The Impact of Materials and Design Procedures Used in Architectural Facades on Improving the Thermal Performance of the Building's Inner Environment for Hot, Dry Climate Cities, Baghdad /Original Article

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تأثير المواد والإجراءات التصميمية على تحسين الأداء الحراري للبيئة الداخلية للمبنى في المدن ذات المناخ الحار الجاف / بغداد مثالا

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Abstract

The research idea addresses improving the thermal performance of buildings in Baghdad by selecting and employing facade materials to reduce heat gain and energy consumption associated with cooling in a hot-dry climate. The study discusses the pivotal role of facade materials in interacting with solar radiation, heat transfer, and inward thermal transmittance, as well as their capacity to store and release heat in ways that maintain thermal comfort within architectural spaces and reduce reliance on mechanical cooling systems. A range of traditional materials such as stone, earth, and concrete is presented alongside modern materials like high-performance glass and thermal storage materials—phase change materials (PCMs)—with an explanation of the variation in their heat-gain performance by measuring their effectiveness in buildings where they have been used, their costs, and their adaptability to Baghdad's climate. The idea also proposes integrating traditional and smart materials within an integrated design framework to achieve functional distribution and appropriate insulating layers, while taking into account local climate, economic, and environmental factors. The overall notion indicates that improving a building's thermal performance requires a rigorous design approach that balances functional and economic factors, thereby contributing to reduced energy consumption, increased thermal comfort for occupants, and the sustainability of buildings in the face of climate change

Keywords: Heat load, Architectural facades, Thermal insulation materials, Phase change materials (PCMs), Energy efficiency, Hot and dry climate

المستخلص

تتناول فكرة البحث تحسين الأداء الحراري للمباني في مدينة بغداد من خلال اختيار وتوظيف مواد الواجهات لتقليل الحمل الحراري واستهلاك الطاقة المرتبط بالتبريد في البيئة الحارة – الجافة. يتناول البحث الدور المحوري للمواد في الواجهات في التفاعل مع الإشعاع الشمسي، ونقل الحرارة، ونفاذيتها نحو الداخل، إضافة إلى قدرتها على تخزين الحرارة وإطلاقها بطريقة تحافظ على الراحة الحرارية داخل الفضاءات المعمارية وتقلل الاعتماد على أنظمة التبريد الميكانيكي. وتم عرض مجموعة من المواد التقليدية كالحجر والتربة والخرسانة، إلى جانب مواد حديثة مثل الزجاج عالي الأداء ومواد التخزين الحراري :المواد متغيرة الطور (PCM)، مع توضيح تفاوت أدائها في الحمل الحراري من خلال قياس كفاءتها في الأبنية التي استخدمت فيها والتكاليف والقدرة على التكيف مع مناخ بغداد. كما يطرح فكرة الدمج بين المواد التقليدية والذكية ضمن إطار تصميمي متكامل لتحقيق توزيع وظيفي وطبقات عازلة مناسبة، مع مراعاة عوامل المناخ المحلي والاقتصاد والبيئة. وتُشير الفكرة العامة إلى أن تحسين الأداء الحراري للمبنى يتطلب نهجًا تصميميًا محكمًا يوازن بين العوامل الوظيفية والاقتصادية، ما يسهم في تقليل استهلاك الطاقة ورفع معدل الراحة الحرارية للمستخدمين واستدامة المباني في ظل التغيرات المناخية .

الكلمات المفتاحية: الحمل الحراري ، الواجهات المعمارية ، مواد العزل الحراري، المواد متغيرة الطور، كفاءة الطاقة ، المناخ الحار الجاف.

1. Introduction

The city of Baghdad is considered one of the cities facing significant challenges regarding controlling the thermal load of buildings, due to the hot and dry climate. The materials used in architectural facades play a vital role in reducing the thermal load and improving energy efficiency in buildings. The selection of suitable materials can greatly contribute to improving thermal comfort inside buildings and reducing the energy consumption required for cooling.

The materials used in architectural facades include a variety of options, such as fired clay bricks, hollow concrete, glass panels, Thermstone, and granite. Each has a different impact on external and internal thermal comfort. Smart materials, such as phase change materials (PCM), can also be used in facades to improve thermal performance. These materials work by storing and releasing heat, helping to reduce peak temperatures inside buildings during hot summer periods. Incorporating these materials into the facade design can lead to improvements in energy efficiency and reduction of thermal load. Therefore, choosing appropriate materials and design procedures for architectural facades in Baghdad can have a significant impact on reducing thermal load and improving energy efficiency, contributing to achieving a more comfortable and sustainable living environment.

1.1. Research Problem and Question

The research problem lies in the lack of clarity regarding how to use materials and apply appropriate design procedures together in the architectural facade design of buildings in hot, arid urban environments, including Iraqi cities, with the aim of reducing heat load and improving energy consumption efficiency. This problem includes studying the impact of different materials on the thermal performance of buildings and how to integrate thermal insulation technologies: materials and design procedures to achieve a comfortable and sustainable indoor environment.

As for the research question:

What is the impact of using materials and design elements in the architectural facade design on reducing the heat load in buildings, and how can energy consumption efficiency be improved by integrating thermal insulation technologies and materials in the facades of buildings in Iraqi cities?

1.2. Research Objectives

The research aims to achieve the following objectives regarding the impact of materials used in architectural facades on reducing heat load in Iraqi cities:

a. Analyze the effect of applying insulating materials in facades, including phase change materials (PCM): exploring the use of phase change materials in facades to store latent thermal energy, and their impact on reducing energy consumption and improving energy efficiency in buildings.

b. Analyze and compare the effect of using local insulating materials in reducing heat transfer through facades, thereby reducing energy consumption for cooling.

c. Develop a strategy for designing sustainable facades using materials and techniques to enhance the thermal performance of buildings in hot climates.

2. Theoretical framework

2.1. Thermal loads in buildings

Thermal loads in buildings refer to the amount of energy required to heat or cool a building to maintain a comfortable temperature. These loads are influenced by several factors such as building design, construction materials, and the ratio of windows to walls. In Iraq, especially in Baghdad, thermal loads are a major challenge due to the harsh climatic conditions, with temperatures reaching very high levels in summer.[1],[2],[3]

The hot climatic conditions in Baghdad require the use of highly efficient air conditioning systems to meet cooling needs. Studies indicate that proper orientation of buildings can significantly reduce thermal loads. For example, orienting a building toward the north can reduce heat loads through glass by up to 24.9% [1]. The use of insulating materials can also reduce annual heat loads by up to 55% [2]. Some techniques are used to improve the thermal performance of buildings, such as the use of insulating materials such as gypsum and high-density concrete, which can reduce annual heat loads by up to 49% when the building is covered with 5 cm thick thermal insulation.[3] The integration of phase change materials (PCM) into building walls can also significantly reduce energy consumption for cooling.[4],[5]

Therefore, managing thermal loads in buildings in Baghdad is a major challenge due to the harsh climatic conditions. Significant improvements in thermal performance can be achieved

through proper orientation of buildings, use of effective insulation materials, and integration of technologies such as phase change materials. Urban design strategies should also take into account the preservation of green spaces.

2.2. Architectural facade elements and their impact on thermal performance

Architectural facades are key elements that affect the thermal performance of buildings, playing a vital role in improving energy efficiency and thermal comfort. In the context of buildings in Baghdad, it is important to choose appropriate materials and designs for facades to achieve a balance between aesthetics and thermal functionality.

The materials used in facade design greatly affect the thermal performance of buildings. In Baghdad, the effect of five types of materials commonly used in facades on outdoor thermal comfort was analyzed. These materials include fired clay bricks, hollow concrete, glass panels, and granite. The results showed that the materials used in tall buildings have a significant impact on thermal comfort, while the impact was less in low-rise buildings [6]. Glass facades are also a common feature in modern designs, but they can lead to an increase in the thermal load of buildings. Therefore, it is important to use design strategies that take energy use and thermal comfort into account from the outset. In hot and humid climates, improving the design of glass facades can reduce heat load and increase thermal comfort [7]

There is also a trend toward using what are known as dynamic facades, which studies have shown to be innovative solutions that can significantly improve thermal performance, especially in hot and dry climates such as Baghdad. For example, dynamic facades can reduce energy consumption by up to 46% during the cooling season [8]. (Figure 1)

Therefore, there is a need to integrate dynamic systems and smart materials into facade design to achieve better thermal performance. It adapts to different climatic conditions and achieves a balance between aesthetics and thermal performance, especially in environments such as Baghdad. By selecting the appropriate materials and applying dynamic designs, improvements in energy efficiency and thermal comfort can be achieved, contributing to environmental and economic sustainability.

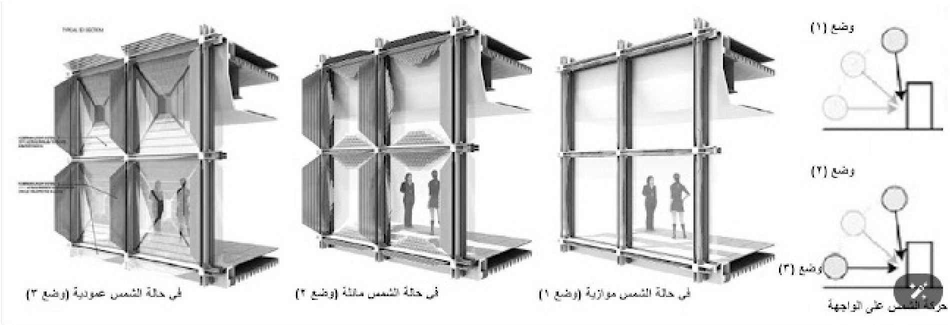

Figure (1) Dynamic facades: Source: Diwaniya Architecture website

2.3. Facade design strategies to reduce thermal loads

Facade design strategies are key factors in improving energy efficiency and reducing thermal loads in buildings. These strategies involve the use of innovative materials and techniques aimed at improving the thermal performance of buildings, especially in hot climates such as Baghdad. These strategies include:

Double skin facades (DSF)

Double skin facades are an effective solution for reducing thermal loads. These façades provide additional thermal insulation by creating an air gap between the two layers, which helps reduce heat loss in winter and heat gain in summer. Studies have shown that the use of double-skin façades can significantly reduce energy consumption, especially when combined with technologies such as solar chimneys.[9],[10] As shown in Figure (2).

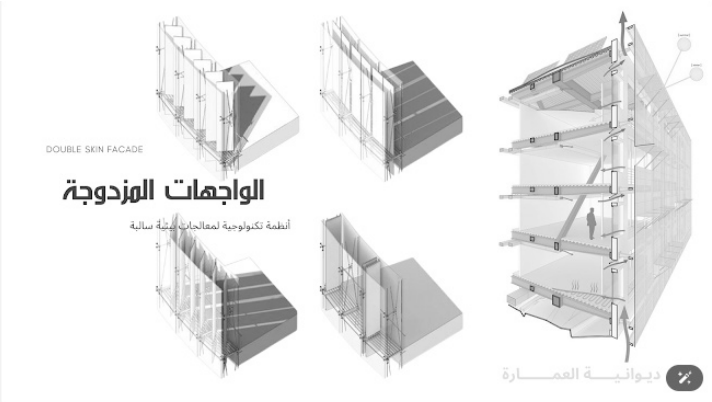

Figure (2) Two-layer facades: Source: Diwaniyat Al-Amara website

The impact of orientation, shading, and passive design strategies

Building orientation and the use of shading techniques play an important role in reducing thermal loads. Proper building orientation can minimize direct exposure to sunlight, while shading can reduce heat gain through glass surfaces and roofs [1]

The basic principles of passive solar design are also considered one of the influential factors in improving the efficiency of energy consumption within facilities, and the importance of applying these principles to achieve an effective thermal balance is increasing, as architectural elements such as wall and hallway thicknesses, insulation materials, and window areas and locations directly contribute to reducing internal thermal loads, by incorporating passive solar design elements, reliance on air conditioning systems can be reduced, which contributes to saving energy and improving the indoor quality of life for users, in the context of implementing architectural strategies, a careful analysis of thermal comfort factors is required.[11] It is clear that personal thermal comfort is related to several health and social factors, and therefore, passive solar design should include considerations related to the psychological and social comfort of the occupants.

Conducting studies to measure temperature, humidity, and overall site visibility is also considered necessary to ensure a sustainable design that aligns with human needs, which enhances the livability within built spaces and reduces energy consumption rates. The application of passive solar design principles is not limited to improving energy efficiency only, but also extends to integrating appropriate thermal insulation strategies with it. Studies indicate the importance of architectural features such as the building facade and the window-to-wall ratio, which significantly affect energy consumption. In a study on this subject and its applications in the city of Baghdad (the study on insulating wall thickness), the results confirmed that the ideal insulation thickness should exceed 11cm to ensure energy saving and achieve lower levels of energy consumption for cooling.[11]

Use of Thermal Insulation in Buildings

Thermal insulators are considered an essential element in the design of modern buildings, as they play an important role in improving energy consumption efficiency and reducing heating and cooling costs. Research indicates that significant reductions in thermal loads can be achieved by using materials such as rock wool and polyurethane foam. According to a study conducted by Al-Mansoori, good insulation can reduce heat transfer by up to 35%, contributing to energy savings and reducing carbon emissions.[12]

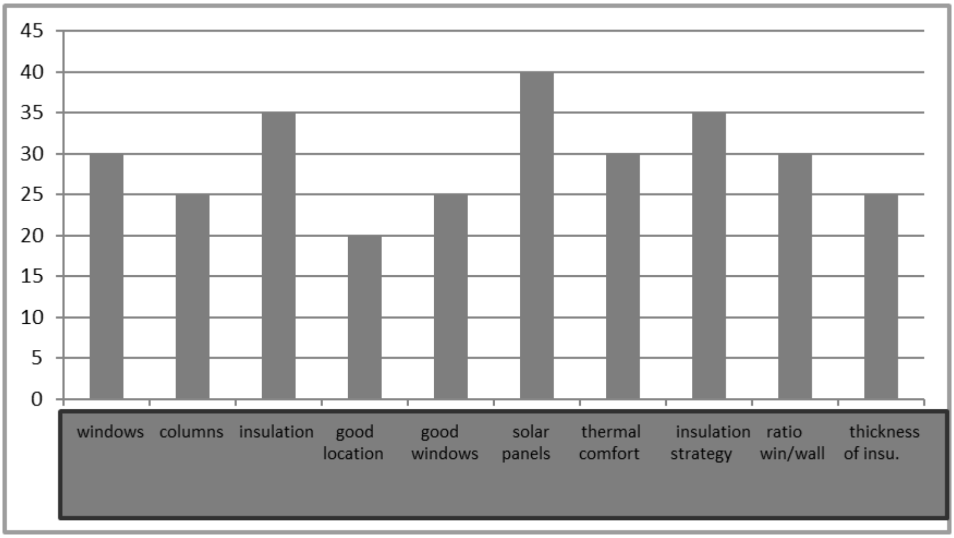

Figure (3) Impact of various passive solar design elements on energy efficiency and occupant comfort.[11]

From the above Figure (Figure 3), it can be seen that the highest percentage was for incorporating passive solar design elements, which obtained 40%, and the lowest was for choosing the optimal location of the building, which was 20%.

The Central Statistical Organization (Urban Statistics Department), 2012, Ministry of Planning - Iraq, has established a number of facts about insulation materials based on laboratory experiments, summarized as follows:

1. The use of natural or synthetic packaging materials, whether internal or external, does not bring the overall heat transfer coefficient within international standards. It remains higher than the permissible limit, so it is necessary to add thermal insulation materials to the walls
2. Internal packaging materials reduce the heat load by a higher percentage than external packaging materials for both natural and synthetic materials.

3. Modern packaging materials currently available in the local market are not characterized by different thermal specifications than natural ones. Therefore, the use of either of them gives the same heat load value, and there is no difference between them except in terms of aesthetics, appearance or cost.[13]

Phase Change Materials: PCM

Phase change materials (PCM) are a recent innovation used to improve the thermal performance of buildings. These materials store and release heat as temperatures change, helping to achieve thermal stability within the building. (Figure 4). In Baghdad, these materials can be effective due to the large temperature changes between day and night.[14],[2] Phase change materials are materials capable of absorbing and releasing a huge amount of latent thermal energy by changing their state from solid to liquid within a small temperature range. These materials go through a series of phases in which their physical states change between solid and liquid due to temperature fluctuations, resulting in the storage of a quantity of energy. This process is known as thermal potential energy (Figure 4), where a large amount of energy is stored or released in a small temperature range. The melting point of phase change materials ranges from 19 to 28 degrees, and phase change materials can store thermal energy more than fourteen times per unit volume. The energy storage of traditional building materials can be increased by directly incorporating phase change materials into building materials. These materials can be integrated with different building materials such as bricks, concrete, gypsum board, cement mortar, glass, etc..[15]

As for the possibility of using phase change materials in Baghdad buildings (Figure 5), these materials can be an innovative solution to improve thermal performance. Given the high temperatures in summer, these materials can help reduce the need for air conditioning by storing excess heat and releasing, This can lead to improved thermal comfort and reduced energy consumption.[2],[14]

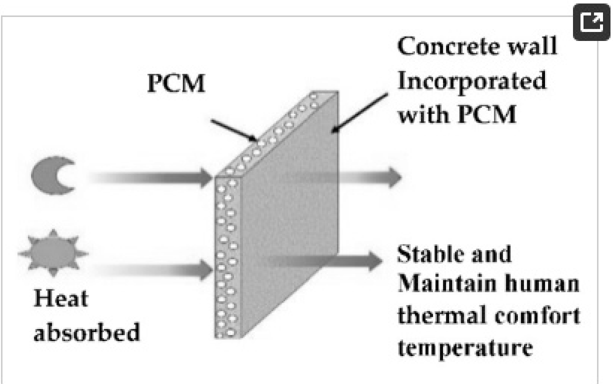

Figure 4: The effect of using phase change materials on heat stabilization in the indoor environment. Source: [https://www.mdpi.com/1996-1944/15/23/8428]

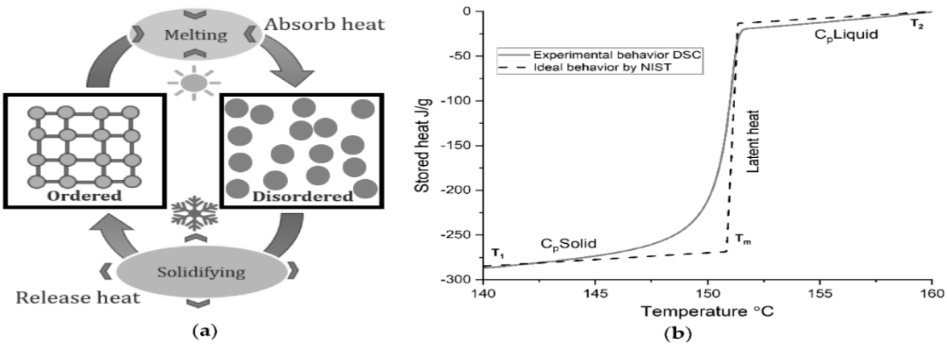

Figure 5: Release and storage of latent heat in phase change materials. Source: [https://www.mdpi.com/1996-1944/15/23/8428]

Facade design strategies such as the use of two-layer facades, phase change materials, vacuum panels, thermal insulation, building orientation, and passive design strategy can significantly contribute to reducing thermal loads and improving energy efficiency in buildings, especially in regions with hot climates like Baghdad, these strategies help improve thermal comfort, and also contribute to reducing energy consumption and carbon emissions.

2.4. Displaying samples of materials used in facades in buildings in cities with a hot and dry climate, including Iraqi cities / Baghdad

Cities with hot, dry climates - including Iraqi cities - have experienced significant climatic changes as a result of rapid urbanization and changes in land use. These changes have significantly affected the city's microclimate, resulting in higher temperatures and lower levels of humidity and vegetation cover.

Iraqi cities, including Baghdad, have witnessed significant urbanization since 2001, with built-up areas increasing from 863 km^2 to 1469 km^2 by 2020. The expansion continues to increase to this day.

This urbanization has led to a decline in agricultural areas and vegetation, contributing to an increase in surface temperatures.[16],[17]

Rapid urbanization since the beginning of the new millennium has led to an increase in daily minimum and maximum temperatures in Baghdad by 3 and 2°C respectively between 2000 and 2015.[18] Studies have shown that temperatures in Baghdad are increasing significantly, with surface temperatures increasing from 26-47°C in 2001 to 32-56°C in 2020.[16] However, there is a positive trend for annual temperatures in Baghdad, as the data showed an increase in maximum and average temperatures - as shown in the table of Iraqi climate data (Thermal Insulation Code: Table 2) - while there were slight decreases in minimum temperatures.[19] In terms of climate change in Baghdad, it is manifested in higher temperatures and lower relative humidity and precipitation rates, indicating a climate trend towards drought.[20]

Rapid urbanization and changes in land use in Baghdad have led to noticeable climate changes, including rising temperatures and decreasing vegetation cover.

This requires strategies to mitigate their negative effects on the local environment and the indoor environment of buildings.

Table (2) : Iraqi climate data. Source: Iraqi Thermal Insulation Blog 2013

No.	City	Design Dry Temperature		Humidity		Average daily thermal range	Elevation above sea level	Latitude	Altitude
		Summer	Winter	Summer	Winter				
1	Baghdad	47	1	16	82	18.7	34.1	33.23	44.23
2	Basrah	47	2.5	38	89	15	2.4	30.57	47.78
3	Mousul	46	0.5	18.5	90	18.5	223	36.32	43.15
4	Sulaymaniyah	42	1.5	2.5	77	15	853	35.55	45.45
5	Kirkuk	46	2	14	81	16	331	35.47	44.40
6	Najaf	48	4	14	82	17	50	32.0	44.32
7	Simawa	47	4.5	14	85	13.5	6	31.30	45.25
8	Sanchar	42	1.5	17	78	12.5	538	36.32	41.83
9	Haditha	46	1	18	98	15	108	34.07	42.37

In terms of the built environment, the building materials used in the city of Baghdad have varied throughout history, as traditional buildings used straw and clay for construction, which had a large heat capacity and were suitable for the reality of the city, and these materials evolved over time to include clay bricks, cement blocks, reinforced concrete and other types such as ACM aluminum panels, double glazing, ceramics and porcelain, which we will mention, their properties and comparison between them.

Clay bricks have been extensively studied for use in building facades in Baghdad's hot, dry climate. Research has shown that facade materials, including clay bricks, significantly affect thermal comfort in high-rise buildings.[21]

Ordinary cement blocks have many advantages for use in Baghdad's construction sector. It offers good thermal performance, with potential energy savings of between 1.2% and 13.88% compared to traditional materials.[22] Modern brick factories in Baghdad can produce environmentally friendly bricks using advanced technologies, minimizing pollutants and environmental impacts compared to traditional methods.[23] However, traditional brick manufacturing can lead to environmental damage, including air pollution with volatile organic compounds, fine particulate matter, and gases such as nitrogen dioxide and sulfur dioxide, and there is support for modern and environmentally friendly brick production methods in Baghdad.[23] The building materials used in facades and their thermal properties can be summarized through as illustrated in (Table 3).

Table(3) : Thermal properties of facade materials [24]

Material	Thermal conductivity (W/m2k)
Solid Brick	0.54
Perforated Bricks	0.36
Lime Brick	1.23
Thirmston	0.21
Concrete blocks	1.2
Hardened concrete	1.49
Cement mortar	1.14
Plaster	0.36
Marble	2.5
Mosaic	2.02
Asbestos Slabs	0.6
Plastic tiles	0.46
Fiber	0.25
Tar	0.24

Building materials differ in their thermal conductivity. Thermstone, fiber, and tar are the best heat insulation materials with very low conductivity, making them suitable for hot climates like Baghdad. On the other hand, hard concrete, marble, and Kashi mosaic have a high thermal conductivity, making them heat-conducting and needing additional insulation layers. Perforated bricks outperform solid thanks to their voids that reduce thermal conductivity, while mortar and plaster provide relatively average insulation. Choosing materials with low conductivity helps improve the energy efficiency of buildings.

2.5. Study of shading systems and solar reflectors

Shading systems on building facades and solar reflector systems are effective solutions for improving the energy efficiency of buildings (Figure 6) , especially in hot and dry climates. These systems aim to reduce solar heat gain and improve thermal comfort inside buildings. Shading systems are used to reduce the solar radiation entering the building, thereby reducing the need for artificial cooling. These systems involve the use of techniques such as self-shading facades, where the shape of the facade or its components are designed to provide partial protection from solar radiation. These strategies can reduce heat gain and improve the energy efficiency of buildings.[25],[26]

Figure (6): Different shapes of horizontal and vertical solar refractors on building facades.
Source: [https://www.linkedin.com/posts/aymanmelouk_%D8%A7]

Solar reflectors are a popular solution in hot climates, reducing direct solar radiation on windows and walls. In a study conducted in Saudi Arabia, the use of solar panels integrated into buildings as shading devices was evaluated, and it was found that horizontal devices with a 45-degree angle of inclination were the most effective in providing shade and generating electricity.[27] Another study showed that the use of solar reflectors can save up to 26.1% of total energy consumption in buildings with all-glass facades in hot climates.[28] Shading systems and solar reflectors are vital tools for improving the energy efficiency of buildings in hot and dry climates. By reducing solar heat gain, these systems can reduce energy consumption and improve thermal comfort inside buildings. The strategic design of these systems, such as choosing the right angles and materials, plays a crucial role in achieving optimal performance.

2.6. Analyze and evaluate the thermal insulation values of the facades (with materials, with breakers, both)

Building facades are one of the key elements that affect the thermal performance of buildings, especially in hot climates. The thermal insulation strategies used in these facades vary between the use of traditional insulation materials, solar reflectors, and air-gap facades. As previously discussed.

With regard to insulation materials:

Studies have shown that the use of insulating materials such as reflective coatings and advanced materials such as phase change materials can significantly improve the thermal performance of facades. Coatings with high reflectance values can reduce surface temperatures by 2.62°C in summer and reduce annual cooling loads by 13.78%, while the use of phase change materials as an internal layer can improve internal temperatures by 1.83°C and reduce annual cooling demand by 13.23%.[29]

As for solar panels:

They are an effective solution in reducing direct solar heat gain, improving thermal comfort and reducing energy consumption. Studies have shown that the use of solar reflectors with a reduced window-to-wall ratio can significantly reduce indoor temperatures and cooling loads [30]. Solar reflectors can reduce the internal temperatures of buildings by 1.24 to 3.04°C in hot climates, contributing to significant energy savings.[31]

When comparing the effectiveness of insulation materials and solar reflectors, we find that each offers unique advantages. The comparison shows that the use of insulating materials and solar reflectors can significantly contribute to improved thermal insulation of building facades, improvements in thermal comfort, and reduced energy consumption in hot climates. To achieve the best results, a combination of different strategies is preferred to achieve an optimal balance between the thermal performance of the building and the thermal comfort of the users.

3. Analyzing examples

There are different types of technical elements to address the facades of buildings, including:

- Movable Louvers
- Double Skin Facade
- Thermally treated facades
- PV Facade
- Solar Filters - Solar Filters
- Windows Intelligent Windows

All of them have a clear impact on reducing the energy used in the building, as shown in some examples below:

• **Kiefer Technic Showroom Building**

Showroom designed by Ernst Giselbrecht + Partner, 2011 and located in Austria (Figure 7). The building is a showroom and office building with facades that move according to the general weather conditions, (a dynamic facade consisting of 112 aluminum panels that move and fold in rows).

Figure (7): Kiefer building facades
Source: [https://www.archdaily.com/89270/kiefer-technic-showroom]
.[32] Energy Savings Ratio = 8.9 - 38.5%

• **AL Bahr Towers**

Al Bahr Towers 2012 are two 25-story oval-shaped towers in Abu Dhabi. The idea comes from the traditional mashrabiya, a perforated wooden curtain with geometric patterns inspired by traditional Islamic architecture. The Mashrabiya envelope partially wraps around the towers to shield them from the scorching desert sun to the south, revealing the northern part of the facades. The mashrabiya consists of transparent umbrella-like modules that open and close in response to external solar conditions. Sensors mounted on the facades send data on solar conditions to the Building Management System (BMS), a centralized, automated control system to manage the operation of various building systems, including HVAC and vertical transportation. The south roof of each building incorporates photovoltaic cells to generate enough energy to power the mashrabiya system. The system avoids the use of dark glass, which inevitably reduces light penetration. Instead, the system lets in daylight for part of the day, minimizing the need for artificial lighting. (Figures 8 and 9).

The towers are one of the first buildings in the Gulf region to receive a silver green rating from the U.S. Green Building Council's LEED program.

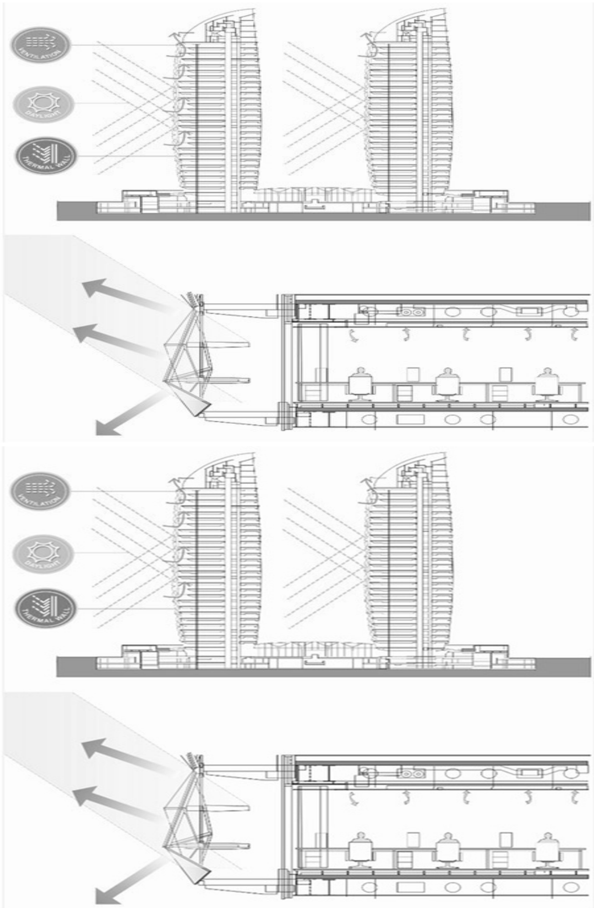

Figure (8). Al Bahar Towers, Abu Dhabi, United Arab Emirates: Illustration by P. Armstrong Source:[33]

Energy saving rate: Prevents 50% of sunlight from penetrating the building [33]

Figure (9): External facades of Al Bahar Towers/Abu Dhabi.
Source: [https://www.albayan.ae/editors-choice/asfar/2015-11-23-1.2512401]

- **Building: Phoenix Central Library**

The Phoenix Central Library building in Arizona was designed by DLR Group, a renowned architectural firm known for sustainable projects. It was inaugurated in 1995, with subsequent updates and expansions to maintain service levels and technology. The building uses energy-reflective materials that contribute to energy efficiency. It features a façade design with dynamic sunshades on the south side, as shown in (Figure 10)

Figure (10): The south facade of the Central Library building in Phoenix.
Source: [https://www.albayan.ae/editors-choice/asfar/2015-11]
Energy savings percentage: 1.3 – 9.2 %

- **Buildings of the King Abdullah Financial District in Riyadh**

The building uses insulation materials and insulation techniques in its facades to ensure good performance in the desert climate.(figure11) These include: Double skin facades, solar shading, and thermal insulation to reduce heat transfer and high internal temperatures. Double skin facades are used to reduce heat flow into the interior, as there is a space between the two facades that allows air to flow, reducing heat transfer. Solar shading is achieved by using external covers or screens to cover the facades and protect the building from direct sunlight.

As for thermal insulation: it is done using insulating materials such as polystyrene foam or polyurethane inside the walls of the building to reduce heat transfer.

The buildings are designed reductively to minimize the area of the facades exposed to direct sunlight, reducing the amount of heat entering the building. External claddings are installed on metal rods that support sections, and the building uses Hollow panels, which are up to ten times more efficient than traditional insulation materials. https://artic.com.sa/king-abdullah-financial-district-kafd/

Figure (11): Facades of King Abdullah Financial Center in Riyadh.
Source: [https://www.arch-centre.com/ar/projects/office-public/project-132-king-abdallah-financial-district]

Comparison between the three examples, shown in the following table (4).

Table (4): Comparison between examples in terms of energy saving. (The Author)

Building information	Insulations at external elevations	Design procedures	Both : insulations and Design procedures	Energy saved ratio
Kiefer Technic Showroom Building\ Austria	———	Dynamic aluminum panels in facades	———	8,9 - 38,5%
AL Bahr Towers\ Abu Dhabi, UAE	———	1- Transparent, umbrella-like units on the facades that open and close in response to external solar conditions. 2- Solar cells to power the facade units above. 3- Transparent glass to take advantage of natural lighting.	———	Prevents 50% of sunlight from penetrating the building
Phoenix Central Library\ Arizona, USA	———	Dynamic sunbreaks on the southern facade	———	1.3% 9.2 –
King Abdullah Financial District KSA, Riyadh	———	1- Double Facades (DSF) 2-Solar Shading	Thermal insulation materials in facades: Hollow panels	Up to ten times better insulation.

4. Analyzing Results and Recommendations

1- Efficient design measures, whether passive or active, on building façades reduce the need for thermal loads, thereby saving energy - especially during critical months in cities with hot dry climates such as Iraqi cities, including Baghdad.

2- When using active design measures, the designer must take into consideration the amount of energy required to operate electronic and electrical additions.

3- Insulation layers in external façade walls reduce thermal loads.

4- Using a combination of design measures and insulating materials in the façades of buildings in hot dry cities - such as Iraqi cities including Baghdad - can significantly contribute to reducing energy loads, and is more efficient than using insulating materials or design measures separately.

5- It is necessary to consider the importance of natural and mechanical ventilation in thermally insulated spaces to prevent the occurrence of the Greenhouse Effect.

6- It is important to select natural or manufactured insulating materials with minimal or no environmental impact (in terms of emissions) to avoid harming indoor air quality.

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