Traditional Mashrabia and their Re-inventions for Cooling the Air and Constructing Identity in the Contemporary Architecture of the East

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Abstract

This research identifies the features of the regional element 'mashrabiya' prevalent in the arid zones. It will help the preservation and development of the diversity of traditions in synthesis with scientific and technological advances necessary to improve the living conditions of people facing global environmental challenges-global warming, resulting from CO2 emissions.

This study examines the mashrabiya as a part of a self-regulating air exchange system designed to create a favourable microclimate. An intricate air exchange system, visible from the outside and concealed in the building interior and underground. Mashrabiyas made it possible to achieve a comfortable environment without emitting any CO2. The mashrabiyas in this system are the conductors of air.

This research applies the method of comparative analysis based on theoretical scientific works on the issue. From the standpoint of an interdisciplinary discourse, regional prerequisites for the demand for such houses are determined. Particular attention is paid to the mashrabiya in buildings was not only a decorative element, but also part of the system of passive microclimate regulation.

The study concludes that comparing the traditional and innovative use of mashrabiya in architecture, the use of the traditional forms without considering the circulation process in a building system does not contribute to a favourable living environment.

Keywords: Architecture, Arid zones, Mashrabiya, Eco-self-regulating air system, Regional identity, Globalism.

Introduction

Globalization has presented a serious challenge to people in preserving their distinctiveness and identity. Architecture has been affected by globalization since the 1960s, and constructing ecologically sustainable buildings has become essential. One traditional element that can help in constructing sustainable buildings in arid climatic conditions is the Mashrabiya.

The Mashrabiya is an integral part of many buildings in the Middle Ages, designed to regulate the air exchange system in the arid zones. This system is a sophisticated method of cooling interiors, comprising a lattice system, from simple to luxurious interiors and façades. It connects all the spaces of a building into a single interconnected air volume with underground rooms, in a "communicating vessel" type, with a supply and ventilation atrium, the air tower-badgir or malqaf.

The lattice element on the windows and balconies such as "mashrabiya" or "shanashil" (Arabic) is called "şahnişin" in Turkish and "panjara" in Central Asia. Wooden lattice in the Kazakh language is called kerege. The wooden lattice is a traditional element in Islamic architecture, with records of mashrabiya's use dating back to the 12th century in many cities of the Middle East, including Baghdad, Iraq, Iran, and Egypt and other regions.

There is a trend in the 21st century towards developing regional architecture that connects the distant past and modern progress, explaining the return of the Mashrabiya in modern Eastern architecture. (Bekleyen & Dalkiliç, 2011).

People in the arid zones (Fig. 1), including northern Africa, the Arabian Desert, Iran, and southern Central Asia, have been creative in transforming a semi-arid climate into favourable ones, using the principles of self-regulating air exchange in buildings, which still work today.

Fig. 1. The world's aridity zones—yellow areas indicate regions with hyperarid or arid levels of precipitation
Source: Harris, 2003

The study, preservation, and development of traditions in synthesis with scientific and technological advances are essential to improve the living conditions and face the global environmental challenges.

The invention of the Mashrabiya in the Middle Ages is part of the microclimate regulation system of the past, achieving modern levels of residential comfort without CO2 emissions. (Abdelkader & Park, 2017). Presently, architecture is the most significant source of CO2 emissions, consuming enormous amounts of electricity. Using the achievements of the medieval regional air exchange system in modern residential and public buildings in arid regions could be a solution to today's global challenges (Fathy 1986).

This paper aims to investigate the consistency, superiority, or inconsistency of modern Mashrabiyas with the results of microclimatic regulation of the ancient microclimatic systems.

The study poses two questions:

1) Do modern kinetic "envelope Mashrabiyas" perform the function of microclimate regulation, match, surpass or lag behind the ancient systems in terms of results?
2) Is the modern innovative Mashrabiya of the 21st century able to transform the microclimate of the arid zones of the dry hot deserts without the use of electricity or is it only a rehash of the external decorative sunshade grid and identical "clothing" of regional architecture?

The aim of this research is to show that the Mashrabiya is part of a giant self-regulating air-exchange system hidden in the thickness of a building and the underground. It employs the basic principles of physics to explain the air exchange processes in the volume-spatial structure of the regional arid house, where traditions are the result of multi-disciplinary relationships.

This study considers the trends of modern regional architecture in the 21st century and is particularly useful for newly emerging countries to preserve their independence in the process of global, economic, political, and cultural integration. Any aspect from the history of intellectual and cultural achievements of a community is a value for all time and can change the assessment of the region's identity in the present and the future, such as the invention of the Middle Ages Mashrabiya.

A Review of Literature

This paper examines the research on the mashrabiya in the modern contexts. Through a critical review of literature, the paper analyses the findings of several scholars who have explored the use and functionality of the mashrabiya in traditional buildings. The paper also addresses the issue of imitation of traditions and the decline of tradition in modern architecture. By synthesizing these works, this paper aims to provide insight into the status of knowledge on the mashrabiya and identify the research gaps.

In recent years, the use of mechanical means for air cooling has increased in the Middle East, resulting in high levels of energy consumption. To address this issue, experts have turned to traditional self-regulating and ecologic air exchange systems in traditional buildings, such as those studied by Siani (1980), Talib (1984), Fathy (1986), Petherbridge (2011), Abdulkareem (2016), Ardiani and Koerniawan (2017), and Handayani, Mochamad, and Budiarto (2018). These studies show that the regulation of air temperature and its transformation from uncomfortable to comfortable levels is an achievement of regional houses of the Middle Ages. The "architectural bodies" of the traditional buildings depend on the climate and the rules of syntax and patterns of configuration in each case. On the other hand, authors of articles on mashrabiya, Akçay, & Alothman– 'Fashion Inspired by Architecture: The Interrelationship between Mashrabiya and Fashion World'(2018) and 'Theoretical Framework for the Evolution from the Traditional Mashrabiya to Modern Mashrabiya' (2017) evaluate Mashrabiya as an important expression of Eastern identity. They question the assumption that architects possess a comprehensive knowledge of Mashrabiya. The purpose of Alotman's research is to provide a comprehensive and fully documented reference material on Mashrabiya, with a new and logical arrangement of the subject matter that unites disparate studies. However, none of the previous research has covered the topic in a comprehensive, integrated manner. (Akçay & Alothman 2017, 2018; Alothman, 2017).

In contrast, Hmud (2011) raises the issue of "imitation of traditions" and argues that superficial copying is not genuine tradition. He criticizes the lack of a clear identity and blind adherence to Western methods in modern buildings in the Arab world.

In the dissertation entitled 'Modelling and thermal optimization of traditional housing in a hot Arid area' Khan (2015) investigates the use of night ventilation as a passive cooling strategy for a traditional courtyard house in a hot dry climate. He has explored the volumetric and spatial structures of the traditional houses built as a system for converting unsuitable air into a comfortable environment.

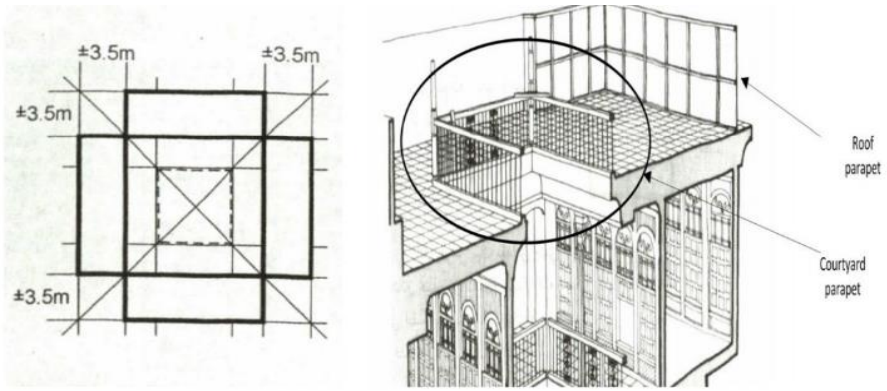


Fig. 2. Floor plan and section view of the internal courtyard-shaft, atrium-well of the house.
Source: Khan, 2015

The section of the internal atrium-courtyard (well-shaft) demonstrates how carefully the masters approached the task of creating of gratings-mashrabiyas for the unimpeded movement of air flows day and night into the inner spaces of the house.

Khan (2015) points out that even a small portion of the parapet is executed in a labor-intensive technique to create the finest lattice that participates in air conditioning. The magnificent mashrabiya have crafted by the master artisans of the region that transformed the externally austere, enclosed architecture of the traditional dwelling into a fairyland of shade and shimmering light filtering through the delicate lattice work of the mashrabiya.

> "Modeling was done using the CFD of the courtyard and room sizes, and in some cases, included modern technologies such as ceiling fans. The results show that a house with a courtyard can provide thermal comfort to its occupants. "However, some help from new technologies, such as ceiling fans, is required to keep indoor air quality within acceptable limits", indicating that the author does not trust the traditional system. At the same time, he concludes that "…the nature of indoor air flow varies from day to night, and that the thermal conditions during the day depend more on the intensity of solar radiation than on other factors, "(Khan, 2015: 223).

He has come very close to the problem, but did not focus on the basis of the identified decisive factor. To make the point, the conclusion of Raggett can be cited. He says, "there is no better example than the countries of the Persian Gulf, where a sharp change in the economic situation had a profound impact on the values of society and ideology.

Friedrich Ragette the author of the book "Traditional Housing Architecture of the Arab Region", discusses the explicit loss of valuable knowledge from traditional experience. He provides examples of reasonable methods for achieving architectural unity from the Atlantic to the Persian Gulf (Ragette, 2003:106). However, (Ragette, 2003:239), he raises the question of how appropriate regionalism is under the umbrella of globalization. Describing the features of traditional Arab housing, Ragette (2003) focuses on shading and ventilation as important conditions for organizing the microclimate in response to the hostile climate of the hot deserts of the arid zone.

In conclusion, Ragette makes a fair statement:

> "There is no better example than the countries of the Persian Gulf, where the sharp change in economic situation has had a profound impact on the values and ideologies of society. It is not surprising that this has been reflected in modern architecture in the Persian Gulf"
>
> Ragette, 2003:239

Jean Nouvel and Zaha Hadid have specifically focused on the mashrabiya, which identifies the region, and more precisely on its artistic image. The mashrabiya is part of the most important air exchange mechanism in Arab housing, controlling the microclimate but remaining invisible to the eye.

As Miguel de Cervantes once stated, "History is the depository of great actions, the witness of what is past, the example and instructor of the present, and monitor to the future" [https://www.goodreads.com/quotes/tag/history]. This was Cervantes' response to Friedrich Ragette's inquiry on the appropriateness of regionalism under the umbrella of globalization. In the age of globalization, it is crucial to preserve and transmit timeless values to future generations, such as the regional achievements of nations on the planet and, in particular, in architecture.

This critical review of literature on the mashrabiya reveals a gap in understanding among architects regarding its functional purpose. It also highlights the issue of imitation of traditions and the decline of tradition in modern architecture. Further research is needed to better understand the functional purpose of the mashrabiya and its potential for incorporation into modern buildings. Additionally, research should explore how to balance regionalism and globalization in modern architecture to preserve traditional architectural elements while meeting the demands of contemporary society.

Research Methodology

This research aims to evaluate the role of mashrabiyas in regulating the microclimate in traditional and contemporary architecture in the arid regions of the Middle East, and how they contribute to constructing regional identity and eco-friendly design. The study is based on the qualitative method of comparative analysis and literature review, including theoretical and empirical works on the topic of mashrabiya and its functions in traditional and contemporary architecture, as well as the interdisciplinary studies on regional climatic and cultural contexts. The following steps were taken to gather data:

Survey of Literature: The research started with a comprehensive review of existing literature on the topic of mashrabiyas and their functions in regulating air temperature, ventilation, and natural lighting in traditional architecture of the Middle East, as well as their re-inventions and adaptations in contemporary architecture. The survey covered various sources, including books, journal articles, conference papers, and online resources.

Conceptual framework: Based on the literature survey, a conceptual framework was developed to guide the research and identify the key variables and hypotheses. The framework integrated concepts from architecture, environmental design, cultural studies, and sustainability, and aimed to explain the relationships between mashrabiya, microclimate, identity, and eco-friendly design.

Case studies: To illustrate the application of the conceptual framework, four case studies were selected from different regions of the Middle East, representing different types of mashrabiya and their re-inventions in contemporary architecture. The case studies were chosen based on their relevance, diversity, and availability of information.

Data analysis: The data collected from the literature survey, the conceptual framework, and case studies were analyzed using content analysis, thematic analysis, and comparative analysis. The analysis aimed to identify the common themes, patterns, and variations in the use of mashrabiya in traditional and contemporary architecture, and evaluate their effectiveness in regulating the microclimate and constructing identity.

The research methodology employed for this study is based on the Pascal's Law. In its analysis, mashrabiya-grid is assigned a role as a self-sufficient system "responsible" for the microclimate. The scientific method of the research is based on the Pascal's Law. Pascal's formula for pressure is $F = PA$, where F is the force applied, P is the pressure transmitted, and A is the cross-sectional area. In this research, A is the area of the thermal zone in the body of architecture, as in the traditional house, it is solar radiation that is the direct cause of pressure difference resulting from the non-uniform irradiation of parts of the traditional house.

Validation: To ensure the validity and reliability of the findings, the research employed the triangulation method, by cross-checking the data from different sources and perspectives, and by seeking feedback from the experts in the fields of architecture, environmental design, cultural studies, and sustainability. The feedback helped to refine the conceptual framework, validate the findings, and generate recommendations for future research and practice.

Overall, this research methodology combines qualitative methods of literature survey, case study, and data analysis, to provide a comprehensive and nuanced understanding of the role of mashrabiyas in regulating microclimate and constructing identity in traditional and contemporary architecture of the Middle East. The methodology emphasizes the importance of interdisciplinary and cross-cultural perspectives in addressing global challenges of sustainability and cultural diversity, and contributes to the development of a knowledge base for evidence-based design and policy-making.

Findings and the Discussion

The mashrabiyas in the medieval buildings have not only been a decorative element, but also part of the system of passive microclimate regulation (Fathy,1986). They allowed air to pass through the walls and trap solar radiation. All internal spaces of a house: living and non-living rooms, courtyards, galleries, staircases, and the underground spaces with air ducts were interconnected by grilles (Firsanov,1982).

The mashrabiyas are also used in modern architecture to create recognisable urban appearances, but questions arise, if the modernised 21st century mashrabiya is only a decorative shell used for sun protection without being part of the whole air-regulated building system. Often, the architects efforts have not achieved the result of the medieval climate control system without CO2 emissions. Hence, it is in danger of becoming a stamp and becoming part of the global monotony. Rieder (2013) expresses a similar idea, pointing out that modern architects are not taking part in the whole process. They focus on decorating buildings rather than on functional innovation and thoughtful design.

The use of self-regulating air exchange is one of the most controversial topics. The microclimate and comfort of a building depends on the duct system. It is essential for improving people's living conditions due to the global environmental problems.

The builders in the past have understood that the environment has enough air masses with increased temperature +50°C and low pressure, and the air masses with increased pressure are not enough for constant circulation in a house (Khan, 2015). Thus, they have made spare rooms with lower air temperature underground (Firsanov,1982). Building additional volumes was expensive, but the cost had to be accepted. It was vital to build air storage spaces, vertical shafts - badgirs, malkafs, air ducts, serdabs, iwans, supply and exhaust ducts, etc. Together they form a single 'communicating vessel' consisting of residential and non-residential spaces to circulate or transport air at a lower temperature than in the environment (Gianni, 1988).

It is the law of physics that governs the daily air exchange in a house. Air masses always move from a high-pressure zone to a low-pressure zone. Thus, it is necessary to ensure an unobstructed route through the space of the house between all the floors and the underground spaces, using a mashrabiya system. The same pattern of heat exchange occurs in the Earth's atmosphere, and this is the first condition for the origin of the air circulation processes.

The task of the architecture in warm climates is to lower the temperature of the living spaces by moving cooler air masses from the storage rooms into the living spaces. The exchange of air masses will be constant, provided that there is a temperature difference between the environment and the living spaces of the house during the day and night (Fathy, 1986). The most important aspect however is the origin of the air exchange process in the body of the house, which is initiated by a deliberate irradiation of, for example, a south-facing iwan, a roof, a courtyard-well-chimney, or a niche to create a thermal zone (Kisamedin, 1988).

In order for the circulation process not to stop, there are a few necessary conditions. They are:

- the presence of a thermal zone;
- low temperature air storage - underground structures;

- unobstructed air flow
"Thermal zone" - a deliberately heated zone, depending on the type of house chosen, can be located in the courtyard, in the south-facing iwan, on the roof, on the terrace; depending on the scheme of the house, the volume of cool air can be stored in the shady part of the house, in the serdab basement, in the northern iwan and in other parts of the house.

It is well known that heated lighter air always moves upwards in the atmosphere due to the difference in weight compared to cold air masses. Pascal put into action in a "communicating vessel", equalizing the pressure for liquid and gases, the Newton's law of universal gravitation. However, with air, and the determined specifics of the building, the spatial structure of the regional house of the arid zone, as a "communicating vessel", depend on the deliberate irradiation of a specialized part of a building. A thermal zone with rarefied air-vacuum-a low-pressure zone associated with a general house air system in a 'communicating vessel' acts like a "syringe", and draws high-pressure air from the underground room (Dehnavi et al, 2012).

Since the natural laws of Nature (physics) are used in the construction of various regional types of traditional housing, they operate on the entire planet in the same way and not only in the intercontinental arid zone of a dry hot climate. In all climatic zones, where the climate is not favorable, such as, for example, in hot-humid climates, the mashrabiyas are used to dry the air. These can be seen in the works of the ancient master Lal Chand Ustad in the Palace of the Winds (Hawa Mahal, 1799, Jaipur, India). This illustrates the mashrabiya, which covers the lace-like-façade (semi-arid climate). Only in temperate and comfortable climatic zones of the planet, there is no need to transform air.

Perhaps the ancient Arabic builders were familiar with the above laws in question, conceivable that they came to this empirically-by systematically observing the effects of weather, air movement and temperature changes. However, the traditional practice of the arid zone has not yet received proper scientific substantiation and scientific assessment. Instead, the modern architects of the East prefer to build according to the European standards to create favourable climates (Siani, 1980).

The volumes of underground premises of low temperature (high pressure) of the air of a traditional house are insignificant compared to the total volume of the house, but sufficient for ventilation. The ratio of the volumes of a residential building and the underground premises in ancient times was verified empirically, but an underground room cannot constantly “replace” air. Air could end and the same “vacuum” may occur there, if the inflow of air from the environment is not organized. Therefore, the underground premises are equipped with special channels for an air inflow (Lavafpour, 2015) (Figs. 3.4.5).

Fig. 3: A house with an underground serdab - an underground air storage.
The air ducts connecting the serdab with the living spaces of the house.
Source: Lavafpour, 2015

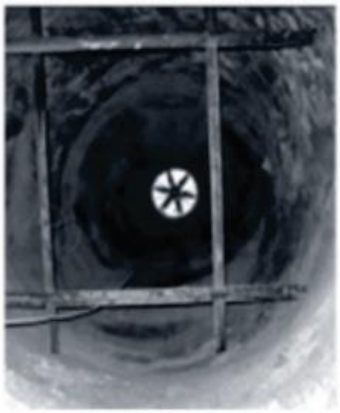


Fig. 4: Underground air intake device
Source: Lavafpour, 2015

Fig. 5: Underground communication passages of linking underground space with the spaces of the house
Source: Lavafpour, 2015

The engineering structures in question, which are not accessible for viewing, contribute to self-regulating the air-exchange and air circulation, hidden inside a residential building and the underground (Figs. 3.4.5).

"Simply using traditional forms without taking into account the transformation of air masses will not give an effect. On the contrary, spaces isolated from each other mean paralyzed air exchanges, and then some rooms become excessively heated, while others cool, but there will be no benefit from this. Since after a few hours, the picture will insolation will reverse and the same will happen with the room temperatures. Such a house will greatly depend on the external factors and bring fuss and discomfort to the residents.

Another thing is the self-regulating system of a house, where the residents do not even notice that it is necessary to open some and close other windows or doors, as he or she is sure that the house itself "takes care" of this, and will certainly be comfortably cool during the day and comfortably warm at night. "Without exaggeration, we can say that this is a giant 'communicating vessel' filled with air, the expansion of which in any place causes a reaction in the form of pressure equalization, which gives rise to a current or air movement" (Kisamedin, 2000:204).

The variety of forms and spatial formations can lead to several fundamental schemes of residential building compositions that could create a microclimate, where the central role is given to the proper organisation of the air exchange process (Kisamedin, 2001). The insulating value of the courtyard is especially relevant in countries with dry winds and dust storms. The main difference in these structures was the ratio of the height of the house to the size of the courtyard, which influenced their diversity of this type of a house over the long inter-continental territory from the Maghreb to India in the arid zone region in the above map (Fig. 1).

3.1. Air Circulation Conditions in Houses in the Arid Zone

There are certain conditions in houses that could facilitate air circulation. They are:

1. A "communicating vessel" must be created to move air masses between all living and non-living spaces of a house: the courtyard.
2. The "communicating vessel" must be fitted with a system of mashrabiyas, by means of which unobstructed connections between the high and low air pressure zones are ensured. The mashrabiyas allow air to seep through the walls. They should be placed above the height of a person. The air circulation should be inconspicuous; this is the most important condition for creating a favourable environment.
3. In addition to the living quarters, technical underground structures need to be built to increase the additional volume of high-pressure air which come through the higher air ducts from the badgir towers or malkafs, and the serbad mines. It is enough to build once, but to use them for centuries without a carbon footprint is especially important in the current phase of the threat of a warming planet due to CO_2.
4. There must be a sufficient volume of cool air in the storage rooms, supplied by the special air ducts.
5. The air circulation in the house air exchange system is regulated by equalising the temperature of the two low and high-pressure zones and slowly "dropping" a volume of air equal to the supply air, which is regulated by the communicating system of the house spaces and underground cold air storage.
6. The core of this system is the thermal zone (courtyard-mine-well), deliberately heated during the day and spontaneously cooled at night, from where the interaction in the 'communicating vessel' between the zones of low and high air pressure begins by moving through the mashrabiya system (Marafa & Alibaba, 2018).

3.2. Conventional Model of a Self-regulating Air Exchange System Using a Mashrabiya

In a house with a courtyard, a longitudinal section (Fig. 6) shows the air exchange system using the mashrabiya gratings. The system connects a serdab, which is an underground structure, with an iwan that has a northern orientation and acts as a "supplier" of high-pressure air. The thermal zone of low pressure is the iwan of southern orientation, which is heated by the sun. As the air around the iwan heats up, the air replacement between all the spaces in the house, connected by mashrabiyas, becomes more active. The mashrabiyas are also connected to the high-pressure air pool of the underground serdab, enhancing the air exchange system further.

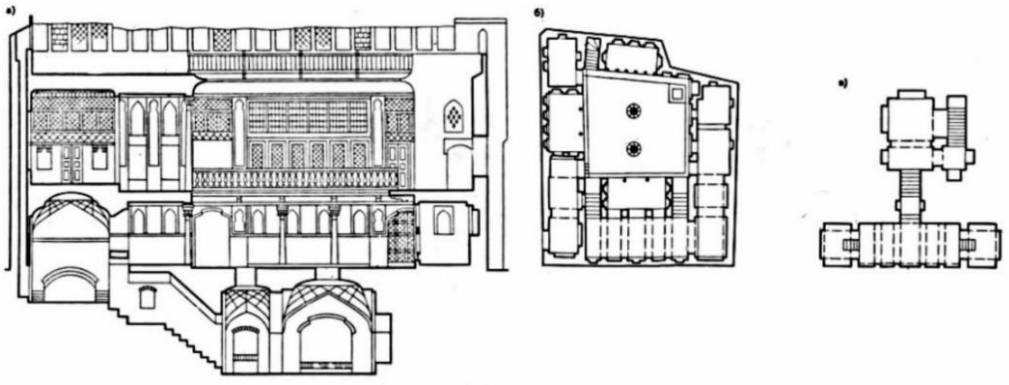


Fig. 6. The basement (Serdab)
Source: Firsanov,1982

A traditional house in the arid zone built in a specific climate exhibits self-regulating circulation due to the changing day and night temperatures, which results in the air exchange

occurring in different directions. This natural process does not require human intervention to regulate temperature changes.

In the design of houses, the internal organization of air space for air exchange is critical. The laws of physics, specifically Newton's law of gravity are used to determine that cold air masses, being heavier, are located below the warm air masses. To move the cold air masses from the lower levels of a house to the upper levels, an opposing force is necessary. The force of solar radiation creates a heated "thermal zone" at the upper level of the house, where low air pressure causes the high-pressure air to rush in along an architecturally-designed path based on the principle of air pressure equalization in the "communicating vessel" according to the Pascal's law.

Abdulkareem (2016) has calculated that a courtyard, by contributing to the air exchange process, is able to reduce the air temperature by 6.4 degrees. When the temperature of the environment is at 32.2 °C, the temperature of the underground structure is 25.8 °C. Abdulkarim however, questions the system of natural cooling. He asks "... if the courtyard is so valuable, then why is it not used most of the day except in the early morning?". The temperature difference between the roof and the level of the first floor of the atrium is 1.7 °C, and the temperature difference between the level of the first floor of the atrium and the underground room is also 4.7 °C, which is an indicator of air transformation, by the floor temperature increase. In this context, let us return to the question of the author of the article: what is the value of the courtyard, which is used only in the early morning?

The courtyard is not used most of the day except early in the morning. It has no utility functions. It is a deliberately irradiated thermal zone of an inner atrium-chamber or well, through which the air exchange occurs. At midday in the inner courtyard, or more precisely in the shaft-well, under the influence of the highest solar radiation, the air molecules heat up, expand, burst, and there is a zone created of low pressure, into which the air masses from the rooms around the courtyard rush. Their place is replaced by air masses from the darkened ground floor of the house. It is the law of physics that air always moves from a high-pressure zone to a low-pressure zone.

In a cross-section of a house, the courtyard looks like an open atrium. The courtyard's role in the life of the house is limited to its purpose: at midday, it deliberately warms up and becomes a low-pressure thermal zone that draws air from the underground space like a pump. The movement of air resembles the movement of a liquid: water, which would fill the communicating vessel from below - from the underground space.

During the day: The courtyard-atrium is indeed a thermal zone as seen in the Fig. 7

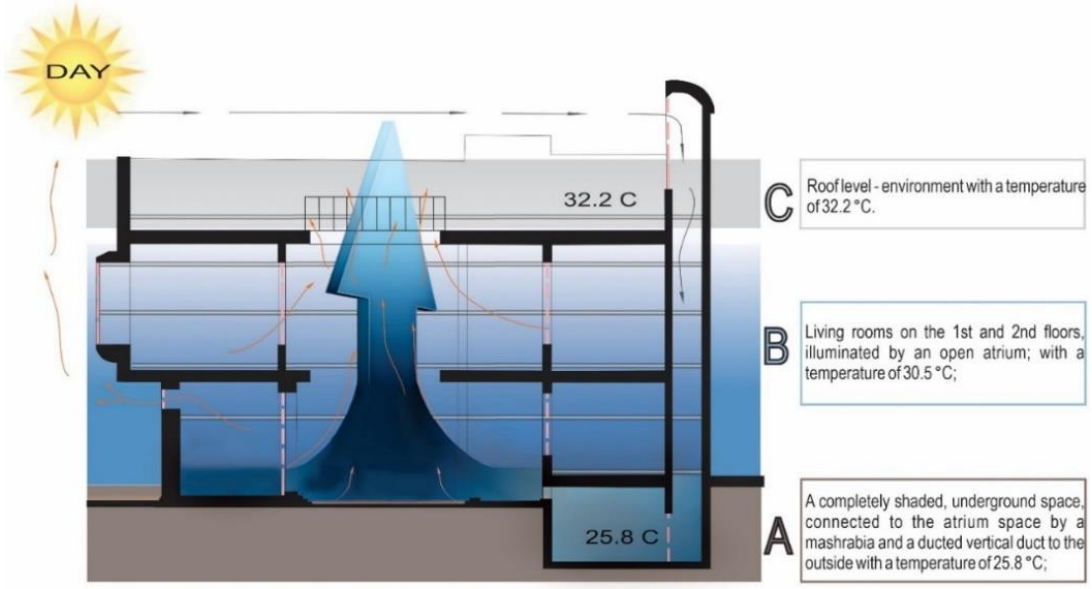


Fig. 7: The courtyard-atrium as a low-pressure thermal zone in cross-sectional house design. Source: Author

Fig. 8 shows the air exchange at night, when the ambient temperature is lower than the temperature of the residential premises and the atrium and underground premises. In such a situation, air replacement occurs in the opposite direction, when the ambient air with increased pressure displaces, and scatters the heated air of the house with reduced pressure, into the environment. Thus, the pressure releases through all the openings of the house. The movement of air resembles the movement of a liquid: water, which would fill a communicating vessel from above.

An excessively high air exchange rate would have destroyed the temperature difference, as the volume and the area of the underground rooms and buildings, as well as the mashrabiya areas, had been calibrated by centuries of experience handed down from generation to generation. As the volume of increased air pressure of the underground floor was designed for a barely noticeable air exchange, and a rapid air exchange, like a draft, it would also have been harmful for human health and would have threatened the equalization. Indeed, it would have led to a paralysis of the air exchange (Foruzanmehr, 2018).

At night, the low-pressure courtyard is "pulled in" by the ambient air of the high-pressure environment.

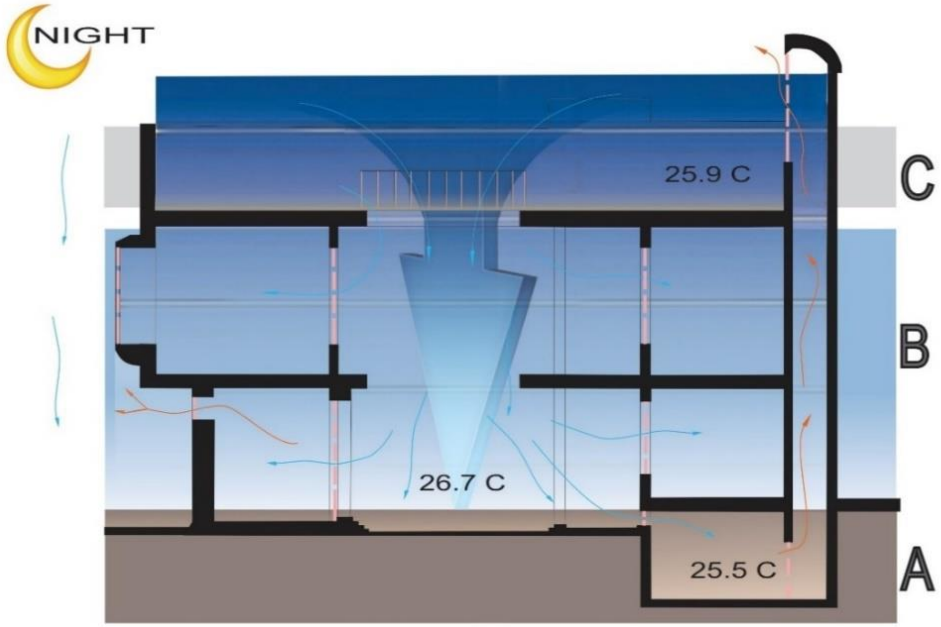


Fig. 8: Air Exchange Dynamics during Nighttime Cooling in Residential Premises with Atrium
Source: Author

In total, at 7.2°C, the effect of conditioning or maintaining air temperatures favourable for a person, and the temperature inside the house at noon was 25°C, and this is a good, comfortable temperature. Let's return again about the value of the courtyard at night. It is highlighted that an open atrium-a well-a shaft at night inside the house is invaluable, when the ambient temperature and air decreases, and its pressure rises. Then the air of the internal volume of the low-pressure house draws into the open atrium-the well-the shaft. The air of the increased ambient pressure squeezes out from the house and scatters the air of a residential building heated during the day into the environment.

Traditionally, when the outside temperature becomes excessively high, the patio is covered with a damp cloth. Lowering the temperature inside the patio means lowering the temperature difference inside the house and slowing down the air movement, saving cool air from the underground space (Forés, 2010). To implement this law, it is necessary that the house be built as a 'communicating vessel' with a common bottom-an underground structure-a zone of high air pressure, equipped with a vertical air duct for air inflow and exhaust in the form of serdab, iwans of northern and southern orientation.

Indeed, the "communicating vessel" for the movement of air masses should be equipped with a mashrabiya system-gratings between all the residential and non-residential spaces of the house with an internal radiation zone and the environment through windows on the outer, enclosing walls. Therefore, the windows facing the street were also equipped with gratings-mashrabiya. By themselves, mashrabiyas are not the "first place", but play a huge role in the participation of air exchange.

The "first place", day and night, is the atrium shaft, a courtyard that during the day, is a thermal zone. Here is the use of solar energy, deliberately heating the courtyard during the day, and spontaneously cooled at night, from where the "dialogue" begins in the "communicating vessel" between the zones of low and high air pressure. It is the mashrabiya system that transforms this through.

In the arid region, where the climate is less harsh and ruthless, houses with one, two or three iwans were usually erected. In such buildings, the proportions of the courtyards are more spacious than the shafts, and the thermal zones are in the South-oriented iwans, where the air exchange follows the same law of physics **(**Hessari & Chegeni, 2021).

3.3. Re-Invention of the Traditional Mashrabiyas

For hundreds of years in the Middle East, the sun was saved with the help of mashrabiya for protection from the sun. Mashrabiya has never been a decoration or luxury of a dwelling. It was a vital device for lowering the temperature inside living quarters, but today "mashrabiya" is just a stamp.

Globalism brings to the modern world uniform criteria in the formation of the buildings, new building technologies, building materials, and the formation of uniform standards for urbanisation, including high-rise construction. These manifestations of our civilisation are considered progressive**,** but when the whole world becomes uniform, they can also become monotonous. It is a worrying symptom of an underlying social problem. However, the modern world cannot do without solving the global environmental problems (El-Shorbagy, 2010). Therefore, traditional housing skills need to be studied and used rationally; unique features need to be introduced into modern architecture, and environmentally friendly building materials need to be used. As Talib (1984) points out, one of the drawbacks of modern architecture in the Arab countries is the lack of a clear identity and blind adherence to Western methods, far removed from the Arab civilization and society.

The search for regional signs of global uniformity has now reached the most advanced level of the architecture of the 21st century and has put forward the Arab East with the return of the artistic traditional image of the medieval Arab mashrabiya. The efforts of two prominent contemporary architects John Nouvel and Zaha Hadid play a significant role in this endeavour, as visible in the architecture of the "Tower in Doha", Qatar (2013) and "King Saudi Arabia's Oil Research Center" (2017).

This study analyses the principles of operation of the medieval mashrabiya and the principles of operation of the modern innovations in the architecture of the arid zone with a shell in the image of "Mashrabiya" based on the projects: the Doha Towers in Qatar (architect Jean Nouvel, France) (Figs. 8-10), the King Abdullah Petroleum Research Centre or KAPSARC in Riyadh (architect Zaha Hadid), (Figs 11-13) and Al Bahar Twin Towers in Abu Dhabi, UAE (Abdulmajid Karanouh, Aedas Arquitectos.) (Figs. 9-11).

Fig. 9: Tower in Doha by the Architect J.Nouvel
Source: https://www.designboom.com/architecture/jean-nouvel-burj-doha-shapes-gulf-citys-skyline/

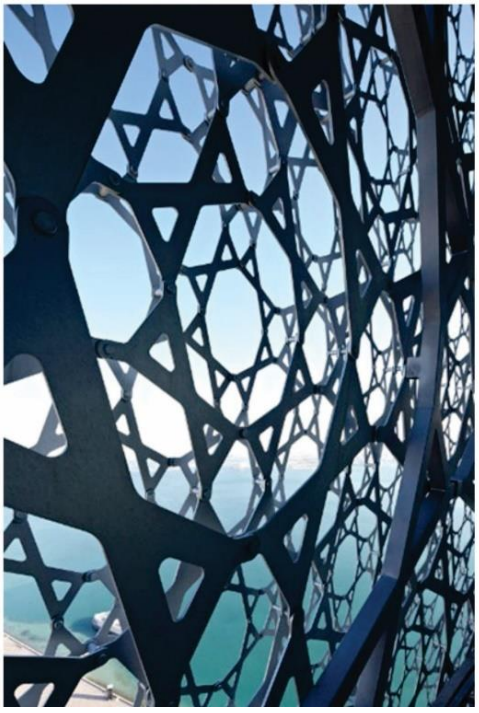


Fig. 10: An openwork mesh cover is "dressed" on the tower
Source: https://www.designboom.com/architecture/jean-nouvel-burj-doha-shapes-gulf-citys-skyline/

Fig. 11: Dome completion of the openwork clothes of the tower
Source: https://www.designboom.com/architecture/jean-nouvel-burj-doha-shapes-gulf-citys-skyline/

Each of these objects are the first innovative breakthroughs in changing the very approach to the architecture of skyscrapers, dressed in glass and steel according to the principles of Art Nouveau, where the regional motif in architecture comes to the fore as an artistic image. Mashrabiya is "covered" over the entire volume of the skyscraper, the energy efficiency of the tower in Doha is silent, and we can see an air conditioner in the interior of the tower dome (Fig. 11).

The King Abdullah Petroleum Research Centre or KAPSARC in Saudi Arabia oil research center, (Architect Zaha Hadid) (Figs 12-13.) has been completed in 2017. It is located on an area of 7 hectares and comprises 5 buildings. The main building, designed in 2009 by Zaha Hadid Architects, was the first super green building by Zaha Hadid Architects to be awarded the Leed Platinum certification.

12. **13.**

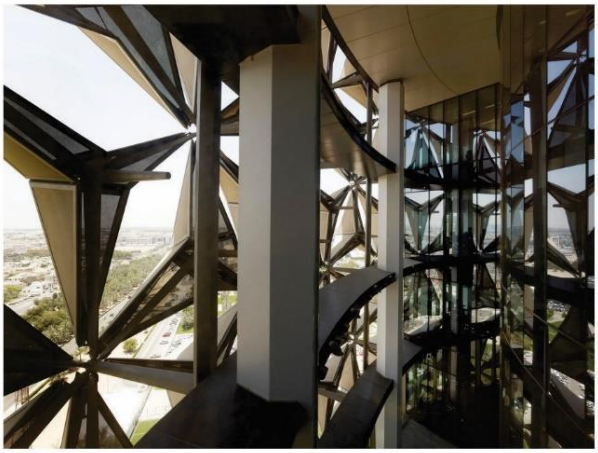
Fig. 12 &13: King Abdullah Petroleum Studies and Research Center (KAPSARC) Saudi Arabia.

The openwork "shrouds" and wraps the entire building complex and create a unique architecture. The novelty of openwork mashrabiyas in skyscrapers, mosques, museums, opera houses and metro stations are overwhelming, but perhaps sooner or later the phenomenon will become irrelevant.

The envelope of the paired Al Bahar Towers is a stunning mashrabiya-style kinetic "blanket", "draped" over a glass wall. The innovative kinematic "mashrabiya" is made up of modular panels. The designers took the decor of the traditional mashrabiyas and transformed them into coherent kinetic "clothing" that responds to the movement of the sun, trapping not only solar radiation but also the air whereas the traditional mashrabiya retained solar radiation but let air in for natural air-conditioning. On the roofs of the tower, to the South, there are photovoltaic cells that generate about 5% of the total energy required from the renewable sources, which is used for water heating.

The Al Bahar Towers were one of the first buildings in the Gulf to receive an LEED Silver rating. The towers have been named the best skyscrapers of 2012 by the International Council on Tall Buildings and the Urban Environment (CTBUH) (Abdulmajid & Kerberb, 2015).

Fig. 14: Twin towers of Al Bahar dressed in mashrabya. Abu Dhabi, 2012
Source: https://www.livinspaces.net/ls-tv/discussing-the-design-an-indepth-look-at-the-design-of-the-al-bahar-towers-in-abu-dhabi-by-aedas-architects/



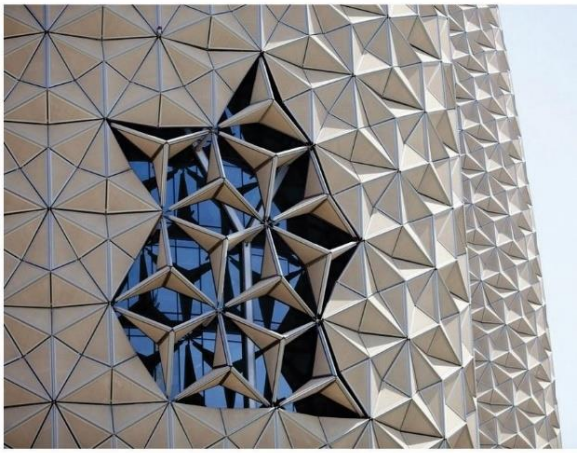


Fig. 15 & 16. Kinetic mashrabya - 21st century innovation. Arch. Aedas
Source: https://www.livinspaces.net/ls-tv/discussing-the-design-an-indepth-look-at-the-design-of-the-al-bahar-towers-in-abu-dhabi-by-aedas-architects/

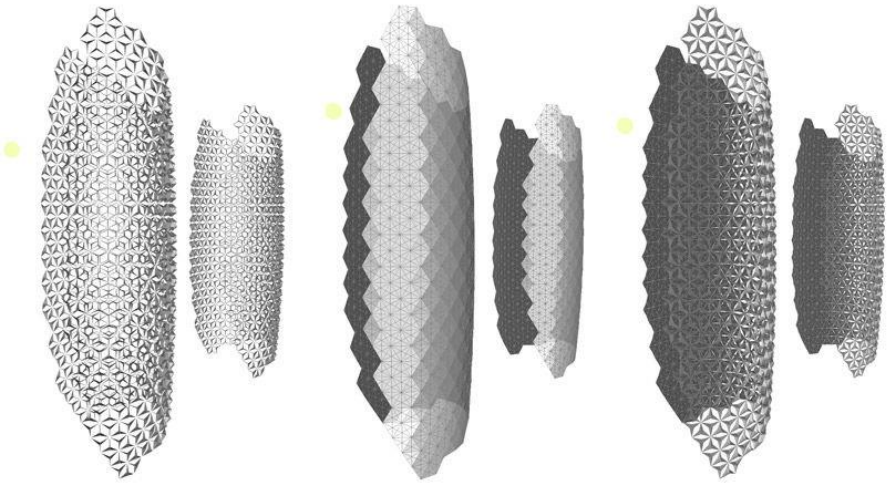


Fig. 17: Kinetic shell - mashrabya. 2012 Architect Aedas
Source: https://www.livinspaces.net/ls-tv/discussing-the-design-an-indepth-look-at-the-design-of-the-al-bahar-towers-in-abu-dhabi-by-aedas-architects/

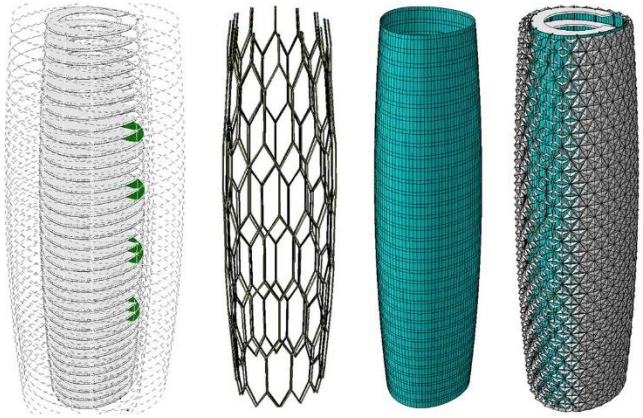


Fig. 18: 1-Kinetic shell, 2-mesh construction, 3-glass, 4-openwork mashrabya, 5-kinetic, mesh and openwork mashrabya.
Source: https://www.livinspaces.net/ls-tv/discussing-the-design-an-indepth-look-at-the-design-of-the-al-bahar-towers-in-abu-dhabi-by-aedas-architects/

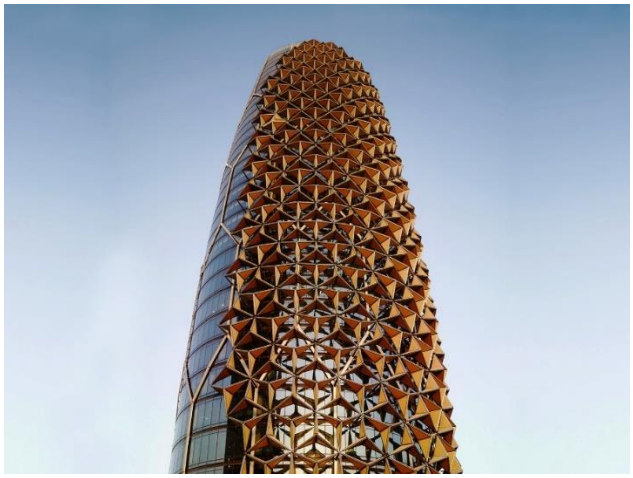


Fig. 19: Golden pineapple clothing - kinetic mashrabiya creates different patterns throughout the day in the architecture of the building
Source: https://www.livinspaces.net/ls-tv/discussing-the-design-an-indepth-look-at-the-design-of-the-al-bahar-towers-in-abu-dhabi-by-aedas-architects/

As can be seen, the openwork lattices resembling the mashrabiya in the architecture of the 21st century have become:

— Not genuine, but external copies of traditional ones, and the main argument is not a challenge, but a demonstration of a challenge to globalism in search of identity.
— Innovative mashrabiya of the 21st century, only the outer decorative openwork shell exists but they do not fulfil their true essence–contribute to ventilation.
— Kinetic blinds, moving along the sun, delay radiation as much as possible. However, they only serve as blinds, and the modern device is not capable of replacing hot air with cooler ones.

The architecture of the Al Bahar Towers in Abu Dhabi combines the traditional and the modern technology with kinetic sun protection. The main task set for the architects and engineers of the Aedas Architects was to create an office centre capable of maintaining a favorable climate inside without high energy costs. There is no mention about the traditional air exchange system (Gianni, 1988).

The creators of the skyscrapers were able to realise the seemingly impossible "to achieve a comfortable microclimate inside the building without the use of a grandiose air conditioning system", but still using electricity. Winter in the arid zone is comfortable, but that time of year lasts 3 months, and then the temperature starts to rise to 50º, sometimes even higher.

In contemporary architecture, Mashrabiya serves as a means of establishing identity. However, modern 21st century advancements have yet to replicate the microclimate regulating benefits of traditional medieval architecture. Despite modern building technologies and European spatial organization standards, buildings lack the traditional "breathing system" which allows them to be integrated with the environment. Kinetic blinds, which adjust their position based on the sun's location, are primarily used for shading and minimizing radiation absorption. However, they do not possess the capability of the traditional Mashrabiya to exchange hot air with cooler air, resulting in a purely decorative function.

Mashrabiyas were a part of the medieval technology for organizing air exchange and were used in one, two, three-iwan houses, using air storages-serdabs, mines, and air ducts-all of these are devices for lowering the air temperature, achieved due to the temperature differences between the internal and external air.

This is natural air conditioning without the use of electricity. Ignoring the achievements of the past in an age of global environmental problems with CO_2 emissions is neither logical nor rational. In fact, Ibrahim Al Jaidah, the executive director of the Arab Engineering Group in Qatar believes that it is important not only to assimilate local colour, but also to transform it to a different scale, so you should not make "reprints" of national architecture. It is better to explore modernity and technology and through this continue to demonstrate national identity. Modern projects can not only convey a narrow understanding of identity: the characteristic of colour, the symbolism of a place, its meaning, but also identity-tradition transferred to a modern way of expression.

The architectural technique of adorning a building with an openwork shell, as demonstrated by pioneering architects Jean Nouvel and Zaha Hadid, can be considered an art form. This outer shell, much like a phrase in Arabic, serves as a recognizable symbol of a nation, state, or region. However, in the modern era, the use of mashrabiyas as an openwork shell serves primarily as a means of sun protection and does not contribute significantly to the building's ventilation.

To make the point, the conclusion of Raggett can be cited. He says, "there is no better example than the countries of the Persian Gulf, where a sharp change in the economic situation had a profound impact on the values of society and ideology. It's not surprising that this was reflected in the modern architecture of the Persian Gulf" (Ragette, 2003:256). The mashrabiya, identifies the region, or rather its artistic image, which Jean Nouvel and Zaha Hadid have focused on. In fact, the mashrabiya is part of the most important mechanism of the Arabic air exchange building systems that control the microclimate of self-regulating air exchange.

Conclusions

This paper thus concludes the following.

1. Traditional environmentally friendly arid zone architecture is a medieval achievement of the vast intercontinental region of the planet, which includes the Maghreb countries, Saudi Arabia, Iran, Central Asian countries and other countries. This architecture is currently influencing global architecture. However, unfortunately, it is not not yet done formally, because the interdisciplinary links in architecture in general, and in architectural physics, have not yet reached a level to address the 'no carbon footprint' in accordance with the Paris Agreement under the UN Climate Change Convention governing measures to reduce the levels of carbon dioxide in the atmosphere from 2020.
2. Global regionalisation is a phenomenon of the development of the world at the global level. It is a very progressive phenomenon that allows us to look at the achievements of humanity of any historical period in relation to scientific and technological progress and environmental issues.
3. Mashrabiyas are a system of grilles that protects against solar radiation and allows air to pass through the walls, resulting in self-regulation of air exchange throughout the building.
4. Modern kinetic "mashrabiyas" play the role of sun protection and do not participate in the organisation of air exchange according to the principles of the traditional system. They only convey a modernied artistic image of the regional architecture.
5. The kinetic mashrabiyas in the Al Bahar towers in Abu Dhabi, maximising the position of the sun during the daylight hours, reduce the need for air conditioning. However, they are not part of the air-exchange system and are inferior to the ancient achievements in organising the microclimate by means of the architecture itself.
6. The principle of a traditional air exchange system in dry, hot climates is based on the intensive insolation of a shaft-well-atrium a courtyard located in the centre of the house, which is deliberately irradiated. The difference in temperature and pressure between the courtyard and the house at different times of the day leads to a passive air exchange. The air masses from the high-pressure zone go to the low-pressure zone, creating a comfortable microclimate in the house. The body of the traditional house as a 'communicating vessel' evenly equalizes the air pressure on all floors, where the air moves not only up and down, but also horizontally. This is why the traditional house has virtually no large openings. Even small windows are covered with mashrabiyas; they do not let in solar radiation, but they do let in air, which is a microclimate regulator.

Today, the mashrabiyas are used for decorative purposes to give an exciting facade to architecture. This study offers a comparison of the results of modern innovations of the 21st century with the traditional system, and shows that they do not use all the functional characteristics of the traditional architecture in regulating the microclimate of buildings.

Indeed, the greatest invention of the medieval East, the traditional self-regulating air-exchange system with mashrabiyas grilles challenges the architecture of the 21st century to be as innovative and meaningful as they have been.

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