Thermal Behavior of Double Skin Facade in Terms of Energy Consumption in the Climate of North of Iran-Rasht

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Abstract

Industrialization and increasing demand for the consumption of fossil fuels cause that energy becomes a strategic factor. Energy crisis and the emergence of modern architecture led designers to pay more attention to the important task of building's envelope. Building skins play an important role in building thermal behavior and reduce energy consumption. If Double Skin Facades properly designed it can improve thermal comfort conditions and can reduce energy consumption. DSF's efficiency in each region highly depends on the climate. The number of DSFs is few especially in Moderate and humid climate of north of Iran, but there is an increasing tendency to use them. This study seeks to prove this hypothesis: It seems by changing the size of cavity between Double Skin Facades, it can achieve a favorable temperature for indoor thermal comfort. For this purpose a theoretical framework based on literature studies as a first step. Theoretical thermal performance of DSF was studied before it was applied on designed building by using thermal simulation software then absorption of direct and indirect solar gain in the building simulated in ECOTECT and various states were examined. For the assessments the number of hours of employee's comfort, direct and indirect solar gains and hourly temperature of floors in the building designed using DSF were calculated. Suitable width of air voids has been studied in this research too. It was found that designed building with DSF-Shaft box type with 75 cm cavity width is more suitable for the climate of Rasht.

Keywords: Double Skin Facade, Reducing Energy consumption, Optimizing, Office Buildings, Moderate Climate.

1. Introduction

There is an increasing demand for higher quality office buildings. Occupants and developers of office buildings ask for a healthy and stimulating working environment. In 1990s, concern about global warming has resulted in a resurgence of interest in naturally ventilated offices (Gratia and De Herde, 2004:399-409). Nowadays many high-rise buildings all over the world have all glazed facades or large areas of glazing. This substantially increases heating and cooling load requirements. To improve glazed facades from an energy point of view, double skin facades (DSF) are proposed recently. DSF curtain walls have been constructed since 1903 (Poirazis, 2004). DSF which manage the heat interaction between indoor and outdoor spaces, is being adopted as facade system on many buildings in Europe and elsewhere (even in Moderate climatic zones) while maintaining a transparent facade. The concept of the DSF is not new; and dates back to many years ago were in central Europe many houses utilized box-type windows to increase thermal insulation (Oesterle, Lieb, Lutz and et al., 2001). Ventilation of the facade can be natural (buoyancy driven), mechanical or a combination of both (Saelens, Roeld, Hense,2008:638-650). Design strategies of DSFs in each region has to be considered regarding the climatic conditions and local characteristics such as temperature, solar radiation and wind velocity in order to result in energy consumption reduction. Iran is now at the stage of development in all circumstances it should consider the issue of sustainable development more seriously. This study is focused on strategies for double skin facade systems that are intended to the particular climate type of North of Iran-Rasht. To achieve the results, we design an office building and compare it's behavior with and without double skin facade. Simulations were performed and analyzed with the thermal program ECOTECT with a climatic relationship with Meteonorm.

2. Literature Review

Studies concerning DSFs are undertaken in different climatic conditions, e.g. For Hot and Humid(Wong, Parsad and et al.,2008) investigated on a new configuration of Double Skin Facade in hot and humid climate. It was found that significant energy saving is possible if natural ventilation could be exploited through the use of double-skin facade. In this research, CFD was used to analyse various thermal comfort parameters with different double facade configurations to determine a new type of double-skin façade configurations which will provide a better indoor thermal comfort in the hot and humid climate through natural ventilation strategies for the high-rise buildings. For Moderate climate;(Faggembau, Costa, Soria and et al.,2003:217-228 and Gratia and De Herde, 2004:41-60)investigated in two separate articles. Faggembau and et al paper is a presentation of a code for the numerical simulation of ventilated and conventional facades. It is based on time-accurate, one-dimensional discretization for the channel and the different solid zones, and allows heat fluxes and temperature distributions in the facade to be obtained over

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the course of one year. The numerical code allows advanced elements to be integrated into the facade, such as phase change materials, selective surfaces and improved glasses. The code has been validated by comparing it with analytical solutions where possible, with reference situations and with experimental measurements obtained in real-site test facilities in different climatic conditions. Gratia and De Herde choose to study a multistory double-skin facades behaviour. Simulations were realized with TAS software on the building proposed in the frame of the subtask A of the Task 27 (performance of solar facade components) of the International Energy Agency. Simulations were performed on the chosen building with and without double-skin facades. The authors decide to study eight types of days; and we analyze the double-skin facade behaviors for various operations. The thermal behavior of the building with and without double-skin are compared. The study of these eight cases showed the importance of the dynamic use of the double-skin. The operation of this one must be obligatorily related to the climatic conditions as well external as interior and a bad operation of the double-skin could lead to catastrophic results.For Cold climate;(Hossegen, Wachenfeldt, Hansen, 2008) investigated on a planned office building in the city-center of Trondheim, Norway, is used as a case for considering whether a double-skin should be applied to the east facade in order to reduce the heating demand, thus making the double-skin facade a profitable investment. This paper describes how a double-skin facade with controllable windows and hatches for natural ventilation can be implemented in the simulation program. The simulation results indicate that energy demand for heating is about 20% higher for the single-skin facade with the basic window solution compared to the double-skin alternative. However, by changing the windows with an improved U-value in the single-skin alternative, the difference in energy demand is almost evened out. The number of hours with excessive temperatures is, in contrast to other studies on the subject, not significantly higher for the double-skin alternative. However, the predicted energy savings are not sufficient to make the application of a double-skin facade profitable. And Hot and Arid climate (Hamza,2008:240-248) investigation adopts an analytical approach using a dynamic simulation software (IESVE), to convert general intuitions on the performance of a double skin facade, in hot arid areas, into the grounds of understanding its performance based on research. In this paper, a comparative analysis of cooling loads on a single skin base case is compared against three possible changes to the physical properties of the external layer of the double skin facade. A dynamic thermal performance software APACHE-Sim is used (integrated environmental solutions IESVE, version 5.1). Simulation results indicate that a reflective double skin facade can achieve better energy savings than a single skin with reflective glazing Figure.1

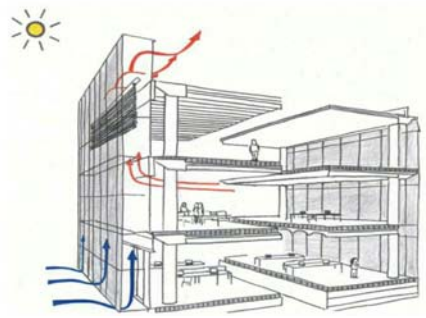

Fig. 1. One type of double skin facade function (http://cajaislant.com/blog-cajaislant/, 2018)

Hadianpour et al. (2014). In this article investigated the capacitance of Double Skin Facade in architectural design in a Hot and Arid climate of Yazd, in order to reduce energy consumption and the problem of flare in the cavity between two layers in warm months of the year. To solve this problem, the effect of the size of the ventilation valves and the change in the depth of the cavity between the two pairs is investigated. Result of the simulation shows that the total energy consumption in a double-sided building with the specifications mentioned in the article is less than a double-faced building. Mahdizadeh et al.(2014) investigated the effect of the number of interior and exterior Double Skin Facades on the energy levels of office and educational buildings in Tehran climate to reduce energy consumption in the building. The result shows that in Double Skin Facade, the change in the number of inner-layer walls is more effective in reducing energy consumption, and the change in the number of outer wall layers to reduce energy consumption does not play a role. Zolfaghari et al. (2015) In a study investigated energy analysis of Double Skin Facade with phase-change materials in a high-rise building in Tehran's climatic conditions. The results show that the use of a double skin façade with phase-change glass reduces the energy consumption in the cold and hot months of the year compared to the typical Double Skin Facade. Investigations about DSF, it's thermal behavior and energy performance in the Mediterranean climate are just starting, while DSF buildings are being constructed adopting recommendations from investigations and experiences from other latitudes (Torres,Alavedra, Guzman and et al., 2007) investigated for Mediterranean climate particularities for Barcelona, Spain. A whole year study using TAS simulation software was carried out for a Double Skin Facade corporative office building. Four different cavity as well as three different external opening areas for cavity's natural ventilation purpose for two Double Skin Facade typologies were simulated. Results demonstrated that a Multistory Facade, depending on its configuration, might save up to 5% on annual cooling loads respect to a Corridor Facade. Enayati (2014) in a study on the use of a two-dimensional view of the Museum of Contemporary Arts in Rasht, the factors of the ratio of the transparent surfaces (window) to the outer layer, the air cavity width and the width-to-high elevation proportions by Energy Plus software (with the interface of the Design Builder) Modeling and evaluated. and concluded that if Double Skin Facade is not properly

designed, it will not only reduce energy consumption in the building, but also can increase energy consumption.
DSFs were built in office buildings since 80s In Iran. The Supreme Audit Court of Iran (SAC) in Tehran is shown in Figure 2.

Fig. 2. The Supreme Audit Court of Iran (SAC) in Tehran. (http://www.altechiran.com/project_item_f.aspx?id=169510863, 2018)

3. ECOTECT and Simulation

One of the methods to optimize energy use and the essential tools for studying energy consumption in buildings is applications that are used as energy simulation software or energy analysis. The ability of such softwares is to estimate the need for constructional energy that has not yet been built and is in the design stage, enabling the designer to make necessary adjustments to reduce energy consumption and design optimal buildings before the construction phase (Ghiabaklou, 2009). Most of the software used to simulate and analyze the thermal design of buildings has numerical and mathematical environments and is efficient for Mechanical engineers. But since many decisions took place before architects began designing, software that was usable for architects and has an appropriate three-dimensional and graphics environment was less affordable (Medi, 2011). Ecotect is a comprehensive energy, light and sound analysis tool that can analyze relevant analytics in a fully graphical environment by using three-dimensional models built in its own environment or by other software applications. The dimensions of the simulation in this software can be from a small zone to an urban complex. Currently, the Ecotect program is able to meet many of the requirements for heat, light and acoustic heat transfer calculations and is taught and used in many universities in Europe and the United States (Ghiabaklou, 2009). In the structure of Ecotect, in addition to the possibility of checking the lighting levels and the sound characteristics, the ability to display the changes in the interior temperature of the building, the charts of cooling and heating, and the spatial distribution of radiant temperature. In addition, the expected comfort levels for inhabitants on a daily basis from month to year or year in the form of an hour to hour, along with the analysis of the stationary thermal performance of the designated thermal thermal absorption and dissipation, is visible(Medi, 2011).The prediction of the performance of two-dimensional views requires thorough thermodynamic studies. These studies, due to the fact that the air flow factor is a key factor in the productivity of these views, is highly complex and can not be done by Ecotect, and for the exact calculation of these calculations, other software such as Energy Plus, Design Builder and Fluent(CFD simulation) are required. However, due to the fact that the aim of studying the thermal behavior of two-dimensional views was in the Ecotect, research and simulation was done on this issue by determining the appropriate cavity width based on the number of comfort hours.

4. General Information

Based on the geometry of the facade (width openings, cavity height and width, etc.), Oesterle etal.(2001) categorized DSF into the following groups: box window, shaft window, corridor facade and multi-story. If the DSF extends over the entire height and width of the building, the term, facade, is appropriate. If the facade is divided into smaller units, three main categories can be defined. If the partitioning consists of vertical ducts, the expression shaft facade is adopted. When the facade is horizontally partitioned, the term corridor facade is usually employed. If the facade is both horizontally and vertically subdivided, the DSF is called window or box (Figure 3). The term windows can be used for systems in which the windows act as DSFs. The term box is more appropriate for entirely transparent envelopes with horizontal as well as vertical partitioning (Azarbayjani,2010)

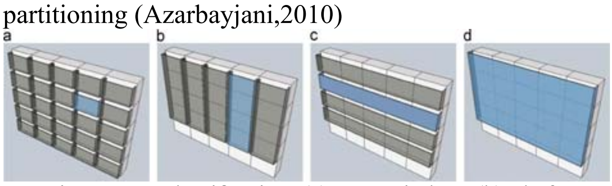

Fig. 3. DSF classification: (a) Box Window, (b) Shaft-Box(c)Corridorand(d)Multi-Storey Double'Skin Facade. (Azarbayjani,2010)

4.1. Box Window

In this type, the facade is horizontally and vertically subdivided, with entirely transparent envelopes. Horizontal and vertical partitioning divides the facade into smaller and independent boxes (Figure 4). Box window is the oldest form of DSF. The cavity between two facade layers is divided horizontally and vertically along constructional axes and floors respectively. This type of window is common in areas with high external sound levels and special requirements (Osterle, 2001).

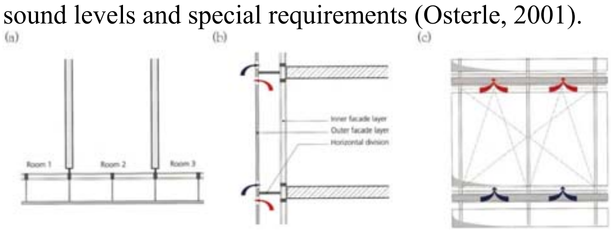

Fig. 4. Box-window type: Plan (a); section (b); elevation(c) (Osterle, 2001)

4.2. Shaft Box Type

In this case, a set of box-window elements are placed in the facade with continuous vertical shafts that go along a number of stories to create a stack effect. On every story, the vertical shafts are linked with the adjoining box windows by an opening. The stack effect draws the air from the box window into the vertical shafts (Osterle, 2001).

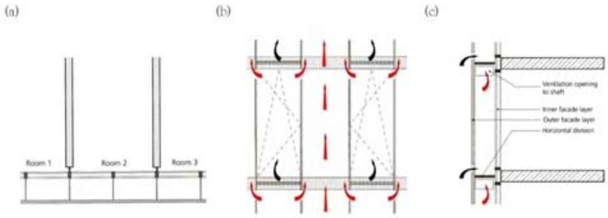

Fig. 5. Shaft box facade: Plan (a), section (b) and elevation(c) (Osterle, 2001)

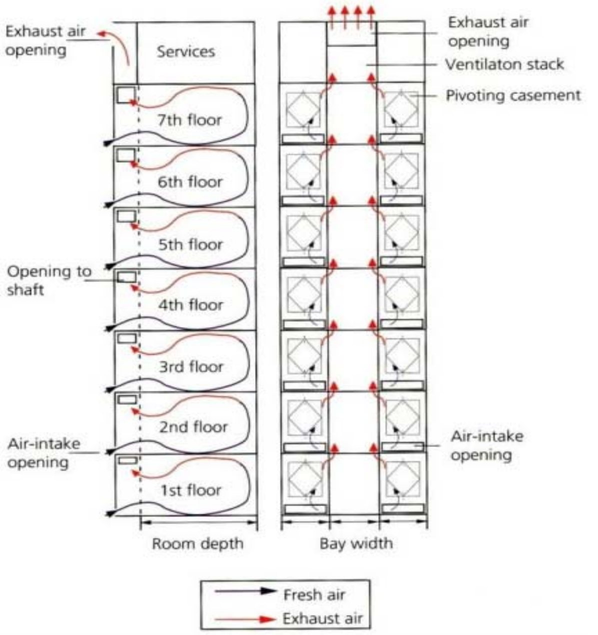

Fig. 6. Shaft box facade: Plan (a), section (b) and elevation(c) (Osterle, 2001)

4.3. Corridor type

When necessary, divisions occur horizontally along the corridor for fire protection or ventilation reasons. The intake and extract openings are situated near the floor and the ceiling. They are usually staggered to prevent extracted air on the floor from entering the space on the floor immediately above (Osterle, 2001). A plan, section, and elevation of a corridor facade are illustrated in Figure 6. As shown, the intermediate space is not divided at regular intervals along its horizontal length and air flows diagonally to prevent extracted air from the lower story being sucked in with the air supply of the above floor Figure 6.The section of corridor facade shows the separate circulation for each story.

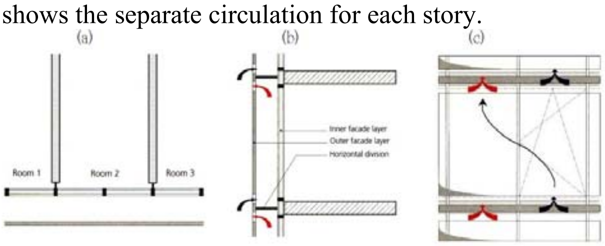

Fig. 7. Corridor facade: plan (a); section (b) and elevation (c) (Osterle, 2001)

4.4. Multistory

In this DSF case, the cavity is adjoined vertically and horizontally by a number of rooms. Ventilation occurs via large openings near the ground floor and roof. The room behind the DSF should be ventilated mechanically (Osterle, 2001). For winter conditions, the cavity can be closed at the top and bottom to take advantage of the greenhouse effect created in the cavity. During summers, the cavity is kept open to exploit cooling buoyancy. Multistory facades are suitable when external noise levels are high. However, high levels of sound transmissions that occur in the intermediate space in this facade type are problematic. As shown in Figure 3.9 the external skin is set independently in front of the inner facade. The intermediate space can be ventilated in all directions. The other problem of such a facade is related to fire protection as all the rooms are linked. Another issue with this DSF type is that major thermal discomfort exists for the upper floor chimney zone. In a multistory double skin facade, as a result of solar radiation, the air in the intermediate space between the two skins becomes warmer than the external air. The air in this space will therefore be lighter than outside air. The intermediate space is in contact with external air at the top and bottom, so that a pressure-equalization process occurs. The cooler external air is heavier and thus causes excess pressure at the bottom of the opening, which forces it into the intermediate space. The warmer air within this space is lighter and rises upward, thus causing a state of excessive pressure at the top, whereas the heated air provides less comfort in the upper floors if not totally ejected ,Figure 8.

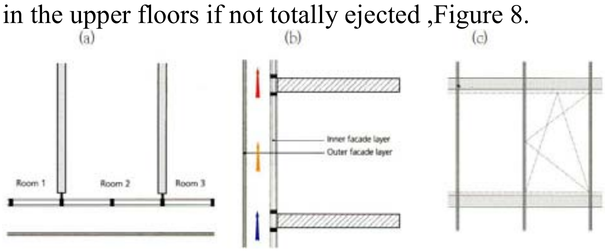

Fig. 8. Multistory DSF: Plan (a); section (b) and elevation(c) (Osterle, 2001)

5. Research Methodology

The building chosen for this research is one office building designed in Rasht which has different height in different directions of the building, South-West side has 3-story high, South-East side has 4-story high, North-East has 5-story high and North-West has 6-story high. Simulations were performed with the thermal program ECOTECT 2011 with and without DSF. The simulation software is fed with climatic data and predefined internal loads, plus thermal characteristics. In order to evaluate the energy improvements in building design, this office building was simulated with single skin at first as a base case then the same building with DSF was simulated. The performance of two buildings considering the number of hours of employee's comfort, direct and indirect solar gains.

6. Case Study

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The studied building is designed for Rasht (37 16 51 N, 49 34 59 E), with Moderate and humid climate. The DSF starts from the second floor and continues to the last one and is applied on all four sides of the building. The building in the middle is a square and it uses half of a square (triangle) on all four sides of the middle square, because the geometry of the dominant vernacular architecture in Gilan, which the center of it is Rasht, is based on the use of square and rectangular modules and is shown in Figure 9.

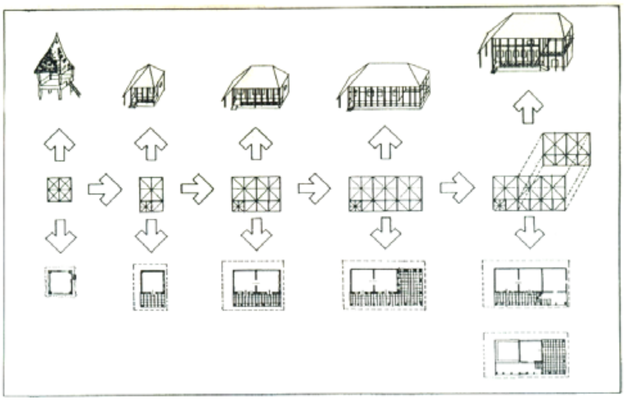

Fig. 9. Expansion pattern of the base unit in construction in Gilan (Diba and Yaghini, 1993)

Lifts and stairs are located on either side of the central hall. The office rooms are on the four sides of the facade. For simulation building plans was created based on existing and proposed physical and environmental conditions common in office buildings. Then 2011 Hourly weather data for synoptic meteorology stations of Rasht were prepared with the help of Meteonorm climatic software and entered into ECOTECT. For determining the total number of hours of indoor comfort, a prototype for reviewing and thermal simulation of office building without double skin facade in Rasht was initially modeled and evaluated. In the second period building with double skin facades was modeled and evaluated again. Building was divided to 14 thermal-controlled zones before the analysis and simulation began. Thermally- controlled zones include office spaces, corridors, conference hall, facilities and air handling units and skylight. It has also considered two uncontrolled areas; for the outer space of the building and a platform where the building, of which have been isolated from ground level (Figure.10&11&12).

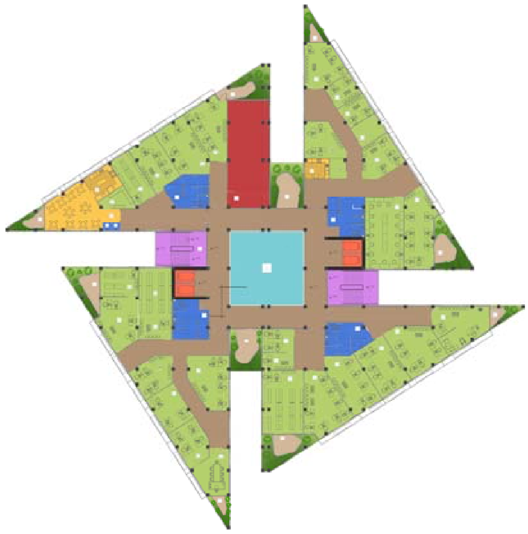

Fig. 10. Building plan designed for simulation (Authors, 2017)

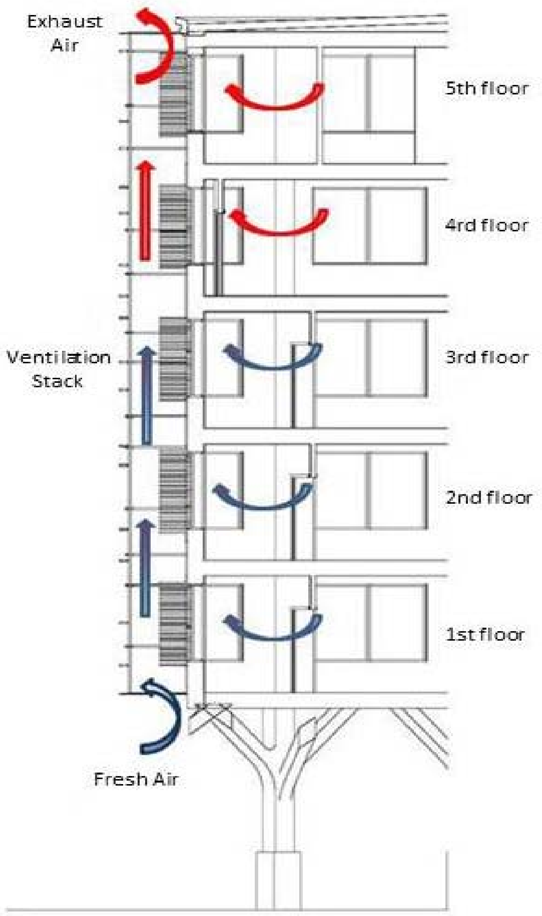

Fig.11. Section of Double skin facade for simulation (Authors, 2017)

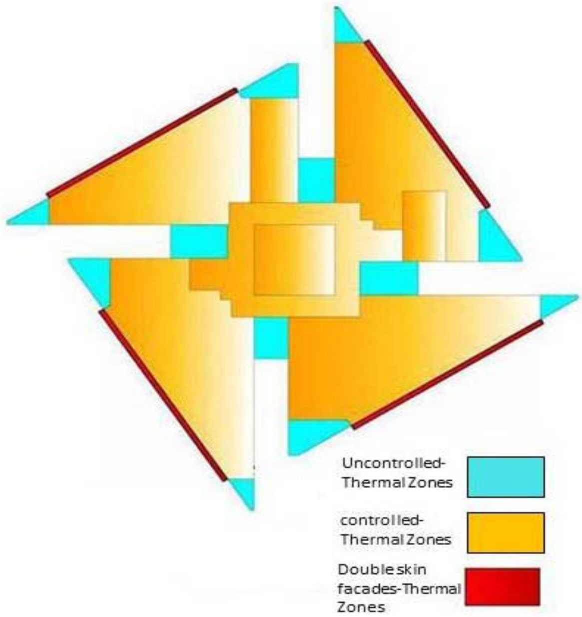

Fig. 12. Controlled and uncontrolled-Thermal zones in Plan (Authors, 2017)

Due to the fact that thermal behavior of DSF has great complexity, some interfering conditions have been imported into software settings in addition to floors and thermal zoning, such as the number of people, type of activities in the space and office equipment. The impact of adjacent buildings is ignored in this study. In the software settings, the thermal comfort range according to the bioclimatic building chart in Rasht, prepared by Kasmaei is 21-26 °C and the following fields for both cases are defined as follows.

7. Simulation Setting

-People clothing in typical situations is 1 Clo.
-According to the bioclimatic building table in Rasht city, the relative humidity of internal comfort zones is 60%.
-Airspeed inside the cavity of DSFs is (1 Meter per second), office spaces (0.5 m/s) and corridors (0/3 m/s).
-Lighting Level for corridors and stairs is 100 Lux and 400 Lux for office spaces.
-The average number of people in thermal zones during the day is 52 people.
-Energy for walking in corridors is 80 W/m^2 and 70 W/m^2 for sitting in office areas (these values are both defined by ECOTECT).
-The influence of wind infiltration rate, according to the existence of different entrance and exit doors, was set from 0.25 to 1 air change per hour.
-Weekly schedule of work and time to turn Off/On the facilities in adjacent spaces of DSFs for weekdays in Iran (Saturday to Wednesday) is from 7 to 15 and for weekends (Thursday) are considered from 7 to 13.
Based on calculated values, Internal Gains (Sensible and Latent Gain) are as follows .Table 1

Table 1
Sensible and Latent Gain in designed building for simulation (Authors, 2017)

Title of thermal Zones	**Sensible Gain (Watt per square meter)**	**Latent Gain (W/m^2)**
Ground floor corridor	795	350
Ground floor offices	2200	880
Stairs and Lifts	750	700
1 and 2 Floors corridors	2120	1120
1 and 2 Floors offices	68330	7590
3 and 4 Floors corridors	1970	980
3 and 4 Floors offices	48800	6710
5 Floors corridors	740	280
5 Floors offices	5183	604
Skylight	4712	550
DSF-1	0	0
DSF-2	0	0
DSF-3	0	0
DSF-4	0	0

Building simulation specifications are:
The Building's 14 thermal-controlled zones are: Skylight, office spaces with 4 thermal zones, Ground floor offices, 1st and 2nd floors, offices, 3rd and 4th floors, offices, 5 floors offices, with corridors around each floor. Office floors includes office spaces, auditorium, meeting rooms, stairs and escape stairs. Multiplicity of thermal zones of office spaces is for a closer examination of floors thermal stratification. However, to speed up the calculations, floors which have similar thermal behavior were placed into one thermal zone. Due to verifying Passive performance of the building with and without DSF, facilities option in software for simulation has been considered in OFF mode (up to the condition of) due to the purpose to analyze and evaluate the building with natural ventilation mode.
Building materials defined for the simulation, are as follows .Table 2

Table 2
Designed building Materials for simulation (Authors, 2017)

Type of building components	Thickness (Millimeter)	U-Value (Watt per square meter per degree kelvin)	Solar Absorption	Thermal Lag (Hours)	Structural Characteristics
Administrative Interconnections doors	40	2.98	0.55	0.4	Hollow core plywood
Stair's doors	6	5.35	1	0.39	Glass Sliding Door
Interior walls	130	1.80	0.506	5	Concrete Block Plaster
Ceilings	185	1.18	0.333	0.7	Concrete Floor Timber Suspended
Exterior walls	230	1.95	0.495	7.8	Double Brick Solid Plaster
Floors	185	1.18	0.333	0.7	Concrete Floor Timber Suspended
Windows	42	2.26	0.75	0.29	Double Glazed Low-E Timber Frame
Roof	75	0.55	0.5	0.7	Metal Deck Insulated
Double Skin Facades(Glass)	42	2.26	0.75	0.29	Double Glazed Low-E Timber Frame
Skylight windows	42	2.26	0.75	0.29	Double Glazed Low-E Timber Frame

DSF basic pattern in accordance for simulation is as follows in table 3:
-Air inlet vents are at the lower part of the facade and air outlet vents are at the top of the façade
-Ventilation between two layers of double skin facades (the cavity) considered natural ventilation
-Layers of double skin facade begins at the level of the first floor and ended at the same level with the roof of the building
-The placement of double skin facades is in every four fronts of the building
-DSF layers on four fronts are parallel two by two
-Investigated intervals between two layers of facade (the cavity) are 25- 50 -75 and 100 cm
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2.2 Results and Discussion

After the required software settings are applied, within a year it will be possible to measure the presence in the comfort zone and also ability to calculate and analyze the performance of each defined zone in this office building .
Modeling and simulation of office building was performed with various cases of DSFs with different width of cavities, checking the number of hours of employees, direct and indirect solar gain. Based on this measures it was found that this office building equipped with DSF-Shaft box type with 75 cm cavity width, due to the chimney effect and Thermosyphon phenomenon has more convenient hours and is better than other cases. It is notable that the natural ventilation system in a building can create a better condition compatible with the environment and reduce the need for mechanical ventilation. In naturally ventilated double skin facade, air enters the space between double skin at the bottom and is removed from the top of the facade due to the effect of wind pressure and the chimney phenomenon. Studies in the first half and the second half of the year with the simulation results of office building in both cases of basic model without DSF and superior case with DSF-Shaft box type with 75 cm cavity width, to evaluate the usefulness of double skin facades. In this study one of the parameters that affect the choice of double skin facades, is the ratio of air inlet and outlet valves which was investigated.

Table 3
Comfort hours of designed building with DSF (Authors, 2017)

Width / Floor (Centimeter)	Ground floor(h)	First and Second floor(h)	Third and Fourth floor(h)	Fifth floor(h)	Total hours of comfort
Box-window facade type					
25 cm	152	164	163	160	639
50 cm	152	166	162	161	641
75 cm	152	167	163	161	643
100 cm	152	168	162	161	643
Corridor facade type					
25 cm	152	164	163	160	639
50 cm	152	166	162	161	641
75 cm	152	167	163	161	641
100 cm	152	168	162	161	643
Multistory facade type					
25 cm	152	164	160	160	640
50 cm	152	165	160	160	640
75 cm	152	165	160	160	640
100 cm	152	165	162	160	640
Shaft box type					
25 cm	152	172	169	171	664
50 cm	152	175	170	171	668
75 cm	**152**	**179**	**175**	**171**	**677**
100 cm	152	175	169	167	663

5.1.1 Comparison of the various proportions of the inlet and outlet air valves Based on preliminary experiments in (Enayati 2014) investigation, it was found that reducing the intake air valve negatively affects the efficiency of Double Skin Facade, so in this study the inlet and outlet air valves were investigated with ratios of 1 : 1 and 1 : 2. It should be noted that the air outlet valve, can not be greater than the width of the cavity. Air intake valves; at the lower part of the facade; and the air outlet valves; at the highest part of the facade and linearly are located along each other. The sizes of the valves are classified in 3 types with different widths and according to the size of the windows. In the first case (ratio 1 : 1), the size of the input and output valves are: Figure13-16

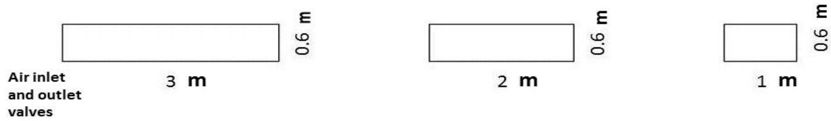


Fig.13. Three different types of air inlet and outlet valves at a ratio of 1 : 1 (Authors,2017)

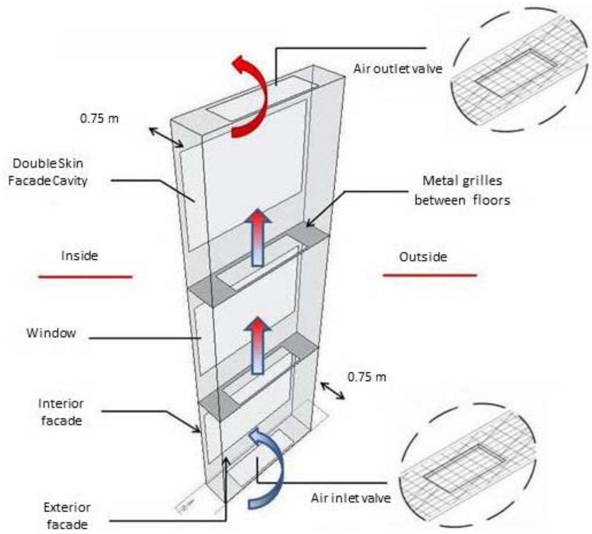


Fig.14. one of the different types of air inlet and outlet valves at a ratio of 1: 1 in double skin facade – shaft box type. (Authors,2017)

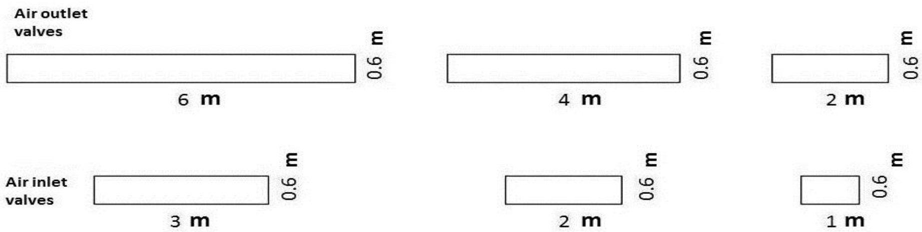


Fig.15. Three different types of air inlet and outlet valves at a ratio of 1: 2 (Authors,2017)

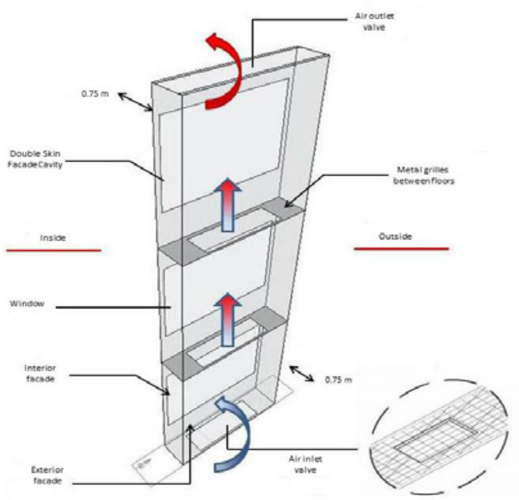


Fig.16. One of the different types of air inlet and outlet valves with ratio of 1 : 2 in double skin facade – shaft box type (Authors,2017)

Table 4
Comparison of the temperature distribution of the optimum double skin facade with different ratio of air intake and outlet valves in the first six months (Authors,2017)

Comparison of the temperature distribution of the optimum double skin facade with different ratio of air intake and outlet valves in the first six months

Zone	**1 : 1 ratio valves per hour**	**1 : 2 ratio valves per hour**	**Percent**
Ground floor	152	152	-
1st and 2nd floors	174	181	Increasing 4%
3-4th floors	177	186	Increasing 5%
5th floors	181	188	Increasing 3.8%

In between each story of building, metal grill is intended to provide air flow. Table 4
Comparison of the number of hours in the comfort zone for a double-sided view with inlet and outlet valves with two different ratios in Table 5-5 shows that with the increase in the level of air outlet valves, the efficiency of the two-pane view increases. Therefore, the air inlet and outlet ports will operate at a ratio of 1 : 2. Figure 17

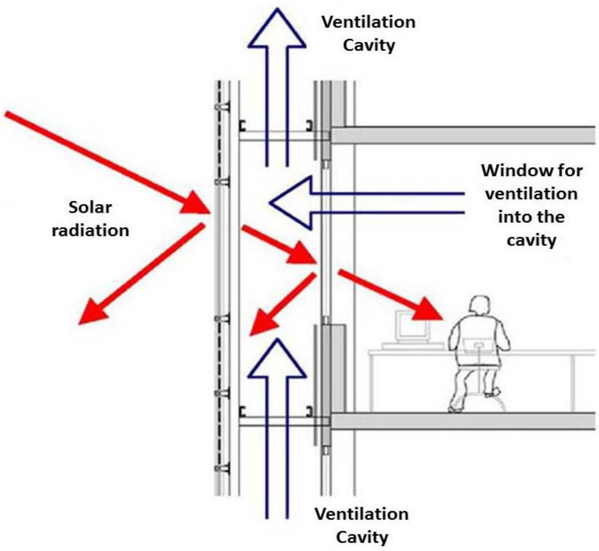


Fig. 17. Section of optimum Double skin facade proportionate to Rasht climate (Authors,2017)

Results for the first and second six months of the year are shown in table 5 to 8 and figures 17 to 20:
The results of simulation comparison of basic model with optimal Double Skin Facade model for Rasht for the first six months of the year (spring and summer). Figure 18
According to the comparison of temperature distribution diagrams (figure 18) and comparison of the minimum and maximum temperature (table 6) for the first six months of the year, it appears that the office building designed in a double-headed view with 75 cm vertical compartments compared to the initial state without a facade In the first six months of the year, in the ground floor, the first one increased by 0.6% and 6.4% respectively, and in the third, fourth and fifth floors, there was a decrease of 9.2% and 8.7%, respectively, in the number of hours of building occupation in comfort zone. The reason for this is that its double-paneled glass is inherently solar-absorbing, and therefore can not accommodate the setting of the administrative zones in the comfort zone, which is why the need for shadowing is raised, which in one a separate article will be dealt with. But despite the reduction in the number of comfort hours in the third, fourth and fifth floors, it is observed that the temperature of 36 degrees and 40 degrees of these classes decreased to 28 degrees, and is very close to the comfort zone. The reason for this decrease is the openness of the upper and lower openings of the double-glazed facade in the spring and summer seasons(Table 7 - 8). In this way, with the opening of the valves, the air is constantly changing and replacing, and therefore, in spite of displacement, the temperature is tangible. Figure 19 – 20.

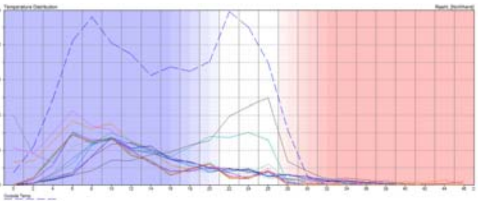
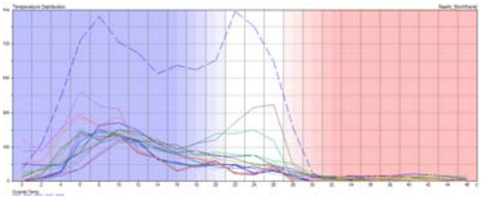
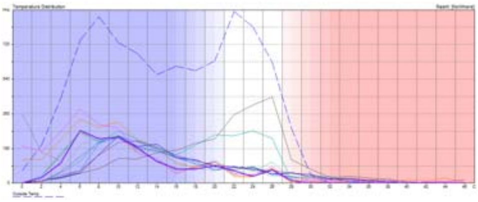
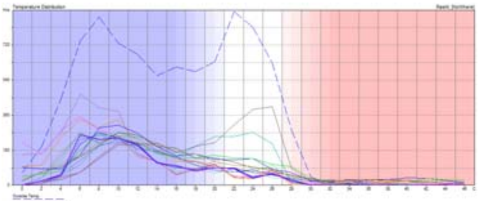
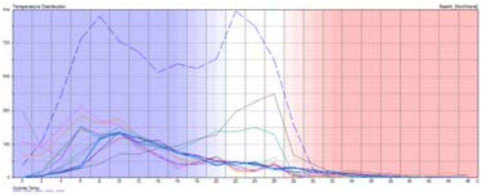
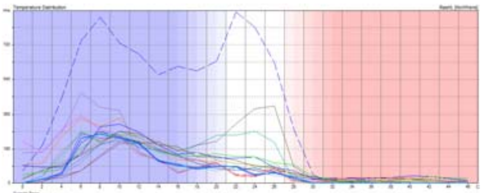
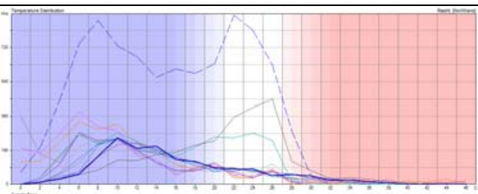
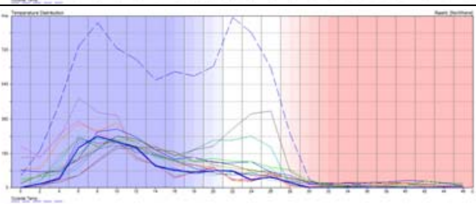
	Ground floor in basic model. Number of hours in comfort = 151 hours
	Ground floor with optimal Double Skin Facade model. Number of hours in comfort = 152 hours
	First&Second floor in basic model. Number of hours in comfort = 170 hours
	First&Second floor with optimal Double Skin Facade model. Number of hours in comfort = 181 hours
	Third&fourth floor in basic model. Number of hours in comfort = 205 hours
	Third&fourth floor with optimal Double Skin Facade model. Number of hours in comfort = 186 hours
	Fifth floor in basic model. Number of hours in comfort = 206 hours
	Fifth floor with optimal Double Skin Facade model. Number,of hours in comfort = 188 hours

Fig. 18. Comparison of temperature distribution diagrams of different building floors in basic model with optimal Double Skin Facade model for the first six months of the year (spring and summer) (drawing, Ecotect).

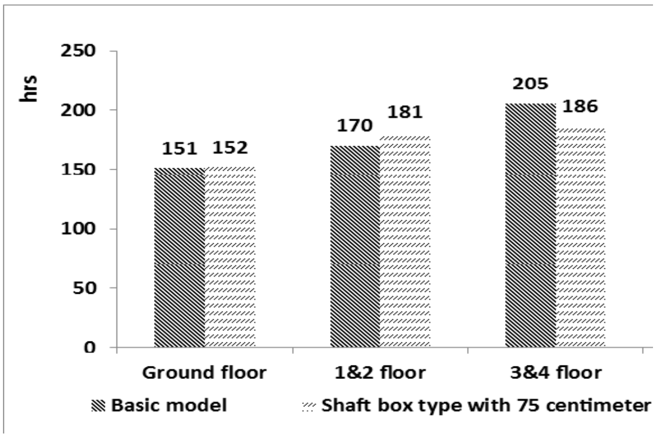


Fig. 19. Comparing the number of hours in comfort in temperature distribution (Authors, 2017)

Table 6
Comparison of minimum and maximum in basic model with optimal Double Skin Facade model for the first six months of the year (Authors,2017)

Thermal zones	Basic Model	with optimal Double Skin Facade model(Shaft Box 75 cm)	Temperature difference(°c)
Ground floor	28-Feb	26-Feb	-2
1&2th floor	28-Feb	28-Feb	0
3&4th floor	2-36	28-Feb	-8
5th floor	2-40	28-Feb	-12

Table 7
Comparing indirect solar gain in both cases of basic model without DSF and superior case (Authors, 2017)

Zone	Basic model(w)	Shaft box type with 75 cm cavity width(w)
Ground floor	400	400
floor ۲-۱	12000	6000
floor ۴-۳	229000	12000
floor ۵	82000	3500

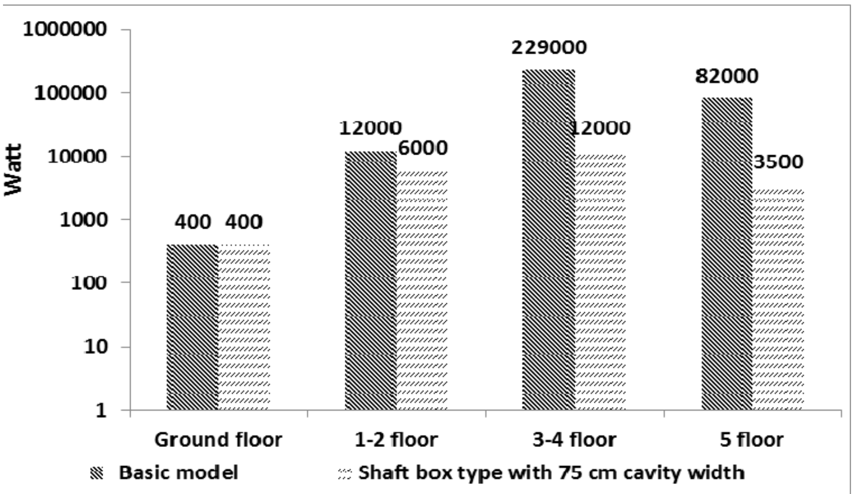


Fig.20. Comparing indirect solar gain in both cases of basic-model without DSF and superior case (Authors, 2017)

Table 8
Comparing direct solar gain in both cases of basic model without DSF and superior case (Authors, 2017)

Zone	Basic model(w)	Shaft box type with 75 cm cavity width(w)
Ground floor	900	360
1-2 floor	34000	3500
3-4 floor	20000	2300
5 floor	3300	380

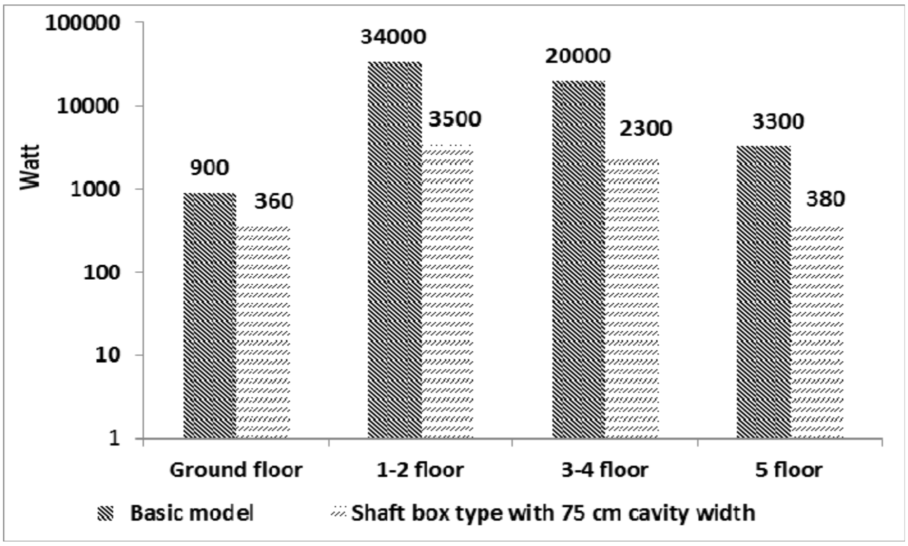


Fig.21. Comparing direct solar gain in both cases of basic – model without DSF and superior case (Authors, 2017)

By comparing the indirect absorption and direct absorption diagrams in the first six months of the year (spring and summer), the presence of a double glazed skin facade can significantly reduce the amount of indirect and direct absorption in all building floors. The results of simulation comparison of basic model with optimal Double Skin Facade model for Rasht for the second six months of the year (autumn and winter) Figure21&Table 9

Table 9
Comparing temperature in both cases of basic model without DSF and the superior case (Authors, 2017)

Zone	Basic model (hrs)	Shaft box type with 75 cm cavity width (hrs)	Results in percent
Ground floor	780	784	Increasing % 0.5
1&2 floor	796	767	Decreasing % 3.6
3&4 floor	574	740	Increasing % 28.9
5 floor	507	754	Increasing % 48.7

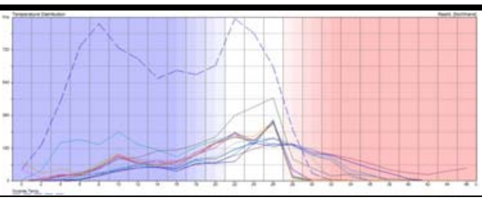
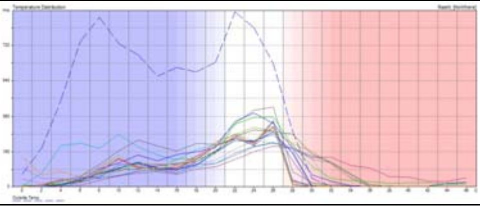
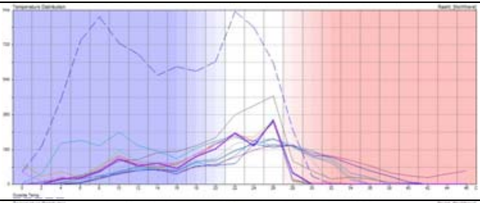
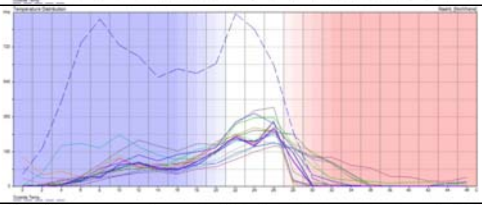
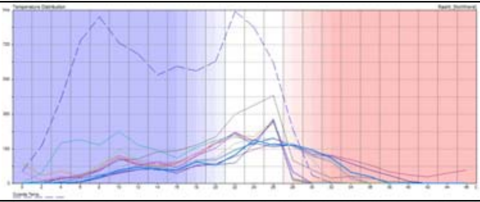
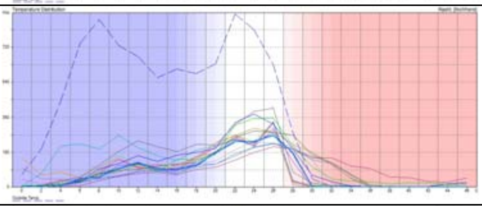
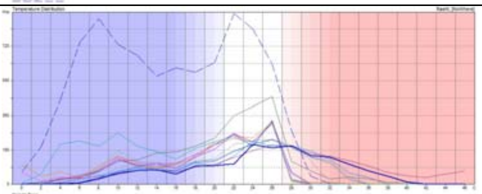
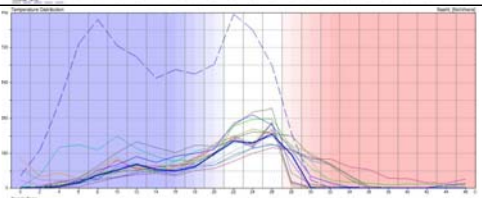
	Ground floor in basic model. Number of hours in comfort = 780 hours
	Ground floor with optimal Double Skin Facade model. Numb of hours in comfort = 784 hours
	First&Second floor in basic model. Numb of hours in comfort = 796 hours
	First&Second floor with optimal Double Skin Facade model. Numb of hours in comfort = 767 hours
	Third &fourth floor in basic model. Number of hours in comfort = 574 hours
	Third&fourth floor with optimal Double Skin Facade model. Numb of hours in comfort = 740 hours
	Fifth floor in basic model. Numb of hours in comfort = 507 hours
	Fifth floor with optimal Double Skin Facade model. Numb of hours in comfort = 754 hours

Fig. 22. Comparison of temperature distribution diagrams of different building floors in basic model with optimal Double Skin Facade model for the second six months of the year (autumn and winter) (drawing, Ecotect).

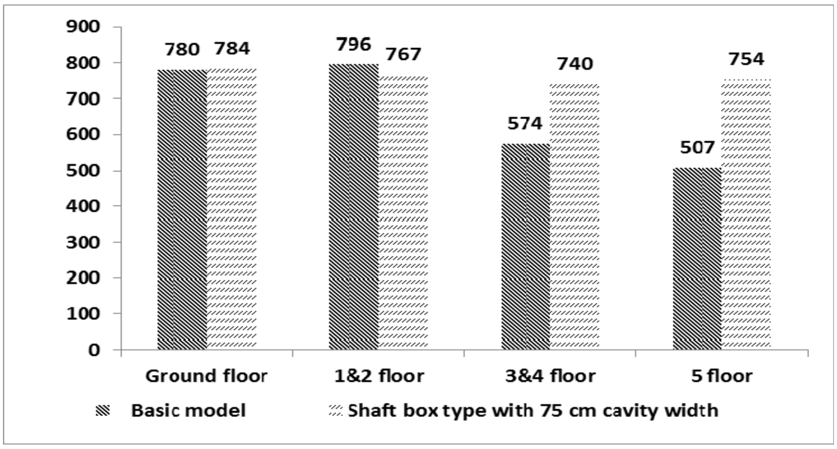


Fig. 23. Comparing the number of hours in comfort
in temperature distribution
(Authors, 2017)

Table 10.
Comparison of minimum and maximum in basic model with optimal Double Skin Facade model for the second six months of the year (Authors,2017)

Thermal zones	Basic Model	Model (Shaft Box 75 cm	Temperature difference(°c)
Ground floor	28-Feb	28-Feb	0
1&2th floor	28-Apr	2-30	2
3&4th floor	4-36	30-Apr	-6
5th floor	4-40	30-Apr	-10

According to the comparison of the temperature distribution diagrams (figure 22) and the comparison of the minimum and maximum temperature (table 10) for the second six months of the year, it is determined that the building is in a double-headed type with a vertical casing of 75 cm, Compared with the initial state without a facade in the second six months of the year, in the ground floor, third, fourth and fifth, increased by 0.5%, 28.9% and 48.7% respectively, and in the first and second classes, by 3.6%, the decrease in the number of exposures of the building in the comfort zone. The reason for this is that in the double-glazed view of the glass by closing the upper and lower elevators, the facade with the temperature in its cavity, as a barrier and protective against cold and cold winds control the building and its acceptable thermal behavior shows that the number of office hours in the comfort of the comfort zone increases. Except for the first and second floors, with the decrease in the number of comfort hours in the administrative zones, the temperature of these classes increased by 2 degrees compared to the non-facade, in the third, fourth, and fifth floors, a decrease of 4 to 6 degrees of additional heat in these classes. The result is more to keep the building close to comfort and less open doors and windows for extra heat extraction. As shown in Table 11& Figure 23.

Table 11
Comparing indirect solar gain in both cases of basic model without DSF and the superior case (Authors, 2017)

Zone	Basic model(w)	Shaft box type with 75 cm cavity width(w)
Ground floor	400	400
1-2 floor	12000	6000
3-4 floor	229000	12000
5 floor	82000	3500

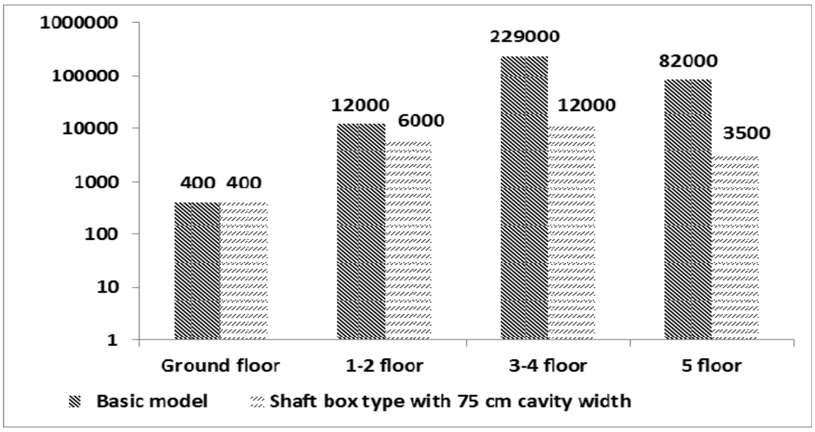


Fig. 24. Comparing indirect solar gain in both cases of basic model without DSF and superior case (Authors,2017)

Table 12
Comparing direct solar gain both cases of basic model without DSF and the superior case (Authors, 2017)

Zone	Basic model(w)	Shaft Box type with 75 cm cavity width(w)
Ground floor	900	350
1-2 floor	34000	3500
3-4 floor	20000	2300
5 floor	3300	380

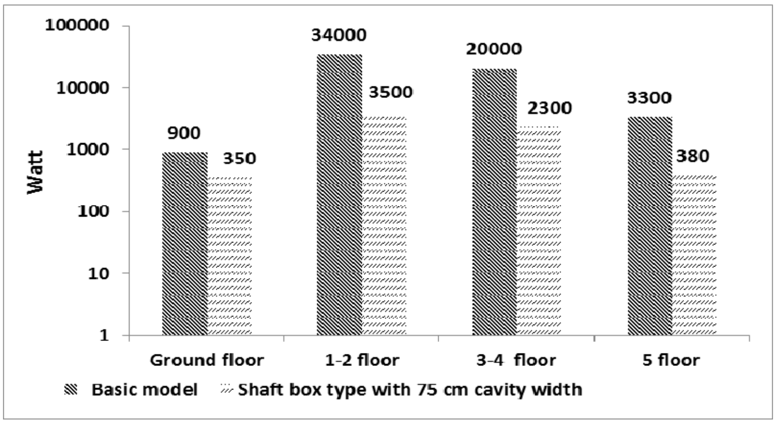


Fig. 25. Comparing direct solar gain both cases of basic – model without DSF and the superior case (Authors, 2017)

By comparing the indirect absorption and direct absorption diagrams in the second six months of the year (autumn and winter), in figure 24 and Table 12the existence of a double-glazed skin facade of the glass significantly reduces the amount of indirect absorption and direct absorption in all building floors.**3. Conclusion**

The aim of this research is to develop strategies for using a Double Skin Facade in Rasht with humid and moderate climate. Double Skin Facade which manage the heat interaction between indoor and outdoor spaces, is being adopted as facade system on many buildings in Europe and elsewhere (even in Moderate climatic zones) while maintaining a transparent facade. Investigations about DSF, it's thermal behavior and energy performance in the Mediterranean climate are just starting, while DSF buildings are being constructed adopting recommendations from investigations and experiences from other latitudes. This gap in humid and moderate climate is strongly felt. Iran, due to it's strategic location is now at the stage of development in all circumstances should consider the issue of sustainable development more seriously. For this purpose simulations and different assessments and factors have been studied. Simulation of different widths of Double Skin Facade indicated that the overall results have been relatively close numbers. This is due to the Moderate and humid climate of Rasht. It should be mentioned that all evaluations and analysis is done in natural ventilation mode and regardless mechanical ventilation system. Results show that heating in the second half of humid and moderate climate reduced. In fact, the temperature of the air in the cavity of the middle layer is more important than the outside temperature, thus cavity between facades, is protected building from the cold. In addition, hot air between the two Skins can be recovered to heat requirement of the coldest parts of the building. In second half of the year by closing valves of the facade and trapping air, can be used to enhance the comfort conditions in office zones adjacent to facades. It was found that this building with DSF-Shaft box type with 75 cm cavity width has more convenient hours and is better than other cases. Thus, using DSF in Rasht can reduce absorption of direct and indirect solar gain and increase the number of hours of comfort in adjacent spaces of DSFs (offices). Results show that double skin facades in Rasht, is appropriate for the second half of the year and it is necessary consider a combination of natural ventilation and mechanical systems; to increase the indoor temperature and time administrative of comfort zone. Location intake valves and the exhaust air cavity must be linear in one direction as well as the lack of barriers to the free flow of air as much as possible. It is recommended to have a double skin facade for whole year in Rasht, using flexible facades that have ability to be removal in spring and summer and also covering in Autumn and winter.

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