. This can be achieved by reducing the amount of light penetrating the exterior of the building and reflecting excess light into the external environment. [26]

a. Transparent wood; Light does not bend when it passes through the augmented wood because the optical characteristics of the polymer and the wood are compatible. Rather, it goes around. This transparency creates a multitude of opportunities of high values of optical haze in translucent wood, which allows it to let in light but obscure the view, [19], [20] and thus can be used in illuminating the interior space. Fig (1), and Fig (2) show the transparent wood in architecture.

Fig (1) The Nanjing Wanjing Garden Chapel Features a Butterfly Roof Vasiliki Marapas — October 10, 2014 — Art & Design- References: azlarchitects & dezeen http://www.azlarchitects.com/

Fig (2) Globeville Affordable Housing complex in Denver, John Ronan

b. Rock salt crystals: The optical transmittance of the defect-free rock salt crystals for infrared light, namely between 200 nm and 20 m, is approximately 90%. As a result, they have been used in optical components (windows and prisms) that are used in this visible range, where there are few non-absorbing substituents and microscopic homogeneity requirements are less accurate than in the visible range. While rock salt crystals are low-cost, they are soft and hygienic progressively covering with 'frosting' when exposed to the atmosphere. This restricts the usage of rock salt to dry settings, vacuum-sealed assembly rooms, or short-term applications such as prototyping. [47] On the other hand, Pink rock and crystal salt shown in Fig (3) are unique and can be used for a variety of reasons. Rooms with a lot of natural light don't need cylinder lamps or bulbs. When the sun falls on the brick, it looks lovely. [29]

Fig (3) using transparent salt bricks on the outer envelope of the building in Siwa
Source: Researcher

c. **Polycarbonate:** is a transparent plastic that transmits more than 90% of its glass-like light. Polycarbonate sheets are available in a variety of opacity that can be utilized in the final product. It also contributes to providing appropriate lighting for the interior spaces of the building. Through the features of these panels that allow enough light to pass through, applications have expanded. Polycarbonate panels provide the best opportunities for natural daylighting as a key element that contributes to sustainable building design. Not only does it allow light to enter the built space, but through these panels it is possible to control the amount of light that enters the space. It also protects from ultraviolet rays, which plays an important role in enhancing lighting properties. The extraction index of transparent polycarbonate is 1.584. It is used to be a safe transparent material in buildings that call for sustainability [34], [55], as shown in Figure (4).

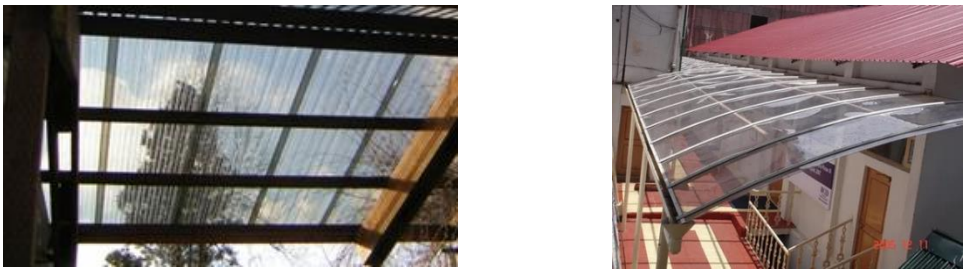

Fig (4) various shots display the transparency of polycarbonate [55]
https://www.tradeindia.com/_next/image

4.1.2 Energy efficiency:

a. Transparent wood: The use of transparent wood contributes to significantly reducing energy consumption costs in buildings. This is through its efficient participation in smart applications instead of the glass in (smart windows) which can block light when it flows through it. It can also be used as a cover for solar panels and improve their efficiency because of its transparency and its ability to minimize the amount of light lost through reflection. The degree of light scattering inside it can be improved, so it can absorb more energy. And using a phase change material instead of a polymer to replace lignin turns wood into an energy storage device. During the day, this soaked wood can absorb heat, but at night, when temperatures cool, a phase-changed substance crystallizes, releasing heat. Due to its excellent thermal insulation capabilities, this material can aid in lowering buildings' energy consumption. On the other hand, it can also be produced using low-energy methods, making it an even more eco-friendly choice. [52]

b. Rock salt crystals: are utilized as storing materials in an indirect sun dryer. To tackle heat behavior with storage materials, the sun dryer was created using SolidWorks flow simulation. The layers of rock were arranged as overlapping spherical beds. The arrangement of rocks in the drying chamber has a major effect on the higher temperature reached during the sunshine time, as well as the duration of the thermal discharge phase. These storage media kept the drying chamber temperature stable for four extra hours in the absence of sunlight. Finally, adding Salt rocks may improve the dryer's efficiency. [21] it can be used in solar panels as shown in Fig (5)

Fig (5) rock salt crystals in solar panels

https://static.dezeen.com/uploads/2021/11/salt-panels-atelier-luma-arles-tower-dezeen-15_dezeen_1704_col_2.jpg

c. polycarbonate: plays a key role in providing daylighting into the building which provides natural light and reduces the use of artificial light, as shown in Fig (6) which results in the reduction of use of electric consumption and increased energy efficiency of the building which leads toward sustainable development at the same time it offers good heat resistance, Polycarbonates are physically stable up to 135 ° C. The heat resistance can be enhanced by adding flame retardants without affecting the visible structures. It provides strong inserts, with energy-saving benefits in a multi-wall format. Polycarbonate also protects from IR radiation and can increase energy efficiency when treated with solar control technology. [34]

Fig (6) polycarbonate panels used in the holly facades of daycare center project, Karoline Goldhofer, in Memmingen, Germany. [60]

https://images.adsttc.com/media/images/6179/5a57/f91c/81a4/f700/002b/newsletter/IMG_0332_a.jpg?1635342888

4.1.3. Durability and maintenance:

a. Transparent Wood : The polymer used in the wood instead of lignin makes it fire resistant, makes it five times stronger, and increases its resistance to weathering. Studies have shown that the absence of lignin leads to avoiding wood deterioration. Meanwhile, researchers are seeking to produce transparent wood from thicker wood to increase its strength by modifying the lignin and making the whole process more environmentally friendly. [49] Due to the nature of wood, the

thicker the pattern, the less transparent it is. Therefore, these patterns can be used as structural walls or columns in a building. [5], [31]

B. Rock salt crystals: Rock salt-based building bricks are manufactured from a mixture of sea salt and starch. The brick has been proven through tensile and compressive strength tests to be stronger in compression than rammed earth, a material often used in desert construction. But just like rammed earth or concrete, this material is strong when compressed but less efficient when tensioned. It is therefore suitable for use in making vaults and arches common in traditional desert architecture, Geboers explains. Moreover, the presence of sea salt gives the material a distinctive transparency, along with a bright white color that reflects light. It is also recommended to use hard epoxy to seal this waterproof material. [21] Given that rocks are solid materials; The types of stress that rocks can be exposed to are tension, compression, and shear, and it is also subject to a form of stress that leads to a change in size or shape. One of the properties of these rocks is that when the pressure is removed; The rock will return to its original shape. As a result of constant pressure, rocks that have been subjected to ductile stress will remain deformed even after the stress is removed. Salt panels have been chosen for many projects due to their flexibility in removing and replacing each panel as necessary; If damaged, it can be recrystallized and restored by placing it back in the water of the crystallization plant. [33]

C. Polycarbonate: It has great capabilities that make it resistant to shocks and cracks, as well as continuing to provide safety and comfort in applications that require high reliability and performance. Shiny polycarbonate steel sheets come in a number of different models, thickness: 0.8 mm - 12.0 mm, and dimensions: 1.22 x 1.83, 1.22 x 2.44, 1.22 x 30.5 meters, as shown in Figure (7). Rigid (monolithic) polycarbonate sheets are extremely durable and impact-resistant yet lightweight, weighing half the weight of glass sheets. The transparent, rigid polycarbonate sheets provide high light transmission with clarity comparable to glass as well as being virtually unbreakable. Polycarbonate also shows good resistance to chemicals, refined acids, aliphatic hydrocarbons, and alcohols. Equally chemical resistance against oils and grease. Polycarbonates are immediately attacked by refined alkalis, perfumes, and hydrocarbons. Manufacturers recommend cleaning polycarbonate sheets using specific cleaning products that do not affect the chemical environment.

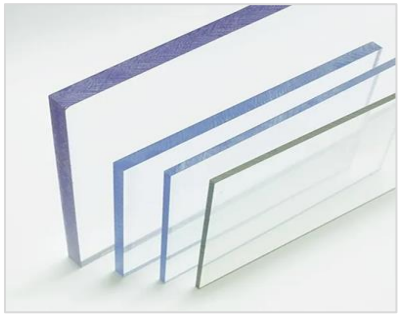

Fig (7) Glossy Polycarbonate Solid Sheet. [56]
https://cdn.piedmontplastics.com/production/media/13600/polycarbonate-clear,-white,-and-brown.jpg

It absorbs shocks more than glass and is known for its high impact. Being susceptible to wear, tear, and impact, polycarbonate is largely preferred during construction. Compared with GPR, glass, and thermoplastic, construction workers prefer to work with polycarbonate because it can smoothly absorb shock and give better resistance to hard shells similar to branches and hail. Polycarbonate snipper snapper is one of the advanced plastics that is used to reduce the color

weight of the structure. The main advantages of lightweight polycarbonate are reduced dead weight, rapid installation rate in construction, and lower transportation and handling costs. It is a highly durable material; Strength and continuity are equal to ordinary concrete beams and sliding walls. (60). Corrugated polycarbonate space is a great roofing material that provides superior physical integrity. Corrugated polycarbonate is preferred by non-corrosive synthetic roofing and siding professionals, and by homeowners for many DIY operations, due to its high impact strength and wide service temperature range. (55)

4.1.4 Safety and security:

a. Transparent wood: Natural wood is one of the most important and oldest natural materials used in construction, which does not cause any carbon emissions that harm the environment. Using wood in construction is a way to store carbon because trees contain this element, so the scientist recommended not removing all the lignin in wood in future applications for carbon storage work.

b. rock salt crystals: salt bricks have antibacterial properties. Another property is the absorption of negative ions diffusion in the environment, so it absorbs negative energy in place although the salt inside the salt bricks does not; because the salt bricks need heat to begin the process of negative ion diffusion, Rock salt includes more than 84 chemicals and natural components, including sodium, calcium, potassium, and magnesium, and it has medical benefits, including aiding in the treatment of respiratory and skin issues, as well as several other disorders. Rock salt can also be used to treat nervous system issues, including psychological issues and inhalation relaxation issues. These salt bricks have also succeeded in creating sauna rooms as the hygroscopic properties of the salt are activated, allowing the natural moisture present in the air to condense on the surface of the salt blocks, triggering a natural ionization process. People benefit through this process, as salt purifies the air, providing a healthy environment from which people can reap health benefits, including increasing energy, reducing stress, and improving mood at the biochemical level. On the other hand, light-transmitting concrete salt crystals LUCEM is the latest production used in swimming pools as a source for heat treatment as shown in Fig (7).

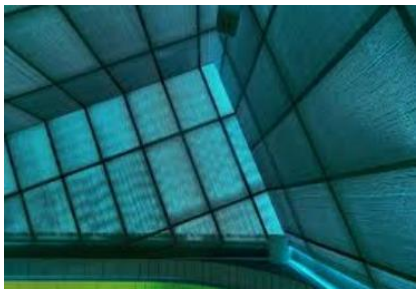

Fig (7) transmitting concrete salt crystals LUCEM in the public swimming pool “Obermaintherme” in the Bavarian city in Germany, 2016

https://inhabitat.com/wp-content/blogs.dir/1/files/2016/12/Krieger-Architekten-Ingenieure-Thermal-Baths3-120x120.jpg

c. **Polycarbonate: The** Polycarbonate panel system is comprised of double or multi-layer polycarbonate material with a U-value of 0.16 which is achieved through layering. But Polycarbonates can be designed to block ultraviolet radiation and provide 100% protection against harmful UV rays; as Installation of UV Absorber protection prevents polycarbonate from exposure to UV rays which can cause rapid deterioration and be responsible for so-called yellow damage and eventually lead to visible light damage. Co-extrusion technology is used for UV protection, through this process a protective layer is produced to enhance the ability of polycarbonate in the ultraviolet part of sunlight. UV protection uses extrusion technology, where a defensive subcaste is produced to test the polycarbonate in the ultraviolet part of sunlight. Using this technology, UV protection is further rainfall resistant and less susceptible to damage due to indecorous adaptation. Polycarbonate is used in glass handling - to strengthen prisons, guard booths, bank security, convenience stores, storm doors, hockey rinks around, and more. Polycarbonate is one of the best choices for safety applications due to its high impact resistance especially blasting and glazing resistance so it is widely used on the roof of a stadium [34] as shown in Fig (8), fig (9), fig (10), fig (11).

Fig (8) Aviva football (soccer) stadium in Dublin, Ireland
https://i.pinimg.com/1200x/2a/d8/3f/2ad83fa7e8a52d225af404c7b306af9b.jpg

Fig (9) The South Railway Station in Shanghai, China.
https://www.travelchinaguide.com/images/photogallery/2013/shanghai-south-station.jpg

Fig (10) Amsterdam Arena in the Netherlands
https://media.coliseum-online.com/2020/01/Coliseum-Summit-news-Johan-Cruijff-ArenA-January-2020-update.jpg

Fig (11) Śląski Stadium in Poland.
https%3A%2F%2Fc8.alamy.com%2Fzooms

Polycarbonate is well known as thermoplastic with great impact resistance and high-temperature resistance capacity which makes it withstand all kinds of climatic conditions; Which results in making polycarbonate as most sustainable material in the world. It can absorb sun heat and reflect harsh sun rays due to which it works as a good insulating as well as heat thermal material enhancing the usability of material in hot and dry climatic zones. As well as it works as a temperature control material when used in cold regions due to the heat absorption property of the material

4.2 Estimating the flexibility of the transparent sustainable materials:

4.2.1 flexibility in forming appealing configurations:

a. Transparent wood: is an appealing sustainable building material in contrast to other building materials like stone or concrete that contain sand. It shares in the creation of stunning architectural designs from natural wood fibers it can be used to make windows, walls, and roofs that let natural light into a building, also because it is produced in the form of standard panels it can share in forming various appealed forms as shown in fig (12)

Fig (12) Parking Garage building in Zutphen made out of Translucent Wood_©foreco.nl
/ww.foreco.nl/media/4223/safewood-select-parkeergarage-z

The Advanced methods of producing transparent wood rely on removing lignin from the wood while preserving the original color of the wood. Therefore, different types of wood have slightly different colors. Manufacturers make clear wood from different types of wood such as balsa, pine, birch, and ash. The color of wood varies and the color of balsa is almost white, while other species have a yellow tint, ash is only slightly yellow, birch is slightly yellow, and pine is rather saturated yellow, so it is possible to create very interesting patterns on the facade only using different types of wood. Another advantage is that the interior space will be filled with positive yellow light, which can improve the mood of the people living there. [49]. [50]

b. Rock salt crystals: The color of the obtained rock salt affects the color of the salt chip used to divide the color spectrum, as White, White Streaks, Brown, Orange, and Red. The mixture of colors that salt brick has, depending on its natural chemical compounds, increases the beauty of the salt wall. Using natural lighting or LED lights makes salt block walls artistic and displays them in a very elegant and inviting manner as shown in Fig (13).

Fig (13) Himalayan Salt Rock Room

https://i1.wp.com/spa-solutions.net/wp-ploads/2017/07/himalayansaltspa-1.png?fit=535%2C293&ssl=1

c. Polycarbonate: is a plastic compound that can be easily shaped by heat, resulting in a variety of products with curvy or complex shapes. Polycarbonate sheets are shaped like steel. Due to its formability, various construction techniques made of polycarbonate seek to capitalize on its applications in many forms of construction, from flexible panels to fixed arches. A common use of polycarbonate is flat and curved dome lights for roofing as shown in Figure (14), Figure (15), and Figure (16).

fig (14) various shapes formed by polycarbonate
https://www.palram.com/wp-content/uploads/2022/05/ezgif-5-701f28b86a-1.jpg

fig (15) BBVA Compass Stadium in Texas
https://images.mlssoccer.com/image/private/t_editorial_landscape_8_desktop_mobile/mls-orl-prd/ck1zwgctvmyaid1zjvwo.jpg

fig (16) SABIC Building in Massachusetts
https://extechinc.com/wp-content/uploads/2016/07/GE-Pittsfield-exterior-2.jpg

Corrugated polycarbonate varies between Clear, Opal, and Smoke, [55] and is also available in various colors. Its dimensions are as follows:

2ft. width x 8 ft. length
2 ft. width x 10 ft. length
2 ft. width x 12 ft. length
Note: actual widths 26 inches
4 ft. width x 8 ft. length
4 ft. width x 12 ft. length
4 ft. width x 16 ft. length

- Note: The actual width of Corrugated polycarbonate is 50 inches and its depth is 3 inches.

4.2.2 The use and applications in various building elements and functions:

a. Transparent wood; One of the latest applications in which transparent wood is used, and for which designers and scientists are working to develop its properties, is the inclusion of

quantum dots in wood to create light diodes (LEDs), this idea focuses on developing and improving the specifications of wood so that it can be used as ceiling boards that can offer light directly from it, so indoor lighting can be achieved directly from the ceiling. The diffused, transparent light that comes from wood is more aesthetically pleasing and more natural-looking than point source light. These panels are merely one of the numerous uses created by several businesses that are heavily involved in interior designs and exterior facade treatments today. Transparent wood is light and sturdy in contrast to glass, which can be cumbersome and delicate. Due to this, it is perfect for use in a variety of applications, including furniture, partitions, bridges, and building facades. A very interesting fact about transparent wood is that it is a more durable material than the natural wood from which it is made and also more durable than the polymers used in its making. For this reason, transparent wooden texture elements are not only an elegant solution but also a very clever one. The only problem is that such beams will not transmit much light but the whole structure will be much lighter and more attractive. And.it is predicted to use transparent wood in forming light and transparent trusses and Vierendeel truss structural systems. [12]

b. rock salt crystals: It is not possible to benefit from rock salt stones since the salt stones are consolidated blocks that must be changed into specific dimensions to create salt bricks which are widely used in the construction process of buildings with salt walls. The standard dimensions of white salt bricks, and orange salt bricks, are 10 * 20 * 5 cm, 10 * 10 * 3 cm, and 5 * 18 * 3 cm. Salt bricks are used to create and manufacture useful products, some of which are notable and useful as follows:

- Build a variety of salt walls shown in Fig (3)
- Making salt rooms; (as walls and floors), shown in Fig (13)
- Building salt domes and slaps, shown in Fig (3)

c. polycarbonate: is widely used in windows, ceilings, roofs, partitions, and fixed and flexible walls as shown in Fig (17) it is a highly effective thermoplastic material that has many features that are very useful for different applications, and it's durability and lightweight and sturdy has high optical clarity and its other properties such as high impact and extreme high-temperature resistance and excellent heat resistance properties also play a major role in the application of the material in such places.

Fig (17) The usage of polycarbonate as fixed or portable partitions.
https://www.spec-net.com.au/press/0617/por_070617/images/por070617_img01.jpg

5. Estimating the concept and common features of Smart and sustainable transparent materials:

The following table is used to estimate the extent of developing transparent materials in the form of applications and reaching efficiency.

Table no (1) the correlation between transparent materials and cues of efficiency.

Points of analysis		Means of efficiency	The applications	Sustainable transparent materials		
				Transparent wood	Crystal salts	polycarbonate
EFFICIENCY	Light efficiency	Optimizing the quality of light with no need for extra applications	Used in the outer envelope of the buildings	√	√	√
	Energy efficiency	thermal insulation capabilities		√	√	√
		Minimize the amount of light lost through reflection.	Used in smart windows	√		√
			Used in solar panels	√	√	
		The composition of the material can be flexibly changed	energy storage device	√	√	
		Need low energy for production		√	√	√
	durability and maintenance	Fire resistance	Indoor and outdoor elements	√		
		strong		√		√
		weatherproof		√		√
	Safety and security	Has no carbon emissions	Used as any element in architecture safely	√	√	√
FLEXIBILITY	flexibility in forming configurations					√
	appealing material	Good feature	Used as any element in architecture	√	√	√
	the ability to be used in various elements and functions of the building	Can be fitted by quantum dots	The transparent wood ceiling panels as lighting systems	√		√
		light and sturdy	furniture, partitions, bridges, and building facades	√	√	√

From the previous analysis it is shown that every material has reached a specific development in the scope of transparency as follows:

a. Transparent wood: creates many opportunities for high levels of visual haze, which allows light to enter but blocks the view, and it can be used to illuminate the interior space through walls and partitions on the facades or inside. The use of transparent wood contributes to significantly reducing energy consumption costs in buildings. It can also be used as a cover for solar panels and improve their efficiency due to its transparency and ability to reduce the amount of light lost through reflection. The degree of light scattering within it can be improved so that it can absorb more energy and turn the wood into a device that stores energy during the day and releases it at night.

b. Rock salt crystals: The optical transmittance of rock salt crystals is high, so they have been used in optical components (windows and prisms) in this visible range. They are also low-cost and healthy, and it is preferable to use rock salt in dry places or for short-term applications. Rock salt crystals are used for energy storage in indirect sun dryers. The arrangement of the rocks in the drying chamber has a significant impact on the high temperature reached during the time of sunshine as well as on the duration of the thermal discharge phase, which may reach four hours in the absence of sunlight.

c. Polycarbonate: polycarbonate panels provide the best opportunities for natural lighting as a major element resulting from another step towards sustainable building design. They not only allow light to enter the built space but also control the amount of light entering the interior space through facades or skylights. It also provides daylight to the building, resulting in reduced electricity consumption and increased energy efficiency. Its energy storage capabilities can be enhanced in a multi-walled form. Polycarbonate also protects against infrared rays.

6. Conclusions:

- The use of transparent materials has become included in all smart systems and applications, and researchers are focusing on improving the properties of these materials and how to increase their efficiency to benefit from it by improving the penetration of daylight into interior spaces through visual facades.
- The research focused its study on three of these transparent materials: transparent wood, rock salt crystals, and polycarbonate. Architecture benefits from the use of these materials in many applications that save energy consumption by taking advantage of natural lighting, reducing glare, and reducing heat absorption. This improvement prevents the addition of shading and insulating systems to adapt to the sunlight used in natural lighting and reduce its damage.
- The study revealed the importance of transparent materials in all smart systems and applications that increase the energy efficiency of buildings. The scientists also focused on improving the properties of these materials and increasing their efficiency to benefit from them in increasing the permeability of daylight into interior spaces to save energy consumption.
- Transparent materials are distinguished by their strength and durability, but with values that differ from each other. Through various experiments and uses of these materials, researchers have been keen to improve their durability and increase their efficiency to

benefit from them more in various building applications. For example, the lignin in wood was replaced with, polymers to make it fire-resistant and five times stronger, and it also increases its resistance to weather factors. Building bricks were also manufactured from rock salt made from a mixture of sea salt and starch. When tested, the bricks proved stronger in compression than rammed earth, a material often used in desert construction, and were therefore attractive for use in making the vaults and arches common in traditional desert architecture. Rigid polycarbonate sheets are also very durable and resistant to shocks, but they are lightweight, as they weigh half the weight of glass panels and are almost unbreakable. Polycarbonate also shows good resistance to chemicals, refined acids, aliphatic hydrocarbons, and alcohols.

- It also shows the importance of using sustainable, transparent materials in the construction process because they have safe and harmless properties and do not negatively affect the environment or the general health of humans. Materials and construction processes contribute 11% of all global carbon emissions over the life cycle of a building. So using wood in construction is a way to store carbon since trees contain this element, so the scientist recommended not removing all the lignin in wood in future applications for carbon storage work. Rock salt crystals also play a good role in preserving the environment, as salt bricks have antibacterial properties in addition to absorbing negative ions spread in the environment. Rock salt contains more than 84 chemicals and natural components, including sodium, calcium, potassium, and magnesium, and has medical benefits, including helping treat respiratory and skin problems. When inhaled, Rock salt can also treat nervous system problems, including psychological and relaxation problems. It was also shown that polycarbonate can be used to block ultraviolet rays and provide 100% protection from harmful ultraviolet rays. Polycarbonate is one of the best choices for safety applications due to its high impact resistance, especially blast and glass resistance.

- Transparent materials are also flexible and able to create attractive compositions. For example, translucent wood creates stunning architectural designs from natural wood fibers. It can be used to make windows, walls, and roofs that allow natural light into the building, and its standard panels can also form attractive multi-colored shapes. Therefore, it is possible to create very interesting patterns on the facade. The color of rock salt also affects the division of the color spectrum, such as white, white stripes, brown, orange, and red, and gives a mixture of colors that doubles the beauty of the walls. The use of natural lighting or lamps also makes salt brick walls very artistic and attractive. Salt also purifies the air, reduces stress, increases energy, and improves mood. Polycarbonate also offers many advantages due to its lightness and unlimited possibilities to create an elegant appearance compared to glass. It is also flexible in design and easy to install. It can also easily undergo a thermoforming process, resulting in a variety of sinuous or complex shapes. Various polycarbonate construction techniques simplify many building features, from fixed arch curves to flexible panels.

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