DESIGNING AN OFFICE COMPLEX USING PASSIVE SYSTEMS AND EMPHASIZING NATURAL VENTILATION IN TEMPERATE AND HUMID CLIMATES, RASHT CITY

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Abstract. The present paper focuses on designing and examining the use of passive systems with emphasis on natural ventilation in temperate and humid climates. Humidity is one of the most important climatic factors affecting human well-being in temperate and humid climates. One of the goals of climate studies in architecture projects is to reach the spaces where humans feel comfortable with the least amount of energy consumption. In the present study, simulation of passive systems for an office building in Rasht in summer was carried out. To simulate, Design Builder V.4.5, with emphasis on three types of ventilation systems, including stack ventilation, double-skin façade and atrium, has been used. Although many of the natural ventilation strategies have been designed to reduce energy consumption using renewable and clean energy, evaluation of the effectiveness and efficiency of such innovative systems is significant. The use of natural ventilation in office buildings not only helps reduce energy consumption, but also significantly reduces operating costs. However, how much are these passive physical projects effective and which natural ventilation method is the most efficient for achieving this goal are the main questions. The results of this simulation showed that the solar chimney system with a monthly average of about 68% of the ventilation rate was more effective and more optimal compared to the other two systems in the ventilation of the building. The double-skin façade and atrium system have 27% and 5% of the ventilation rate, respectively.

Keywords*:* natural ventilation, humid climates, stack ventilation, Design Builder V.4.5, passive systems.

Introduction. Attention to energy consumption and climate adaptation is one of the most important issues raised in the literature of modern architecture and urban development in the world [1, 2]. The amount of energy needed for cooling, heating and air conditioning of buildings is about 6.7% of the world's total energy consumption [3, 4]. Buildings in Iran account for a considerable part of energy consumption [2, 5, 6]. The distribution of energy consumption in a building shows that ventilation and air conditioning systems have the highest energy consumption, especially in office buildings[7, 8]. In general, energy consumption in office buildings is higher than other buildings. The energy consumption of these buildings ranges from 100 to 1,000 kWh/m^2 depending on location of the building, size of the building, and number and type of equipment used in the building[6, 9]. For example, in the United States, the average energy consumption is 300 KWh/m^2 and out of this amount about 79% is allocated to light and ventilation. In order to reduce energy consumption, the use of natural ventilation is one of the most effective factors in creating thermal comfort. This factor, by utilizing draft, decreasing relative humidity and increasing surface evaporation, can create conditions of comfort in humid climates[5]. Proper design architecture can lead to lower energy consumption by using passive system solutions. Systems that collect and store solar energy without the use of secondary energy to be used at the right time are called solar passive systems. With the use of these systems simultaneously in different components of buildings, the expectations in architecture, static supply, safety and energy efficiency will be met. When energy collection and equipment and execution costs are considered as the main design priorities, these systems will be most efficient among other solar systems[2, 10, 11]. In general, air movement is a major component in the desirable ventilation process. Natural ventilation takes place using the pressure difference from wind or temperature difference (buoyancy effect)[12]. The use of wind blowing for natural ventilation has several methods, of which the most important are windows, wind scoops and wind towers. The system uses the temperature difference based on the tendency of hot air to move upwards and the movement of cold air towards the warmer air which causes the air flow, while this displacement occurs in a closed system or closed circuit, it is called thermosyphon. The methods used for architectural design of office buildings include ceiling opening, solar chimney, double-skin façade and atrium. Natural ventilation is carried out in different ways, but the important thing is to choose which ventilation type according to conditions of the area and characteristics of the building (use, height, façade facing the wind, etc.)[13, 14]. In temperate and humid climates, an important factor affecting the thermal comfort is moisture. Therefore, the basic question is: which passive design strategy has a more favorable effect on natural ventilation and reduction in moisture of office buildings [11, 15, 16]. Unfortunately, the attention to climate and its various dimensions in contemporary urban and architectural projects of Iran is either not generally measured or carried out in a superficial and qualitative manner, which has no operational result or its results have not been used in design [17]. So far, many researches have been conducted in the field of passive systems with emphasis on the natural ventilation problem, in many of them, the use of systems such as double-skin façade, atrium, Solar chimney and ... has been focused. The topics studied have often been in an isolated way or individually. In this research, we try to provide an appropriate solution in architectural design in order to increase the natural ventilation by examining and evaluating passive systems with emphasis on the natural ventilation for an office building in the temperate and humid climate of Rasht.

Case study. The site selected in District 1 of Rasht, according to the proposal of the comprehensive plan by the municipality of Rasht, is dedicated to this. The site is located inside the city with an area of about 15,000 square meters, 8000 square meters including parking lots in the courtyard, 5 office floors in a positive balance, amphitheater in a negative balance. The site is located adjacent therapeutic, educational, sports and park uses. Access to the site is through the main street of Gholi Pour. The city of Rasht has a latitude of 19’-37 °, a longitude of 36 ‘-49 °, an average rainfall of 1348.4 mm, a maximum daily rainfall of 133 mm, an average freezing days of 35.6 °, an altitude of 7. It should be noted that this surface difference due to the slope of the earth is 7% from north to south of the sea and forest. Figure 1 is used to understand the project site physically.

Figure 1. Physical understanding of the project site

The average relative humidity recorded from 2004 to 2014 was 80.9%. The wind speed is decreasing in the summer, rising again in the autumn. Establishment of high-rise buildings in the direction of wind flow is non-scientific and non-principled, because it prevents the flow of air towards the city. The annual average of prevailing wind speed in Rasht is 1.7 m/s. Following is the climatic profile of Rasht.

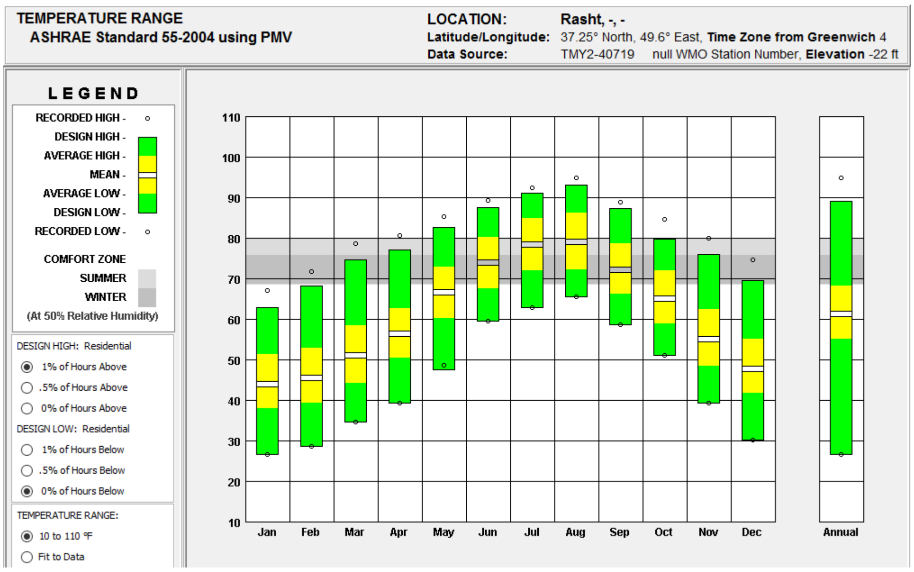


Figure 2. Thermal range in Rasht

Figure 2 shows the thermal range in Rasht, the data is based on the EPW file extracted from the Meteronorm software and based on the geographic location of Rasht, these charts were plotted on the basis of Rasht's atmospheric profile.

Method and Simulation. The method used in this study was simulation using Design Builder V.4.5 software. This software uses the simulation engine of Energy Plus. This software is able to calculate the natural ventilation calculations very accurately. To this end, the research done by Baghaei Daemei et al. (2016) can be mentioned for verification of the software[18]. Using this software, they have evaluated the natural ventilation of a residential building in the temperate and humid climate of Rasht. In this study, a building unit of a three-story apartment was evaluated. The type of ventilation was assessed as single and double-sided. Similarly, Sohail (2017) has evaluated a 25-story residential building and studied the natural ventilation in the Pakistan's climate using the Design Bilder software[15]. The results showed that a building which used fully natural ventilation could reduce energy consumption for cooling by 96% compared to the building using air conditioning systems. The purpose of this study was to investigate three types of ventilation systems including double-skin façades, stack ventilation, and atrium. These systems were on a hypothetical office building of five floors (ground floor, first, second, third and fourth).

The first passive system studied is ventilation in the solar chimney mode. The stack effect is the tendency of air or other gases to rise that occurs due to the low density of hot air to the surrounding air and seen in other chimneys or vertical passages. The air is displaced by the difference in temperature and pressure, and the higher the difference in temperature, the faster the displacement will be. Hot air tends to move upwards, leaving out through ventilation systems and other apertures, and replacing itself with cold air coming from lower surfaces [19]. This system was considered in different parts of the plan, by which the specified sections perform cooling operation on the basis of that. The spaces considered in this study are shown in Figure 3.

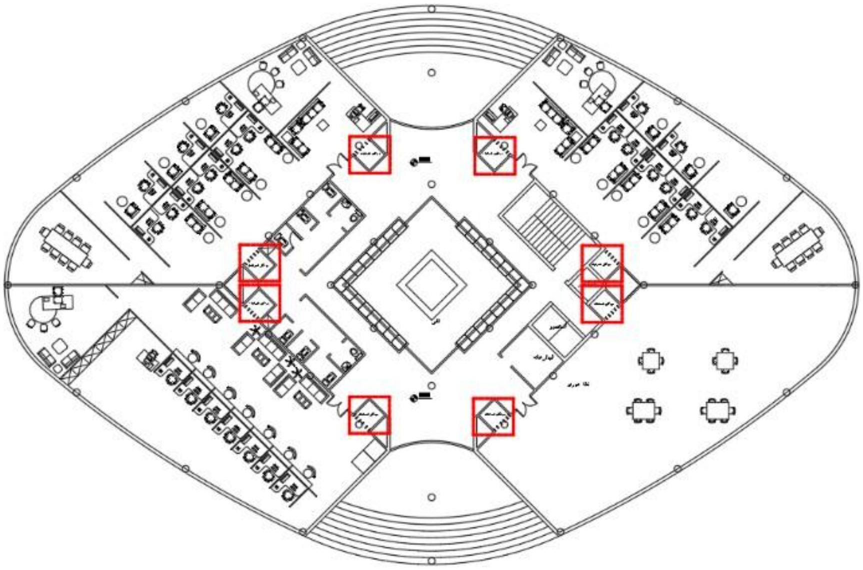


Figure 3. Displacement of solar chimney system in the plan (source: author)

The second passive system studied is ventilation in the atrium system mode. The atrium system is often designed in buildings to provide a light and tranquil environment that is compatible with the needs of residents. By providing a flow path in the building, they can also use the natural ventilation strategy for the surrounding rooms. The functional method is that in the summer, the building uses a gravitational flow system to enter the air through the outer windows and windows above the door of each room and to exit it through the high-surface windows or apertures on the top of the outer space [20]. The natural ventilation rate is calculated using velocity, pressure, gravity, dimensions of the openings and their performance, and dimensions of the openness using the air flow network of Energy Plus [9, 21]. The flow of air between windows, apertures and interior windows was modeled by exchanging an equal amount of air among the spaces. Initially, it was necessary to choose a method for using outside air for ventilation, which was set in the outside air definition method based on the min fresh air per person. The scheduling for when people were present in office working hours was considered to be from 7:30 to 16:30. The settings related to dimensions of openness of the windows or operation dimensions were set to 100%. One of the factors affecting the assessment of the rate of cooling and heating and the issue of thermal comfort is the metabolic rate that varies for men, women and children. This value is between 0 and 1 based on the standard, with an average of 0.9. The type of activity in the software was selected as light work, sitting and walking.

The level of people's occupation was also fully entered into the software based on their presence for the spaces evaluated for ventilation. In all designated spaces, the area was 850 m2. In the following, for six profiles, each one is presented separately in Table 1, introducing occupation levels and heat production by office equipment on the ground floor, the first and the second floors to the fourth floor.

Table 1. Introduction of occupation level and heat production by the office equipment on the ground floor the first and second to fourth floors

Description	Zone	Occupancy (people/m^2)	Schedule	Computer Gain (W/m^2)	Office equipment Gain (W/m^2)
Ground Floor Plan					
16 people who are 8 employees and 8 clients. 8 computers 215 per device. 8 x office supplies (printers) 300 watts per device.	2	16/850=0.018	7:30 am 16:30 pm	8*215/850=2.02	8*300/850=2.82
28 people who are 14 employees and 14 clients. 14 computers 215 per device. 7 x office supplies (printers) 300 watts per device.	5	28/850=0.032	7:30 am 16:30 pm	14*215/850=3.54	7*300/850=2.47
28 people who are 14 employees and 14 clients. 14 computers 215 per device. 7 x office supplies (printers) 300 watts per device.	19	28/850=0.032	7:30 am 16:30 pm	14*215/850=3.54	7*300/850=2.47
Number of people in the dining space 35	16	35/850=0.041	13:00 am 14:00 pm	None	None
First Floor Plan					
28 people who are 14 employees and 14 clients. 14 computers 215 per device. 7 x office supplies (printers) 300 watts per device.	3	28/850=0.032	7:30 am 16:30 pm	14*215/850=3.54	7*300/850=2.47
28 people who are 14 employees and 14 clients. 14 computers 215 per device. 7 x office supplies (printers) 300 watts per device.	18	28/850=0.032	7:30 am 16:30 pm	14*215/850=3.54	7*300/850=2.47
28 people who are 14 employees and 14 clients. 14 computers 215 per device. 7 x office supplies (printers) 300 watts per device.	15	28/850=0.032	7:30 am 16:30 pm	14*215/850=3.54	7*300/850=2.47
28 people who are 14 employees and 14 clients. 14 computers 215 per device. 7 x office supplies (printers) 300 watts per device.	5	28/850=0.032	7:30 am 16:30 pm	14*215/850=3.54	7*300/850=2.47
Second-Fourth Floor Plan					
28 people who are 14 employees and 14 clients. 14 computers 215 per device. 7 x office supplies (printers) 300 watts per device.	3	28/850=0.032	7:30 am 16:30 pm	14*215/850=3.54	7*300/850=2.47
28 people who are 14 employees and 14	18	28/850=0.032	7:30 am	14*215/850=3.54	7*300/850=2.47

clients. 14 computers 215 per device. 7 x office supplies (printers) 300 watts per device.			16:30 pm		
28 people who are 14 employees and 14 clients. 14 computers 215 per device. 7 x office supplies (printers) 300 watts per device.	15	28/850=0.032	7:30 am 16:30 pm	14*215/850=3.54	7*300/850=2.47

The double-skin façade was the third passive system examined. double-skin façades allow natural ventilation while controlling temperature, wind, rain and sound. The working principles of these façades are based on the flow and control of the air in the intermediate space between the façade and a glass skin [14]. In double-skin façades, the inner surface of the glass is often movable and can be opened by residents or automatic equipment. In this system, opening of the windows in a tall building, where bodies are exposed to high pressure of wind, is easily possible [4, 10]. The details of this system are presented in Figure 4.

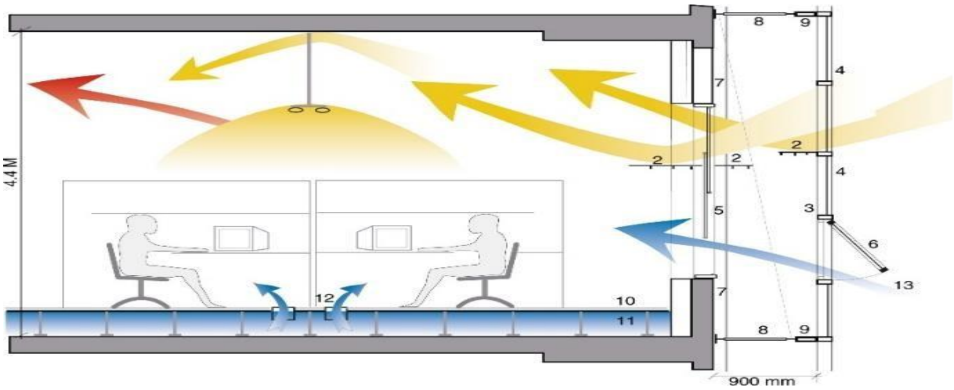
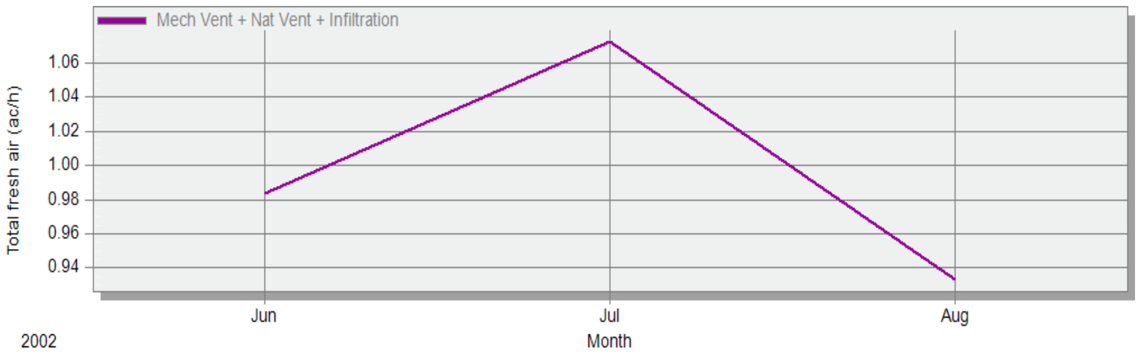


Figure 4. Details of the double-skin façade system

Results and Discussion. This simulation was carried out in the summer on three types of ventilation systems, including stack ventilation, double-skin façade and atrium. Its aim was to evaluate the performance of these systems in the most optimum optimal mode. Specifications related to exterior and interior openings, equipment and presence of people based on design assumptions were entered into the software. The climate studied is Rasht. The simulation output was taken of the software as hourly, daily, and monthly in the form of a chart. In the following, the outputs of the software are presented as monthly, and its minimum and maximum are evaluated as monthly in Chart 1.



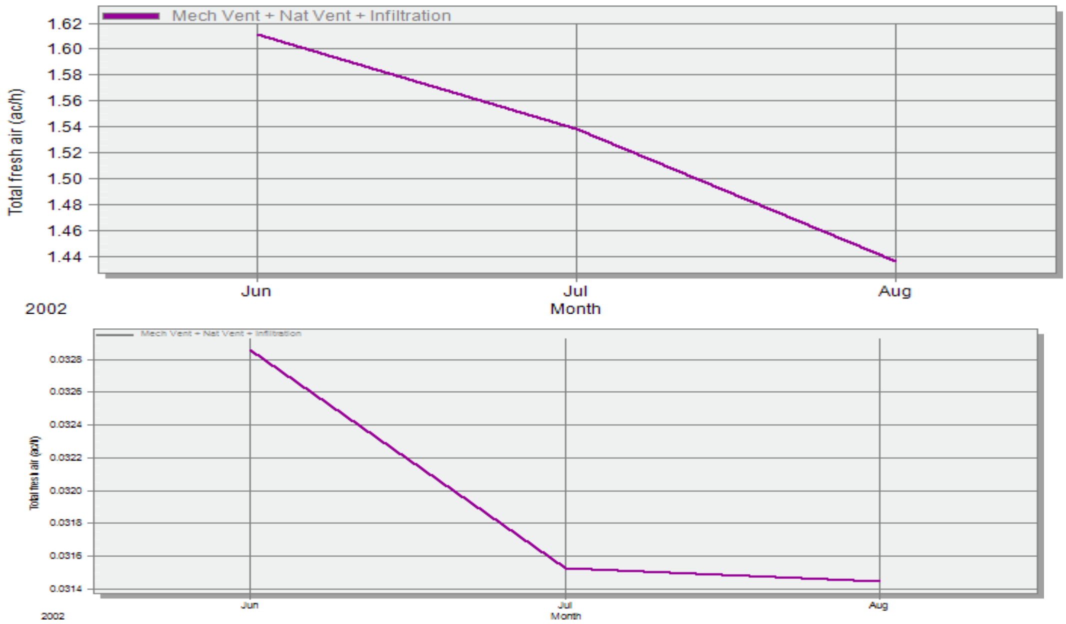


Chart 1. Display of minimum and maximum of natural ventilation rate as quarterly- solar chimney (a) double-skin facade (b) and atrium (c)

According to the monthly chart in the solar chimney system, it can be stated that in the month of Jun, in the beginning of the month and at the end of the month, we see a downward trend in ventilation and wind flow rate. As the peak of this amount is seen at the end of Jun and early July. This is in the situation that the ventilation rate has dropped significantly in the months of July and Jun. Similarly, the ventilation rate in the double-skin façade system noticeably had its maximum ventilation performance at the beginning of Jun, which was also higher than the solar chimney system. With the difference that it was almost halved in July, and this value has reached its lowest level, minimum, in August. In the following, it can be stated that the atrium system had a maximum level in early Jun. It is noteworthy that this amount has significantly reached its lowest level in July and August. In a preliminary conclusion, it was observed that all systems had similarly the same good ventilation performance at the beginning of Jun, and that the value had equally a decreasing rate in the other two months. In order to clarify the results of these systems, they were compared in charts, monthly, in each system.

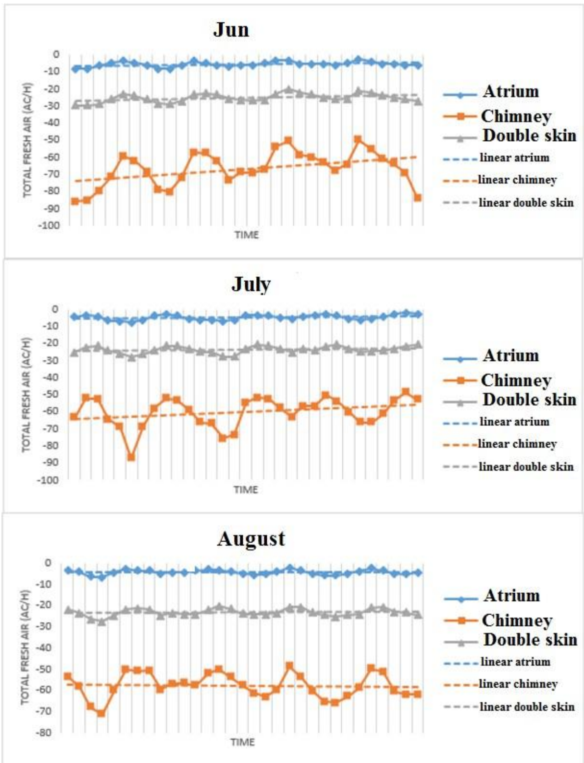


Chart 2. Comparison chart of each month based on various ventilation systems

According to Figure 2, it can be concluded that each ventilation system has one form of behavior per month. This means that three types of ventilation systems have a uniform behavior throughout the day in Jun. This is similar in July, but the solar chimney ventilation system has, compared to other systems, some maximum and minimum throughout the month. As the ventilation rate fluctuates almost every 5 days. Perhaps one of the reasons for this is the difference in pressure caused by the difference in temperature at that time when the air temperature outside the building was different from the interior and due to the functional properties of the solar chimney ventilation system, this difference in pressure and temperature affects its performance. Of course, these fluctuations are also seen in two other systems, but their intensity is lower. In addition, by plotting the regression line equation in the presented charts, it can be seen that in the months of Jun and July and August, the double-skin façade and atrium systems had the same and balanced performance, but the chimney system raised in Jun and July, which shows a better performance for the system so far, but this performance has declined almost in August.

In the following of summarizing the systems' performances, we need to determine numerically and as a percentage that simulation results show which system is optimal for performance. For this purpose, the average performance of the ventilation rate was calculated for each system every three months. In the following, this value was defined comparatively on the chart, and the results were presented as a percentage unit for each system.

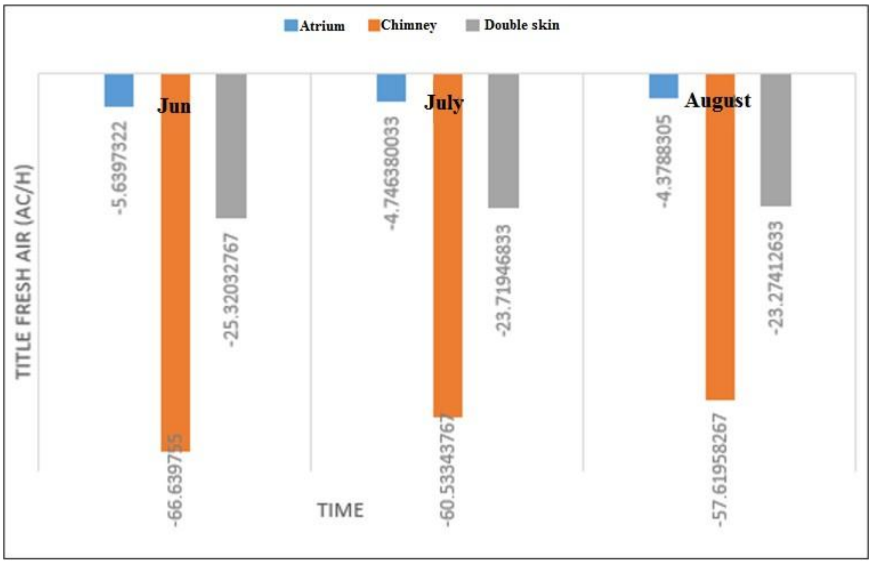


Figure 3. Average air flow rate for each system in the three months of the summer

According to the figure shown in Figure 3, it is seen that how is the air flow rate as an average per month in each system. Based on the results presented as an average, it can be stated that the atrium system has the lowest performance in terms of ventilation. This performance is lower in August than in other months. In addition, the double-skin façade system had a better performance than the atrium system, but as in the previous system, its performance declined in August. The simulation results showed that the solar chimney system has a much more efficient and optimal performance than the other two systems in ventilation. Results are shown in Figure 4.

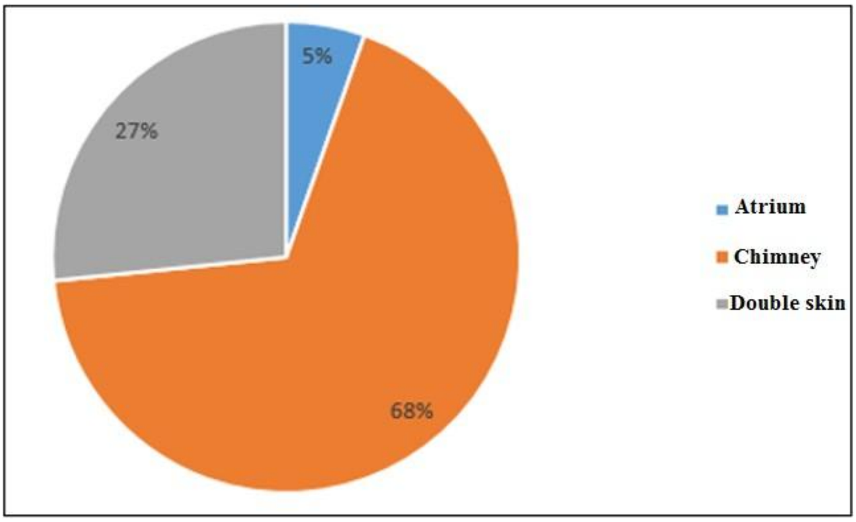


Figure 4. Display of the total average performance of the systems in the month

Conclusion. This paper provided an appropriate solution in architectural design in order to increase the natural ventilation by examining and evaluating passive systems with emphasis on the natural ventilation for an office building in the temperate and humid climate of Rasht. The method used in this study was simulation using Design Builder V.4.5 software. This software uses the simulation engine of Energy Plus and is able to calculate the natural ventilation calculations very accurately. According to the results of the findings, it can be concluded that the solar chimney system had a better performance of about 68% than other systems in total. Similarly, the double-skin façade system and the atrium system had a ventilation rate performance of 27% and 5%, respectively.

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