# An Investigation on the Suitable Features of Double-Skin Façade in Lines with Reducing Energy Consumption in Cold and Arid Climate: A Case Study of Mashhad City

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## ABSTRACT

This research deals with an efficient approach to achieve the optimization of energy consumption by emphasizing the selected and optimized features in the two-shell facade and in the form of a general question under the title that the application of two-shell facades in towers How multipurpose can lead to reduction of energy consumption and thermal comfort in the cold and dry climate of Mashhad city.

The crisis of energy is one of the greatest concerns that the world is facing today, especially in the area of building and architecture. Considering the limitations of determining the areas related to high-rise construction and compiling special construction rules in Mashhad city, in this dissertation, the researcher found the maximum height in the selected sample to be 150 meters with 34 floors as the first. and it is considered the tallest building in Mashhad city, in addition, according to the two tables and considering the most prominent tower in terms of being the tallest and also having the highest number of floors (on average), considering that Some of these towers are older in terms of age and have a lower height, and the towers under construction in Mashhad are on average taller than some of these towers, even though they are famous and prominent, and in addition One reason for choosing the tallest tower with the highest number of floors is that the effect of the variables investigated in this thesis increases with the increase in height, and in this thesis, solutions for the tallest towers are also supposed to be given. Accordingly, in order to investigate the function of double-skin facade and its effect in the climate of Mashhad City and to select a suitable option from amongst four types of double-skin facade, in the current study, first, four types of double-skin façade (multi-story, shaft-box, corridor, box-window) are considered in terms of energy in the climate of Mashhad City which is a cold and arid region, and the study is conducted on a multi-purpose and high-rise building in order to find the most optimal state for the region of Mashhad, and then the speed of wind and the air flow temperature in the façade shall be analyzed and the findings and conclusion of the study shall be presented The results of the study showed that the increase of the depth of middle hole leads to the improvement of the thermal function of the whole double-skin façade with an average of thermal comfort limit.

**Keywords**: *Double skin facades, cold and dry climate, Mashhad city, Optimization of energy consumption، Armitage Gulshan multi-purpose tower*

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## 1. Introduction

The wall of the building, as the main intermediary between the internal and external space, plays a key role in controlling the environmental conditions.

An ideal double-skin façade creates the possibility of setting the heat, light and sound in such a way that the minimum amount of energy is consumed. It should be noted that lack of using an efficient model which could be introduced for the buildings of cold and arid climate and could be used for compensating the losses resulted from lack of paying attention to the component of sustainability and native architecture and overconsumption of nature and lack of controlling the effects of overconsumption of energy and imposing the relevant costs on this area by construction, is felt, because we have to obviate the needs of the future society, too. Accordingly, the study seeks to remove the mentioned defects and to prevent the facing challenges to become able to present a suitable model in lines with the climate, which is an important point, by using renewable energies such as wind and sun.

The present study seeks to introduce and encourage to use the optimized model and pattern produced in the scale of architecture by investigating the thermal behavior of double-skin façade in high-rise buildings of Mashhad City. In lines with all-round consideration of the problems that we are facing, in the form of solving the problem of optimization of energy consumption in high-rise buildings in cold and arid climate of Mashhad City, and to prevent the energy waste, we are going to actualize this issue that paying attention to the cold and arid climate and its effect in architecture and optimizing the energy consumption is possible by presenting a suitable model for the mechanism of such a climate through designing a model of double-skin façade effective in this region. Accordingly, the definition of façade finds importance. Considering the aforementioned issues and the important aspect of optimizing energy consumption in the buildings, the current research seeks to study different aspects of energy in the scale of the building and high-rise construction in Mashhad City and in cold and arid climate. Therefore, addressing such issues is very important. The current study tends to create an optimal design for maximizing the air ventilation of the structure by analyzing the natural ventilation process of double-skin facades in native architecture through presenting a model based in the technology of double-skin facades in order to optimize energy consumption in the air conditioning system of residential-commercial buildings, according to the ventilation characteristics of the structures with two external layers and two skins. It is worthy of note that considering the gap existing in the research; after reviewing the influencing variables such as the depth of the hole and dimensions and the size of entry and exit air vent in order to consider the amount of ventilation inside of the building and to consider four types of double-skin facades, the current study presents the results of the mentioned analyses in the form of tables and diagrams. The samples have been analyzed and evaluated by Rhino Specialized Software by the help of Grasshopper Plugin Software and a part of them by Design Builder Software. Then, the most optimized state possible which has the highest effect on saving energy is discussed in the form of an efficient model usable in today's buildings, and finally the results are presented. To conduct the research by employing the method of field-based study, the façade and plans available in Armitazh Golshan Tower in Mashhad, are identified, surveyed and drawn. To present the finalized produced model after testing the samples considered and drawn in Design Builder Software and their analysis, the final model is obtained from the data analyzed by the software.

The main (general) research question:- How and in what way can the use and presentation of two-shell facades in multi-purpose towers lead to reducing energy consumption and creating thermal comfort in the cold and dry climate of Mashhad? (general question).Other sub-questions (specific) of the research

Presenting what type of two-skin facade types can have the most optimal and best efficiency in optimizing the two-skin facade used in multi-purpose towers in the cold and dry climate of Mashhad city. be (partial question)

The effect of the suitable characteristics of the facade of the two shells, including the depth of the cavity or the buffer space between the two shells, the material of the outer and inner glass layers worked in the facade of the two shells, and the dimensions of the air inlet and outlet valves, in optimization. How is the energy consumption in the multi-purpose tower in the cold and dry climate of Mashhad? (partial question)What solutions can be offered for the use of a smart roof in order to reduce energy consumption and improve the performance of the optimized two-shell facade? (partial question)

## 2.Literature review

**Table1:** Literature Review

| Title of the Article | Author(s) | Summary of Results | Year of Publication | Title of the Journal |
|---|---|---|---|---|
| Investigating the thermal identifiers of the skin of external walls of the building: A case study of rural regions of Ardebil | Mr. Bahram Gosili [1] | The results of the study are summarized in the following items:<br>1.Selecting brighter colors; 2. Selecting an appropriate time in the most optimal hours of the day; 3. Selecting the optimal time for the function of air conditioning system; 4. Decreasing the number of windows; 5. Changing the type of window glass; 6. Using horizontal sunshade in all windows. | 2015 | Housing and the Environment of the Village |
| Thermal improvement of the wall of the buildings in cold climate in Iran by using the features of Trombe wall | Ms. Noushin Abolhassani, Mr. Behrouz Mohammad Kari, Ms. Rima Fayyaz [2] | The walls facing the sun should have dark color. Putting a glass layer in transparent form and creating a gap of entrapped air that reduces the heating load in the southern rooms noticeably, but in the hot months of the year the glass should be covered so that the reduction of heat transfer is done accurately. | 2016 | Architecture and Urban Development |
| Numerical analysis of double skin facades for summer | Mr. Vahid Afshin Mehr, Ms. Fahimeh Aref, and Ms. Marzieh Shanehsaz. [3] | The results indicate that the thermal comfort limit in the city of Yazd is 21.8 centigrade degrees in summer and 20.4 to 23 centigrade degrees in winter, and its approximate moisture has been estimated 18% to 53%. | 2015 | Naqshejahan |
| Influential Parameters in a Solar Chimney's Passive Ventilation: A Case Study of Isfahan City | Ms. Maryam Fakhari, Mr. Shahin Heydari, Ms. Rima Fayyaz [4] | In terms of sustainability in architecture, the consideration and recognition of nature has entered the research which is known as a necessity for sustainable architecture, and paying attention to the triple | 2014 | Architecture and Urban Development |

| | | | | |
|---|---|---|---|---|
| | | aspects of nature i.e. natural physics, spiritual aspect and serving as a sign indicates the sustainable architecture and the presence of nature in the architecture. | | |
| Energy analysis when using double skin façade with phase-change material in a high-rise building in climatic conditions of Tehran | Mr. Seyed Alireza Zolfaghari, Mr. Mehran Saadatinassab, Ms. Elaheh Norouzi Jajarm[5] | This type of façade has a good function due to having phase-change material both in cold and hot seasons, in such a way that reduces energy by around 40% in the cold season and by around 26% in the hot season. | 2014 | Modares Mechanical Engineering Journal |
| Mechanically ventilated double skin facades | Krag, M[6] | The function of natural ventilation in double-skin facades | 2002 | --- |
| Influence of natural ventilation due to buoyancy and heat transfer in the energy efficiency of a double skin façade building | Sanchez, E; Rolando, A; Sant, R; Ayuso, L [7] | The results indicate such an important issue that in case of lack of sun (the sky being cloudy) in summer, open vents are the most desirable options for thermal comfort. | 2017 | Energy for Sustainable Development |
| Predicted thermal acceptance in naturally ventilated office buildings with double skin facades under Brazilian climates | Barbosa, Sabrina; Ip, Kenneth[8] | The results of study indicate that natural ventilation in office buildings with double skin facades under the Brazilian climate is not suitable for reaching an optimal model when being placed in the northeast of Brazil although it is effective in thermal issues. | 2017 | --- |
| Natural ventilation in a double skin façade | Gratia, Elisabeth; De Herde, Andre [9] | Using natural or mechanical ventilation to prevent flush in summer | 2004 | --- |
| Double versus single skin facades in hot arid areas | Hamza, Neveen [10] | Double skin façade, in the role of a reflector, might save energy more than a single skin façade | 2008 | --- |

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In order to consider the function of double-skin façade in the climate of Mashhad and also select a suitable option among the different types of double-skin facades, four types of double-skin facades are taken into consideration in a hypothetical condition, based on the parameters investigated in several articles such as the Article of Mr. Bahram Gosili[1], entitled, “Investigating the thermal identifiers of the skin of external walls of the building”. First the generalities of the building was surveyed; a building having an structure with dimensions of 122.27*39.55*41.16 sq. meters and 17 floors over the ground floor, the height of each is 5 meters, with a floor area of 84567 sq. meters, with southern full-glass and double skin façade, with a distance in the hole depth being 80 cm to 120 cm, with double glazed glass, that with four states of matte and transparent in double-skin façades has different structures based on the ventilation source of retaining space. Then, the proposed details of each of them with the dimension of air entrance and exit being 0.6 meter are presented for analysis, so that by the analyses performed, the most optimal state for the region of Mashhad shall be obtained, and the speed of wind and the air flow temperature in the façade shall be analyzed. Finally, the findings and results of the study shall be presented.

**Table2.** Characteristics of the Spaces under Study and the Dimensions of Openings

| Application of the space | The side of the building exposed to sun | Area of the surface of the wall under study | Surface of the opening | Percentage of opening proportional to the whole surface |
|---|---|---|---|---|
| Information and Security | Southwestern | 12 sq. meters | 9 sq. meters | 75 |
| Information and Security | North | 38 sq. meters | 8.90 sq. meters | 23.42 |
| Management area of the complex | Southwestern | 20 sq. meters | 12 sq. meters | 60 |
| Commercial unit | Southwestern | 150 | 70.63 sq. meters | 47.86 |
| Commercial unit | North | 120 | 35.80 sq. meters | 29.83 |
| Administrative unit, type A | Southwestern | 44.52 | 19 | 55.43 |
| Administrative unit, type B | Southwestern | 16.56 | 9 | 54.36 |
| Residential unit type A | Southwestern | 25.73 | 6 | 23.31 |
| Residential unit type B | Southeastern | 25.73 | 6 | 23.31 |
| Residential unit type C | South | 20.44 | 9.9 | 48.43 |

**Table3:** Specifications of Two glasses in Ordinary Transparent and Low-e Matte Forms

| Specifications of the glass of double-glazed façade | Ordinary transparent glass | Low-e Matte glass |
|---|---|---|
| Absorption coefficient w/m.k | 30 | 30 |
| Specific heat kg/m3 | 840 | 840 |
| Index of refraction 1/m | 1.5 | 1.5 |
| Thermal conductivity J/kg.k | 1.7 | 1.7 |
| Density | 2500 | 2500 |
| Absorption coefficient of visible light | 0.02 | 0.12 |
| Solar permittivity coefficient | 0.84 | 0.42 |
| Solar absorption coefficient | 0.085 | 0.33 |

| | | |
|---|---|---|
| Coefficient of emission | 0.84 | 0.24 |
| Visible light permittivity coefficient | 0.9 | 0.79 |
| Reflection coefficient of visible light | 0.08 | 0.09 |
| Reflection coefficient of sunlight | 0.075 | 0.25 |

Considering the Air Outlet in the Double-Skin Facades in the Pilots under Study and the Status

The outlet is placed on the ceiling and the two vents for the distribution of entering air are placed on the floor. Of course, to explain it more precisely, it should be stated that the temperature and the heat flux arising from the sunlight passing the surface of the glass inside of the double-skin façade are compared in such states: in the state of using a low-e matte glass and using a transparent emitting glass of foreign, ordinary, transparent and low-e type, where the width of the middle hole or the interval of two skins has the dimensions of 70, 80, 90, 120 cm and the surface of the air vent is 0.20, 0.40, 0.08, 0.55 and 1.45. The equipment considered for each room in the mentioned project includes two air inlet vents, two air outlet vents, usual equipment (electronic and electric systems, etc.), six lights, partition, and equipment shelf. The equipment considered for the hall and lobby of the structure includes eight air inlet vents, air outlet vent, furniture, shelves, fire extinguishing system, (electronic and electric systems, etc.), 44 lights, partition, and shelves. To simulate the sample space, the following cases have been taken into consideration: The boundary condition assumed for the walls is of isothermal type (Dirichlet boundary conditions). The temperature in the boundaries is equal to the real temperature of the structure surface resulted from the experimental study of this sample space. For the air outlet, four vents are considered in the structure, with each side being 36 cm. For more precise investigation in the current study, first the boundary conditions considered for the mentioned model are studied according to the following table.

**Table*4:*** Boundary Conditions of the Space Walls in the Hottest and Coldest Season of the Year, at the Time of Minimum and Maximum Sunlight

| Wall | Lower | Upper | North | South | West | East |
|---|---|---|---|---|---|---|
| **Temperature (°C)** | 25 | 27.4 | 26.8 | 26.8 | 25.8 | 28.6 |

| Title | Boundary Condition |
|---|---|
| Floor | Isothermal, 23 centigrade degrees |
| Ceiling | Isothermal, 25 centigrade degrees |
| Walls | Isothermal, 22 centigrade degrees |
| Sitting dummy | Constant Flux, 99 watts per meter of the space |
| Light | Constant Flux, 60 watts per meter of the space |

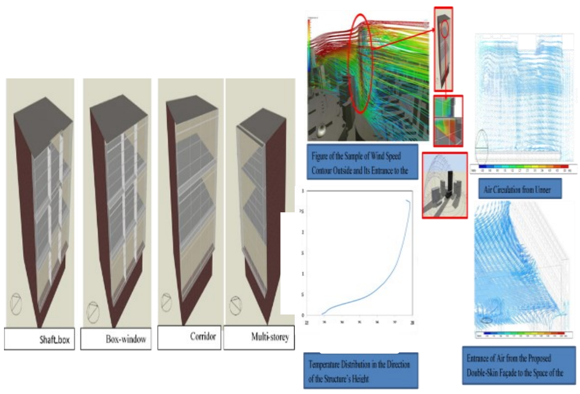


**Figure1:** Four States of Double-Skin Façade

Gridding of the model has been done in the state of Structure, and the cells are in the form of spaces which form a disciplined gridding. As indicated in the following Figure, in areas with high gradient, such as the air entry and exit vents, walls and the vicinity of heat sources, the density of omputational grid has increased so that their effects enter the field of resolution precisely.

**3.Results of Data Analysis**

By using subsurface air distribution system in the structure under study, a uniform thermal distribution is observable on the surface of the structure. Moreover, due to the entrance of air from the floor, a palpable thermal classification has been created from the floor to the ceiling. In order to consider the thermal classification, the temperature contours have been placed in different heights. The thermal distribution was 3.80 meters far from the floor, where the average temperature of the structure is around 24 centigrade degrees. The thermal distribution was 0.9 meter far from the floor, where the average temperature of the structure is around 24.5 centigrade degrees. The thermal distribution is 1.2 meters far from the floor, where the average temperature of the structure is around 25 centigrade degrees. In the following Figure, the increase of temperature due to the presence of people, along the height of the structure is visible well. The temperature has increased 4 centigrade degrees long the height of the structure. By using the modern ventilation system of under-floor air distribution instead of overhead mixing ventilation systems, the energy consumption of the building decreases around 30 percent. In this system, due to the entrance of air from the floor, the air circulation leads the pollutants and the heat resulting from the presence of individuals and equipment upwards. This causes the creation of two temperature regions in the space of the structure: one region includes the space between the floor and the height of 1.8 meters in which the temperature distribution is adequate and the air is quality and clean. Another region includes the space upper than the 1.8 meter height up to the ceiling, where the density of pollutants is higher and the temperature is also higher. In the area where individuals are present, suitable conditions of thermal comfort is provided for them, and due to the reduction of required space for cooling and heating, less air inlet flow is needed, which results in less energy consumption by fans.

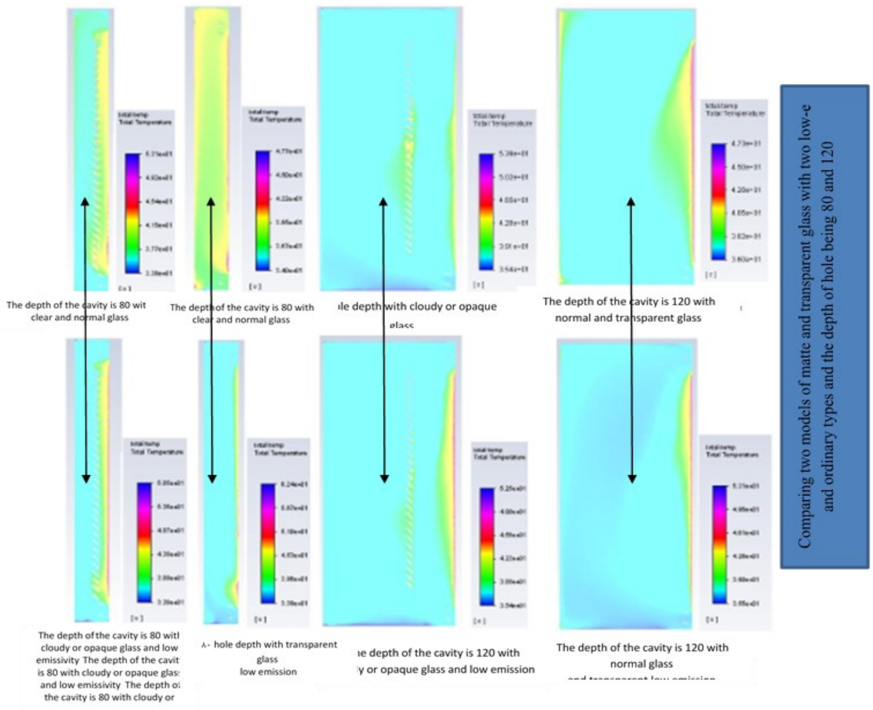


**Figure2:** Comparing the Air Circulation between Two Models of Matte and Transparent Glass with Two Low-e and Ordinary Type and with the Depth of the Hole being 80 and 120

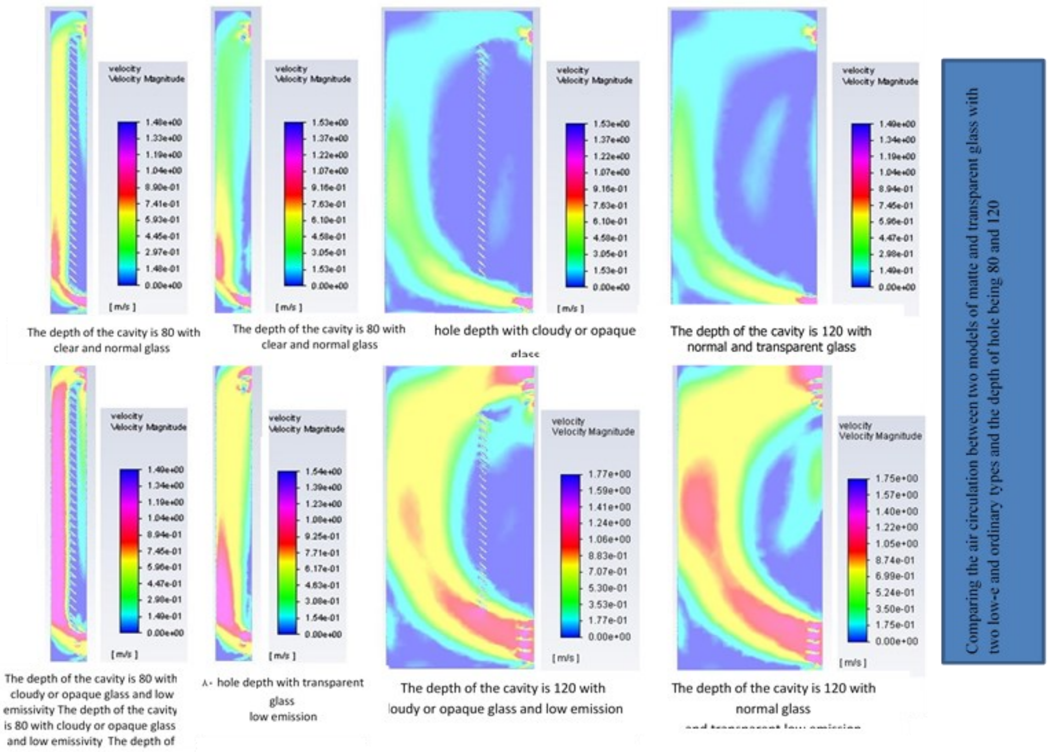


**Figure3:** Temperature Distribution in the Middle Hole of the Double-Skin Wall

**Table5:** Specifications of Two Glasses in Ordinary Transparent and Low-e Matte Forms

| Specifications of the glass of double-glazed façade | Ordinary transparent glass | Low-e Matte glass |
|---|---|---|
| Absorption coefficient w/m.k | 30 | 30 |
| Specific heat kg/m3 | 840 | 840 |
| Index of refraction 1/m | 1.5 | 1.5 |
| Thermal conductivity J/kg.k | 1.7 | 1.7 |
| Density | 2500 | 2500 |
| Absorption coefficient of visible light | 0.02 | 0.12 |
| Solar permittivity coefficient | 0.84 | 0.42 |
| Solar absorption coefficient | 0.085 | 0.33 |
| Coefficient of emission | 0.84 | 0.24 |
| Visible light permittivity coefficient | 0.9 | 0.79 |
| Reflection coefficient of visible light | 0.08 | 0.09 |
| Reflection coefficient of sunlight | 0.075 | 0.25 |

In the following diagrams or tables, the yellow color means comfort, the red means the amount of heat and blue means coldness.

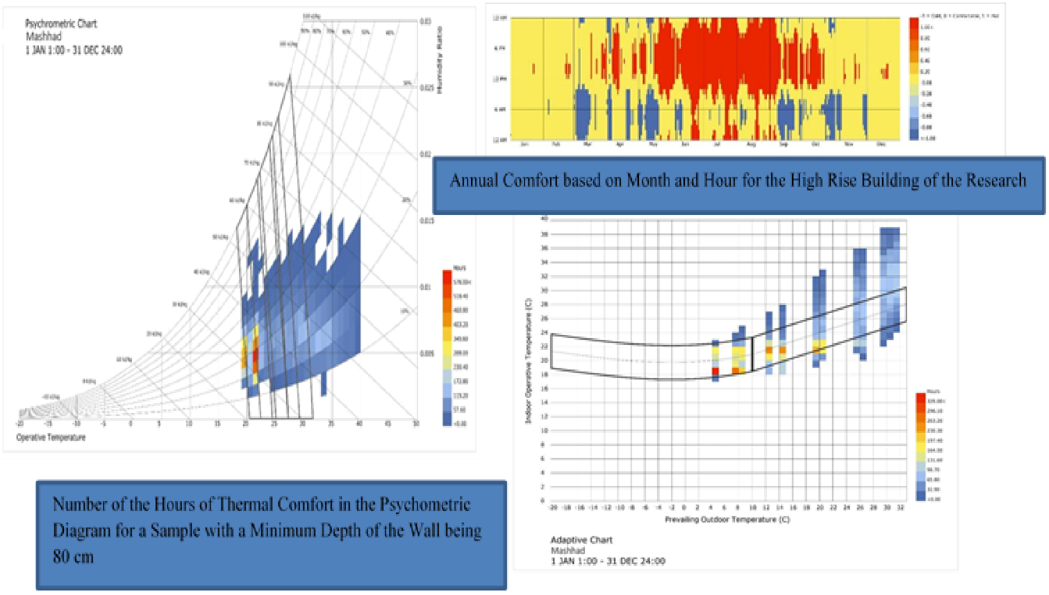


**Diagram**1: An Analysis of Thermal Comfort, Considering the Parameters of Dominant Air Temperature and Internal Operating Temperature for the High-Rise Building with the Minimum Penetration Depth of 80 cm in the Distance between the two Skins

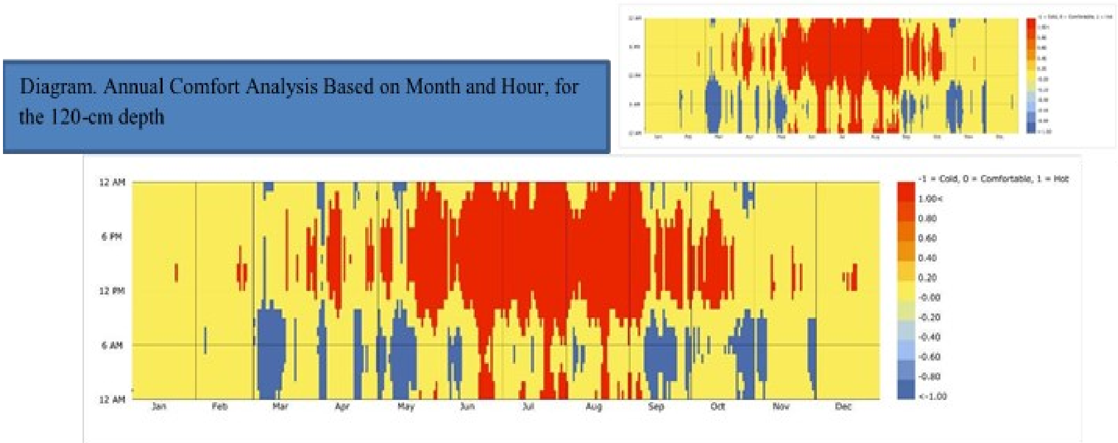


**Diagram2**: Annual Comfort based on Month and Hour for the High-Rise Building under Study, after

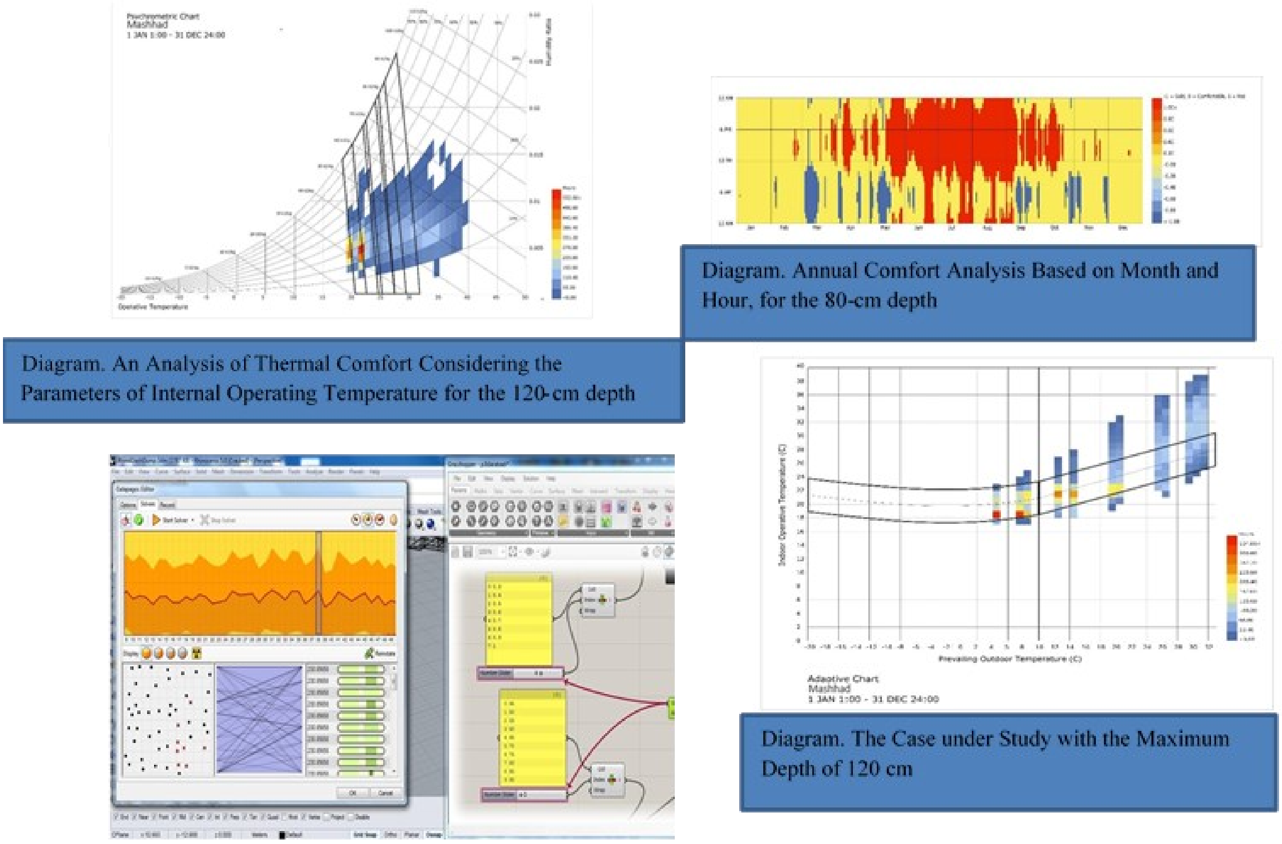


**Diagram3**: Applying the Mentioned Points and in the Optimized Form

**Table6:** Thermal Comfort Range Obtained from Analyzing the aforementioned Diagrams

| **Low Limit of Comfort** | **17.509** | **19.247** | **21.227** | **18.5095** | **17.308** | **16.645** | **18.4078** |
|---|---|---|---|---|---|---|---|
| **The Best Conditions** | 19.259 | 20.997 | 22.977 | 20.2595 | 19.058 | 18.395 | 20.1578 |
| **High Limit of Comfort** | 21.009 | 22.745 | 24.727 | 22.0095 | 20.808 | 20.145 | 21.9078 |
| | **SEP** | **AUG** | **JUY** | **JUN** | **MAY** | **APR** | **AVERAGE** |
| **Low Limit of Comfort** | 22.471 | 24.0205 | 24.2185 | 23.4325 | 22.0375 | 20.155 | 22.7225 |
| **The Best Conditions** | 24.221 | 25.7705 | 25.9685 | 25.1825 | 23.7875 | 21.905 | 26.2225 |
| **High Limit of Comfort** | 25.971 | 27.5205 | 27.7185 | 26.9325 | 25.5375 | 23.655 | 24.4725 |

The numbers mentioned in the table above are based on centigrade degree.

The Results of the Analysis of the Diagrams related to the Case under Study

After considering four models of double-skin façade and based on the analyses made in the current study, from May to August, from 11 a.m. to 7 p.m., high heat is observable and in other cases relative thermal comfort is observable. The highest amount of comfort is in the dominant temperature of 4 to 14 centigrade degrees and the active indoor temperature of 18 to 22 degrees Considering the psychometric table, the highest amount of comfort hours is in the temperature. of 19 to 23 degrees and the relative moisture of 0.004 to 0.007. As can be seen, from May to August, from 11 a.m. to 7 p.m., high heat is observable and in other cases relative thermal comfort is observable. The highest amount of comfort is in the dominant temperature of 4 to 22 centigrade degrees and the active indoor temperature of 18 to 22 degrees.

Considering the psychometric table, the highest amount of comfort hours is in the temperature of 20 to 22 degrees and the relative moisture of 0.004 to 0.007. As can be seen, from May to August, from 11 a.m.

**Table7:** A comparison of the temperature and the heat flux arising from the sunlight passing the surface of the glass inside of the double-skin façade in the state of using a transparent and a matte glass, of foreign, ordinary, and low-e type, with the dimensions of 70, 80, 90, 120 cm and the surface of the air vent being 0.20, 0.40, 0.08, 0.55 and 1.45

| percentage of the changes of the thermal flux passing the surface of the inside glass of double-skin façade | percentage of the changes of the temperature of surface of the inside glass of double-skin | `Thermal flux passing the surface of the inside glass of double-skin façade | Temperature of the internal surface of double-skin faced | Thermal flux passing the surface of the inside glass of double-skin façade | Temperature of the internal surface of double-skin faced | Type of glass | Dimensions of the air inlet and outlet vents in the double-skin façade | Depth of the middle | Row |
|---|---|---|---|---|---|---|---|---|---|
| | | Transparent glass of foreign ordinary type | | Matte glass of foreign low-e type | | | | | |
| 26.3% | 1/83% | 116 | 41 | 85/5 | 40/25 | | 20 | 70 | 1 |
| 25/0% | 1/23% | 120 | 40/5 | 90 | 40 | | 40 | | 2 |
| %24.6 | 1/%10 | 115 | 39 | 92 | 37/57 | | 55 | | 3 |
| 23/%1 | 1/%0 | 105 | 38/59 | 83 | 36/34 | | 80 | | 4 |
| 22/%75 | 0/%9 | 101 | 37 | 105 | 34/49 | | 145 | | 5 |
| 28/1% | 0/86% | 112 | 40/75 | 80/5 | 40/4 | | 20 | 80 | 6 |
| 27/0% | 2/24% | 115 | 40/2 | 84 | 39/3 | | 40 | | 7 |
| 25/%46 | 2/%90 | 121/23 | 38/34 | 89 | 41/09 | | 55 | | 8 |
| %24 | 3/%35 | 131/08 | 36/35 | 92 | 59/09 | | 80 | | 9 |
| 23/%55 | 5/%00 | 143 | 33/01 | 105/6 | 68 | | 145 | | 10 |
| 27/6% | 1/36% | 78 | 40/3 | 56/5 | 39/75 | | 20 | 90 | 11 |
| 21/7% | 0/76% | 80/5 | 39/7 | 63 | 39/4 | | 40 | | 12 |
| 20/07 | 0/%60 | 88/60 | 40 | 68/09 | 39/06 | | 55 | | 13 |
| 19/4% | 0/63% | 90 | 39/5 | 72/5 | 39/25 | | 80 | | 14 |
| 18/%32 | 0/%56 | 103 | 44/06 | 93 | 46 | | 145 | | 15 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 29/8% | 1/14% | 78/9 | 39/6 | 55/4 | 39/15 | 20 | 120 | 16 |
| 24/1% | 3/29% | 81/7 | 39/5 | 62 | 40/8 | 40 | | 17 |
| 21/%4 | 103 | 44/06 | 93 | 46 | 0/%56 | 55 | | 18 |
| 20/6% | 0/51% | 90 | 39/3 | 71/5 | 39/1 | 80 | | 19 |
| 19/4% | 0/63% | 90 | 39/5 | 72/5 | 39/25 | 145 | | 20 |
| 26/3% | 1/83% | 116 | 41 | 85/5 | 40/25 | 20 | 70 | 21 |
| 25/0% | 1/23% | 120 | 40/5 | 90 | 40 | 40 | | 22 |
| 27/0% | 2/24% | 115 | 40/2 | 84 | 39/3 | 55 | | 23 |
| 25/%46 | 2/%90 | 121/23 | 38/34 | 89 | 41/09 | 80 | | 24 |
| %24 | 3/%35 | 131/08 | 36/35 | 92 | 59/09 | 145 | | 25 |
| 21/7% | 0/76% | 80/5 | 39/7 | 63 | 39/4 | 20 | 80 | 26 |
| 20/07 | 0/%60 | 88/60 | 40 | 68/09 | 39/06 | 40 | | 27 |
| 27/6% | 1/36% | 78 | 40/3 | 56/5 | 39/75 | | | 28 |
| 19/4% | 0/63% | 90 | 39/5 | 72/5 | 39/25 | 80 | | 29 |
| 18/%32 | 0/%56 | 103 | 44/06 | 93 | 46 | 145 | | 30 |
| 29/8% | 1/14% | 78/9 | 39/6 | 55/4 | 39/15 | 20 | 90 | 31 |
| 24/1% | 3/29% | 81/7 | 39/5 | 62 | 40/8 | 40 | | 32 |
| 20/6% | 0/51% | 90 | 39/3 | 71/5 | 39/1 | 55 | | 33 |
| 20/6% | 0/51% | 90 | 39/3 | 71/5 | 39/1 | 80 | | 34 |
| 20/%35 | 0/%39 | 48/2 | 38/8 | 38/2 | 38/65 | 145 | | 35 |
| 23/3% | 0/63% | 43 | 39/1 | 33 | 38/95 | 20 | 120 | 36 |
| 20/1% | 0/58% | 44/3 | 39/5 | 35/4 | 39/3 | 40 | | 37 |
| 19/7% | 0/41% | 46/8 | 38/85 | 36/5 | 39/25 | 55 | | 38 |
| 19/4% | 0/39% | 35/2 | 39/5 | 37/6 | 38/7 | 80 | | 39 |
| 17/7% | 0/39% | 44/3 | 38/9 | 38/1 | | 145 | | 40 |

### 3.1. The Results of the Analysis of the Diagrams related to the Case under Study

In this answer to the first question and taking into account the general assumption of the research, we witnessed that the performance of the two-skin facade of this treatise in comparison with the simple facade or in other words the basic state in the discussion of establishing thermal comfort according to the psychrometric diagram of the high-rise tower in The city of Mashhad and the climate specific to this city led to the achievement that the maximum number of hours of comfort was at a temperature between 20 and 22 degrees and with a relative humidity of 0.004 to 0.007, which we saw below. The maximum amount of comfort hours was reached in the prevailing temperature between 4 and 15 degrees Celsius and the internal active temperature between 18 and 22 degrees Celsius.

In order to answer the second question of the research, the performance of the facade type in the research and data analysis and the results of chapter 4 showed that the multi-store facade or the continuous facade in the floors has the lowest amount of energy that is spent in order to optimize the heating and cooling load. Yes, the reason for this important matter was the continuity of all the floors, which was like a barrier or protector of the entire facade of the building against interfering factors such as the passage of heat and cold, this was so tangible that in The conditions are similar to other types of facades, it has the highest amount of air exchange with the lowest amount of energy required for this operation with the value of 5200 (Kw/h) and 8.2 (ACH). For the floors of the research model tower, the minimum annual amount of total heating and cooling energy consumption was equal to 368 (Kw/h) and the maximum amount was equal to 5200 (Kw/h). The best type of two-skin facade and the selected sample resulting from the application of this variable is the double-skin facade of the multi-store type and the weakest two-skin facade among the four mentioned box window facade models, which is our latest and most efficient facade in terms of consumption. The annual energy in the multi-purpose tower was the previous research model, and the weakest aspect of the current research in the research model of this dissertation was in the climate of Mashhad city and in the research model, the minimum annual amount of total heating and cooling energy consumption is equal to 487 (Kw/h). And its maximum amount was equal to 5639 Kw/h.We found that in the cold and dry climate and in the city of Mashhad, not only is the use of this double-skinned facade of the multi-store type effective, but it can also be effective by intensifying some of the characteristics of this facade. , such as the depth of the cavity between the two walls. It has a tremendous effect on these facades in high-rise towers and prevents thermal and cooling fluctuations.

The results of this part were as follows: In this part of the research, we applied the variable cavity depth in the dimensions of 0.7, 0.8, 0.9 and 1.20 in order to find the lowest and highest amount of energy consumption during the thermal load in the summer season and the cooling load in the winter season through the The selection was determined by changing the depth between two walls.

The minimum amount of energy required for air conditioning, both cold and hot, at a depth of 1.20 is equal to 165 (KW/h) and the maximum amount of this energy is equal to 3540 (KW/h), as well as the number of air changes in the highest mode at this depth. From the selected view of the multistore, it is equivalent to 5.29 (ACH) and its lowest value is 3.98 (ACH), as a result, the most optimal depth in the view of the multistore is 120 cm, which is equivalent to 1.2 meters.Also, the weakest conditions of the buffer space between the two walls in the research model tower and in the cold and dry climate of Mashhad city are related to the depth of 1.50 meters, which is the witness of this project, and the amount of energy consumption for air conditioning is equal to 489 (KW/h) and The maximum amount is 5236 (KW/h), also the number of air changes in the highest mode at this depth from the selected multistore view is equal to 2.95 (ACH) and the lowest amount is 1.59 (ACH). In this section and at the end, we proved that not only the two witness depths of 0.6 meters and 1.50 meters were not useful, but they had the opposite result and the amount of energy required for air conditioning (cooling and heating) and also the number of air changes in comparison with the depth of 1.20 meters was more, so in this research it is also proved that the minimum and maximum useful distance between two walls is 0.7 and 1.20 meters.What was done in the survey was evident by increasing the dimensions of the valves from 0.2 square meters to more, we see an increase in the amount of energy consumption and a decrease in the number of air changes at the peak of the heating of Mashhad, i.e. from July 10 to August 9.It is worth mentioning that by increasing the cross section of the air inlet and outlet valves (increasing the speed of air flow), it does not necessarily improve the thermal performance of the two-shell facade in reducing the heat flux passing through the surface of the two-shell facade.Finally, the most optimal type of glass was added to the selected shell of the multistore type with a depth of 120 cm and an opening of 0.2 square meters, at the peak of heat in the period from July 10 to August 9 in Mashhad, low-emissivity glass from Matte type with the amount of energy required for ventilation equal to 2340 (Kw/h) and the number of air changes equal to 6.99 (ACH) and with the lowest temperature equal to 31.5 degrees Celsius and the highest temperature equal to 37.6 degrees Celsius and the minimum heat transfer flux equal to 28.6 W/ m2)) and maximum is 30.9 W/m2).

## 4. Conclusion

According to the output of the Software, it has been found out that the process of double-skin façade function finds necessity in relation to considering the suitable features of double-skin façade to decrease energy consumption in cold and arid climate based on the behavior in order to maximally use the natural ventilation through considering the heat and air flow in the space between the internal and external skin or what is called the depth of the hole, which directly affects the amount of thermal comfort of residents. Paying attention to the fluidity of air circulation between the two holes through the type of glass and the dimensions of the mentioned vents in the external skin of the façade plays a key role in promoting and improving the design and the functional analysis of the mentioned façade. Moreover, all the samples under study and the mentioned factors including the depth of the hole or the distance between the two skins and its dimension, the size of the air inlet and outlet vent and their effects on the function of such facades were modeled and analyzed by Rhino, Plugin Grasshopper and DesignBuilder Software Programs. Considering the direction of the openings that have been all placed on the southwestern side of the building along with the air inlet and outlet vents, optimization has been done on a sample which is a high-rise building in Mashhad City, and is a challenge in this City in the process of high-rise construction. Furthermore, in modeling such elements as the dimensions of the windows, four types of double-skin façade, namely, Box-window, Corridor, Shaft-Box and Multi-storey, were considered in terms of energy in the cold and arid climate of Mashhad. In the current study, validation was analyzed and evaluated by Rhino and Grasshopper Plugin Software, which led to the following results with regards to the double-skin facade with natural ventilation:

1. It was determined according to the sample and the results of energy consumption that the building with multi-Story façade has the minimum thermal and cooling demand, and the building with Box-Window façade has the most heating and cooling energy consumption. Based on the diagrams available in the text with regards to the thermal and cooling energy demand in the building in different months of the year, considering the analyses made, the building with multi-Story façade showed the best result in lines with optimization of energy consumption in different seasons of the year.

2. Accordingly, all the mentioned issues finally caused the necessity of the cooling load to decrease and the amount of heating load in winter and also, in reverse, in summer to increase, considering the climate of Mashhad City. The results obtained indicate that the double-skin façade with the maximum hole distance of 120 cm, with matte glass has the maximum efficiency in winter with the maximum useable heating load being 12.135567 kwh and with the minimum cooling load required in summer equal to 45.110487 kwh.

In this part of the research, based on the review of the previous researches, the gaps or gaps in the researches of other researchers were found, and based on them, a comparison of the present research with the previous researches was presented and that the view of two shells In what areas have been investigated, it has been discussed.Based on this, we can see that in the articles presented in the second chapter of the research background, researchers such as Aram et al. (2023), Hong et al. (2023), Xiaoping et al. (2022), Kato et al. (2022), Pourshab et al. (2020) in order to confirm the contents and results mentioned in this treatise, they discussed the suitability of the multi-store facade as the optimal facade in the researched buildings, and in this respect, the results of the treatise are in agreement with the above researches. A similar mention is provided.In relation to the depth of the buffer space between the two shells, the results presented in this treatise are in line with researches such as Pratt et al. (2023), Qarai et al. (2023), Aram et al. 2023), Chan et al. (2020), Pratt et al. (2022), Kato et al. (2022), Al-Quaid (2022), Platter et al. (2023) and Yoon et al. (2023) and Seraj et al. ) and more cases that of course go back to earlier years such as Zou et al. (2010), Nasrollahi et al. (2020), Qanbaran et al. (2013), Fiorto et al. ), Larsen et al. (2015), Glaze et al. (2015) and more cases that are presented in the second chapter of this treatise, in order to investigate the minimum depth of 70 cm and the maximum depth of 120 cm, similar to this research. Of course, almost all of them reached the optimal depth of 120 cm, except in the research of Lin et al. (2015) and Porshab et al. In the end, he rejects this depth. It should be noted that these researchers had mentioned the depth of 30 to prove inefficiency in their research, while other researchers used the proven depth figures of two shells in order to prevent the reworking of these ineffective or in other words ineffective figures. had removed their own research, so this treatise also by referring to other researchers and in order to avoid rework and only by determining the minimum and maximum depth of 70-120, proved that the depth of 120 cm buffer space between two walls is the most optimal performance It has a multi-purpose tower suitable for the cold and dry climate of Mashhad city.

Also, in most of the researches, ordinary glass was used, such as the research of researchers such as Squarch et al. (2023), Pratt et al. (2023), Aram et al. (2023), Ho et al. The changes such as the depth of the hole and the dimensions of the valves and the type of view of the two shells were only investigated, which, of course, the researcher presented it as a research gap in this treatise, and citing the research of researchers such as Hong et al. (2023), Kato et al. (2023), Al-Quaid (2022), Pleiter et al. (2023), Shakuri et al. (2022), Zhenghalin et al. (2022), Yun et al. (2022), Pourshab (2020), Chan (2009), Grande (2005). ) and other previous and older researches have investigated the effect of optimizing the type of glass from low-emissive opaque and even low-emissive transparent, so in this research also to prove the effect of the type.

We discussed the glass used in the facade of the two shells and similar to these studies, low-emissivity and opaque glass was investigated as the most optimal glass. It should be noted that due to the fact that some researchers have mentioned simple and ordinary ones had worked, therefore, in order to show the superiority of low-emission and opaque glass, all four types of glass, plain, transparent, plain, opaque, low-emission, cracked, and opaque, were analyzed in a comparative manner, all of which indicated superiority The glass was opaque and had low emissivity.

Regarding the height and width of the vents used in the view of the two shells, in the research of researchers such as Pratt et al. 2023), Xiao Ping (2023), Abdouh (2020), Chan et al. (2020) also reached the same result as the present research by examining all the dimensions of the mentioned valves, with the difference that in this treatise, the size of 1.45 The square meter (valve length and width) was presented as a witness of the research so that the researcher could reach a general conclusion, which was that increasing the dimensions of the valves does not necessarily increase the air exchange. In the following, we also saw that the 0.2 square meter valve has provided the most optimal possible condition in this research, as in the mentioned studies.

In this article, which is the output of the dissertation with the same title, after applying energy consumption optimization solutions, we came to the conclusion that in the cold and dry climate in Mashhad city, the optimized performance of the selected features of the two-shell facades in Golshan Armitage Tower, which They have the ability to generalize to other high-rise and growing towers of this region, they have higher and better efficiency than the basic model or the normal single shell (without applying the selected features), which is important through Applying the type of facade of two skins in the form of a multi-store (continuous on the floors), designing the air inlet and outlet with dimensions of 0.2 square meters, creating a barrier between the two skins with a depth of 120 cm, choosing the type of glass inside and outside the two facades. The low-emissive and opaque shell, the creation of a smart roof covering the floors of the opening type to strengthen the features of the facade of the two shells can be opened and closed at the peak of the temperature peak in winter and summer, and finally, the effect of the simultaneous use of all These variables were able to have the best performance in terms of thermal comfort in the cold and dry climate towers of Mashhad city.

According to the previous researches, the researchers expected that increasing the thermal resistance of the materials used in similar projects would reduce the energy wastage, but in this current study, with the addition of two skins, not only the energy consumption compared to the basic model without two skins The shell was optimized, but without changing the material, the amount of cooling and heating and thermal comfort in the towers also faced a significant decrease.

## Reference

1. *Gosili ,B.(2015). Investigating the thermal identifiers of the skin of external walls of the building: A case study of rural regions of Ardebil. Housing and the Environment of the Village, (2), p. 7791.*
2. *Abolhassani, N., Saghafi, M., Fayyaz, R., Mohammadkari, B. (2014).Thermal improvement of the wall of the buildings in cool climate in Iran by using the features of trombe wall. Architectural Studies of Iran, (7), p. 118107.*
3. *Afshinmehr, V., Aref, F., Shanesaz, M. (2015). Numerical analysis of double-skin facades for summer. Naqshejahan, (5), p. 7785.*
4. *Fakhari, M., Heydari, Sh,. Fayyaz, R.(2014). Influential Parameters in a Solar Chimney's Passive Ventilation: A Case Study of Isfahan City. Architecture and Urban Development(16), p. 180191.*
5. *Zolfaghari A.,r. Saadatinassab, M. Norouzi Jajarm, E,.(2014). Energy analysis when using double skin façade with phase-change material in a high-rise building in climatic conditions of Tehran. Modares Mechanical Engineering Journal. (7), p. 118107.*
6. *Krogh, M., (2002) Mechanically ventilated double skin facades., Advances in Building Technology, 12331240*
7. *Sanchez, E; Rolando, A; Sant, R; Ayuso, L.(2017). Influence of natural ventilation due to buoyancy and heat transfer in the energy efficiency of a double skin façade building. Energy for Sustainable Development.(33),P.139148.*
8. *Barbosa, S. abrina; I,(2017). Predicted thermal acceptance in naturally ventilated office buildings with double skin facades under Brazilian climates. Journal of Building Engineering.(7),P.92102.*
9. *Gratia, E., & De Herde, A. (2004) Natural ventilation in a double skin façade. Energy and Building, 2, 137146.*
10. *Hazim Awbi: ventilation of buildings. spon press; 2005Hensen, J., Bartak, M., & Drkal, F. (2002) Modeling and simulation of a double skin façade system., ASHRAE Transactions, 2,12511259.*