Analysis of Wind Behavior in Openings by CFD, in order to Enhance Natural Ventilation in Residential Buildings Design of Moderate and Humid Climate (Case of Study: City of Gorgan)

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Received: July 2019 Revised: October 2019 Accepted: November 2019

ABSTRACT:
Today, increasing environmental pollution due to the use of fossil fuels to provide thermal comfort is one of the problems of this area. The amount of these contaminants in residential buildings are more tangible. By referring to the traditional architecture, it can be seen that natural ventilation was provided by using natural forces (in this article: wind). Therefore, it can be concluded that the proper use of effective elements on natural ventilation can solve the problems created by air conditioning in new buildings. This article was identified different models of locating of openings in buildings (city of Gorgan) and analyzed the wind behavior in each of these models in terms of natural ventilation and finally, the optimal model for natural ventilation was selected. In this article, qualitative research methodology to identify and study the methods of using wind in vernacular habitats was used firstly. Then by CFD modeling and choosing selected models in terms of location of openings in order to improve the natural ventilation, Wind behavior analysis in these models was performed by the simulation research method (Gambit 2.4.6 software for making model geometry and creating grid mesh and ANSYS FLUENT 15 for wind behavior analysis). As a result of analyzes, models that had northeastern-southwest direction, more openings in the southwest elevation and the suction window in the opposite direction were selected as the optimal model for residential buildings in city of Gorgan.

KEYWORDS: Natural Ventilation, Residential Building, Gorgan, CFD, Moderate and Humid.

1. INTRODUCTION

The motives and the background for using a natural ventilation system are different. Complex systems of mechanical ventilation have many components that require space and energy consumption, therefore, integrated use of the system in buildings is challenging. Also, the use of mechanical systems requires expert and skilled personnel, which is another reason for the lack of convenient and accessible use. The quality of the architecture and the proper air for breathing are the functions and results of ventilation in the building. In addition, mechanical ventilation systems have a shorter life span than building structures. On the other hand, because of the complexity of complex systems in these buildings and the presence of ducts that are involved with the structure of the building, the repair and reconstruction of these systems is difficult and sometimes damages the structure of the building. Therefore, mechanical ventilation systems, although they do not create optimal air, lead to a cost. Consequently, the use of these systems was reduced to a point where engineers thought of reuse of natural ventilation systems in buildings [1].

Libraries should be given special attention in terms of spatial quality. Unfavorable air quality (increasing the amount of CO2 in space) has a detrimental effect on mental functions. Therefore, the need for fresh air cycle in buildings not only affects the performance of indoor air conditioning but also improves the efficiency of users [2].

Regarding the study of climate diagrams, the best direction for building a residential building in the city of Gorgan is the one that could take advantage sunlight during the cold season in addition to wind power. given that the southern directions and the angle of 165+ and 150+ degrees (South) are the best in terms of receiving sun energy, and on the other hand, the best and most favorable winds (on average) during the warm and cold seasons of year are from the south, west, and southwest, so the common point between these directions (in terms of radiation and wind) are south, 150 and 165 degrees (south). In orienting the main plan of the building, attention to each of these directions and the installation of appropriate openings can be effective in receiving sun energy and favorable winds for domestic air conditioning [3].

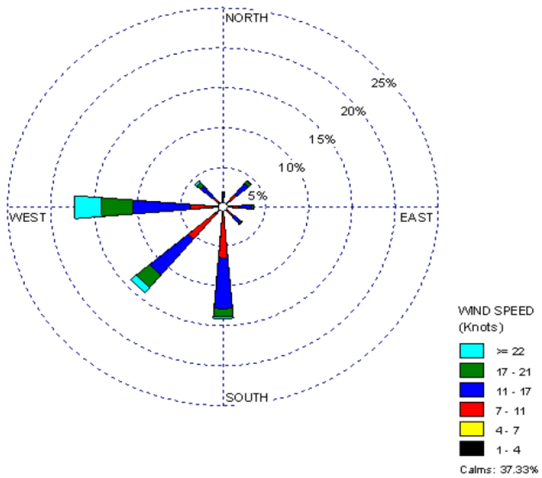


Fig. 1. Annual wind rose in city of Gorgan [4].

2. RESEARCH QUESTIONS AND RESEARCH METHODOLOGY

In this paper, the overall framework for research is organized to answer the following questions:

1. What is the relationship between natural ventilation and building design in a moderate and humid climate (City of Gorgan)?
2. How can the correct placement of openings affect the improvement of natural ventilation?
3. What is the impact of the orientation of a residential building on the natural ventilation of a residential building in a moderate and humid climate (Gorgan)?
4. How will the direction and wind speed (dominant and optimal) affect the residential buildings in Gorgan?

The research method used in this paper is qualitative and quantitative. Qualitative research method has been used in the architecture recognition process of Gorgan. So that first information was collected from library resources and authoritative sites to address the architecture and housing in the city.

In the data analysis, quantitative research has been used. Firstly, the effective parameters on indoor air ventilation were determined. Afterwards, eight opening layout models were selected in a room size of 2.5×6 m², which differed in terms of positioning and opening dimensions, suction and opening distance. The eight models were analyzed by wind engineering and analyzed using simulation research and Gambit software (for the room geometry, creating mesh network around and inside the room) and FLUENT software (for wind behavior analysis). Information about the direction and wind speed that is required input data for FLUENT software is taken using the meteorological average of the Meteorological Office of City of Gorgan.

3. BACKGROUND OF RESEARCH

In the late 1930s, there was great deal of interest in ventilation engineering [5]. Awareness of internal air currents in closed environments is important because of three reasons: thermal comfort, indoor air quality and energy consumption. In 2006, Lomas presented comparative comparisons of three large educational institutions in the UK and the United States and presented solutions for building architectural design using Advanced Natural Ventilation (ANV) [6]. Studies showed that over the past two decades, attention to "indoor air flow" in the form of new knowledge has increased dramatically [7]. In 2008, Asfour examined the quality of ventilation and the improvement of wind movement in vaulted ceilings using CFD modeling [8]. In 2009 Gribble explored the natural ventilation of Egyptian underground graves, in which cool and fresh air is replaced to be used for the following day [9]. Da Grac (2012) examined natural ventilation in a commercial building in Lisbon, Portugal. Initially, eight dominant wind directions out of 32 wind directions are determined, then evaluated the strengths and the weakness of the building against wind using Energy plus & Design Builder, and finally offered some suggestions [10]. In 2014, Hazbei conducted research on natural ventilation of Shavadoon in Dezful; CFD modeling was used to achieve the goals of this study; he described Shavadoon as one of the best ways to adapt to the work environment and comfort using annual temperature of the land and natural ventilation [11]. In March 2015, Heydari introduced patterns using the Gambit 2.4.6, Ansys FLUENT 15 to study and analyze the wind in order to modify the architecture of rural housing in Sistan and Balochestan [12]. However, there is no comprehensive research on natural air flow and natural ventilation in residential buildings in the northern cities of Iran, including Gorgan.

The importance of the effect of ventilation quality on improving the study efficiency and inefficiency of buildings in the field of optimal natural ventilation design can be mentioned in order to express the necessity of addressing the subject of this research. Natural ventilation has long been used in buildings as one of the most important methods of cooling. In the modern era, the prevalence of air conditioning systems has led to the design of isolated buildings and the application of natural ventilation is ignored. In the 1970s, the energy crisis and the emergence of environmental problems have become a reason for renewed attention to renewable energy sources. On the other hand, syndromes and problems caused by the health of users and the decline in indoor air quality, which is the main reason for the use of air conditioning systems, has led to a greater desire for natural ventilation. Today, the design of ideal libraries with the application of natural ventilation requires the existence of theoretical foundations and accurate studies based on new knowledge regarding the feasibility of the application, the design of components and equipment related to natural ventilation. In Iran, despite the brilliant background in the application of natural ventilation in buildings, in the contemporary period, there has been no applied research in the field of natural ventilation in the design of libraries, and most of the research has been descriptive and report. Considering the consumption of major energy consumed in the world for the cooling and heating of large buildings such as libraries and the impact of ventilation on users, and improving the productivity of study in these places, the need for applied research in the field of natural ventilation is determined.

4. COMPUTATIONAL WIND ENGINEERING (CWE)

Studies have shown that in recent decades, attention to "indoor air flow" has grown significantly in the form of modern knowledge [11]. Natural ventilation is an important factor in improving the tolerability and health of indoor environments that is done by wind or floatation or often by combining them. This research is a subset of CWE. Wind computational engineering is known as the use of Computational Fluid Dynamics (CFD) and other computer modeling for wind engineering applications. Applications of CFD simulation in the building domain include:

A) Simulation of CFD for PLW in buildings;

B) Simulation of CFD in natural ventilation (NV) of buildings;

C) Simulation of CFD in WDR in building facades

Therefore, one of the applications of CFD simulation in the field of building is simulation in natural ventilation (NV) of the building. In this paper, this method is used to analyze the wind behavior in natural ventilation of City of Gorgan.

5. CITY OF GORGAN

Golestan province includes Gorgan land and plain. Gorgan and plain is a vast area with a total area of 2,236 square kilometers located in the southeast of the Caspian Sea between the northern slopes of the eastern Alborz Mountains and the Atrak River [13]. The habitat of this area is about ten thousand years old, and exploration on the southern shores of the Caspian Sea in places such as the Hutu cave and the belt near Behshahr indicated that the area's history dates back to the cave period of humanity. The excavations carried out in the Shah Tappe, Yarm Tappe, Torang Tappe and Dasht Gale indicated that this area is one of the major areas of prehistoric civilization and it was after the history of north and northeastern Iran [14]. In the writings of Greek and carvings of Achaemenid era it is mentioned as a civilized city was under invasion of northeastern nations [15]. Nowadays, these lands are the habitats of different ethnic groups are of Aryan, Mongolian and Turanian origin [16]. Turkmens, the most important minority of this population are the most prominent racial group in Iran and the last population who have come from central Asia to Iran in recent centuries [17].

Fig. 2. Golestan province map [14].

5.1. Climate

Based on the quadruple divisions of the Iranian climate proposed by Dr. Hassan Ganji, which is the modified form of Köppen classification, Golestan province is in the temperate and humid climate of the Caspian Sea. In term of climatic data, this area is moderate and humid [18].

Table 1. Climatic data of Gorgan (Writers).

Founded	Position of station	Type of station	Altitude	Latitude	Longitude
1952	Hashem-abad	Synoptic	(m) 13.3	54.24 E	36:45 N

5.2. Weather

According to the table below, there is a difference of 87 mm between the dry months of the year (June, July, August and September) and the wettest month of the year (late February to late March). During the year, the average temperature changes to 25.4 degrees Celsius.

Table 2. Weather of Gorgan [19].

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	0.9	2.5	7.2	11.5	16.8	21.8	26.3	25.6	20.9	15.4	9	3.4
Min. Temperature (°C)	-4.2	-3.1	1.1	5	9.1	12.4	16.9	16.2	11.1	6.5	2	-2.1
Max. Temperature (°C)	6.1	8.2	13.3	18.1	24.6	31.3	35.8	35	30.8	24.3	16.1	9
Avg. Temperature (°F)	33.6	36.5	45.0	52.7	62.2	71.2	79.3	78.1	69.6	59.7	48.2	38.1
Min. Temperature (°F)	24.4	26.4	34.0	41.0	48.4	54.3	62.4	61.2	52.0	43.7	35.6	28.2
Max. Temperature (°F)	43.0	46.8	55.9	64.6	76.3	88.3	96.4	95.0	87.4	75.7	61.0	48.2
Precipitation / Rainfall (mm)	85	73	87	82	42	0	0	0	0	18	59	65

Table 3 presents the comparative data of Gorgan's meteorological stations, which were collected by the Iranian Meteorological Organization from 1952 to 2005.

Table 3. Synoptic data of Gorgan weather station [20].

Gorgan	Center of province
601	Total precipitation/rainfall (mm)
12.8	Avg. of Min. temperature (°c)
22.7	Avg. of Max. temperature (°c)
103.9	Number of rainy day
4.8	Number of snowy day
1952-2005	Census period

Based on the above information, we arrive at Table (4), and by matching these data Köppen classification, it can be concluded that Gorgan is located in the Csa (Mediterranean) region.

Table 4. Data of temperature and precipitation/rainfall in Gorgan (Writers).

17.7	Annual Avg. temperature (°c)
42.6	Annual Avg. precipitation/rainfall (mm)
0	Total precipitation/rainfall in the hottest month (mm)
87	precipitation/rainfall in the wettest month of winter (mm)
0	precipitation/rainfall in the driest month (mm)
35.8	temperature in the hottest month (°c)
-4.2	temperature in the coldest month (°c)
Csa	Result (Based on Köppen climatic classification)

5.3. Wind

In order to determine the most suitable direction for the construction in the project area, the winds of the area should also be considered. Creation of air flow in the interior space is essential for the comfort.

Wind blowing in the area is an important factor in determining the direction of the building. Therefore, in the design phase of the building, and especially when choosing where to locate the building on the site, not only the type of climate and sun, but also the direction and speed of the winds of the area should be considered.

Table 5 shows the distribution of wind speed and frequency in the 8 directions of the studied area that is based on the daily recorded weather data of the Gorgan (2002-2005) meteorological station.

Table 5. Frequency and speed of wind in Octagonal Directions of Gorgan [4]. station [20].

Frequency Distribution (Count)

Wind Direction (Blowing From) / Wind Speed (Knots)

	1 - 4	4 - 7	7 - 11	11 - 17	17 - 21	>= 22	Total
N	23	0	181	107	20	6	337
NE	36	0	318	325	63	11	753
E	37	0	283	255	45	12	632
SE	28	0	227	216	32	14	517
S	96	0	1016	1105	180	32	2429
SW	132	0	790	1019	353	147	2441
W	66	0	590	1145	635	545	2981
NW	35	0	225	338	98	50	746
Total	453	0	3630	4510	1426	817	17291

Frequency of Calm Winds: 6455
Average Wind Speed: 7.97 Knots

6. RECOGNITION OF IMPORTANT ELEMENTS IN THE NATURAL VENTILATION OF TEMPERATE AND HUMID CLIMATE

The climatic equation for a natural ventilation is a related concept but different from natural ventilation potential. Natural ventilation potential, in addition to the possibility of natural forces, also includes the ability of building features to take advantage of the existing forces. In other words, in addition to the possibility of natural effective forces, whether the building can use the benefits of the effective natural forces is also effective in determining the amount of natural ventilation.

6.1. Site features

Site features are site location, texture density and urban heights, vegetation types and levels, street dimensions and orientation, distance between blocks, air pollution and safety. Some of these characteristics are effective on the small amounts of driving forces effective on ventilation, and some of them are considered to be qualitative features of the site.

6.2. Climatic features

Climate factors affecting the natural ventilation are factors such as average monthly temperature, maximum and minimum temperature, night and day temperature difference, relative humidity, wind speed and direction. One of the most important of these factors is the available driving forces for ventilation, which include two wind forces, floatation force and a combination them.

6.3. Building features

Ventilation for the purpose of cooling is highly dependent on the physics of the overall design of the building, the design of openings and special ventilation elements. The physical components affecting the natural ventilation function of the building consist of the following three general components:

- Building proportions in height and level.
- Shell elements including shell form (wall and roof), outgrowths and deformations, size, type and number of openings and shades, properties and type of materials as well as building orientation. The interior components of the spaces including the communication and distribution of spaces, the characteristics of the internal walls (area, type of materials and thermal mass).
- Special ventilation components.

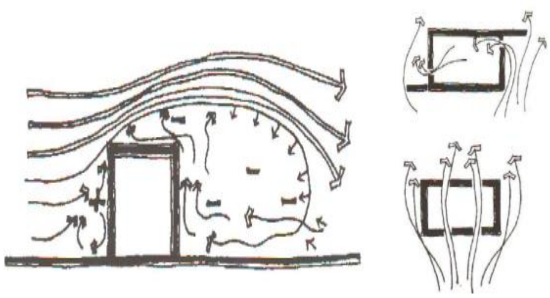


Fig. 3. Building form in according to natural draft [21].

In addition to the above, the natural ventilation efficiency is influenced by other factors such as the type of building usage and the amount of internal heat, residents' control over the performance of openings, and the effect of changing the ventilation patterns. In the present study, a number of shell elements have been tested and the proportions of building and internal components of space in all tests are considered to be constant.

7. ANALYSIS OF WIND BEHAVIOR IN SELECTED MODELS BASED ON FLUENT AND GAMBIT

After identifying the number of simulations, simulation of the plans is done with the help of the FLUENT software. In these simulations, the geometry of the rooms is first simulated by Gambit software. The next stage in the process of simulation is the creation of a mesh network for geometry, and finally, the boundary conditions are defined for inputs and outputs of the wind flow. A mesh network that is designed to analyze the behavior of the wind in the room by Gambit software should include the creation of a mesh outside and inside the room.Creating a mesh network outside and around the room is done to properly analyze the behavior of the wind. Since the behavior of the wind is also important behind the room, so the longer mesh networks in FLUENT software is defined so that the behavior of the wind can be evaluated and monitored as it reaches the room.

After defining the mesh for selected models, the behavior of these models versus wind energy is analyzed using the FLUENT software, the wind speed that is considered in this software as wind speed input, is the same wind speed over the last ten years in Gorgan that is obtained from the data of the Gorgan (Hashem-abad station) and is 3 meters/second.
Table (7) shows the wind speed contours in the selected models, which are presented in Table (6).

8. CONCLUSION

In general, the following practical and executive solutions can be proposed for modeling and repairing existing buildings in Golestan province, Gorgan:

1. The use of effective elements on natural ventilation, it should be noted that the use of elements affecting natural ventilation absolutely does not improve the cooling of the air and may require the use of mechanical cooling equipment on some days, but the use of native elements in many days of the year can reduce energy consumption to a large extent.
2. The elongation of buildings along the northwest-southeast (perpendicular to the most desirable wind in Gorgan) leads to a good natural ventilation in the building by creating a good dispersion of openings in the southwest.
3. Field observations and engineering computational engineering analyzes show that the placement of openings on the southwest and perpendicular to the dominant wind flow and the displacement of the window counteracting the wind flow is highly effective on the natural ventilation inside the building, thus conforming them in accordance with the rules and regulations are recommended for proper natural ventilation.
4. The design of the openings so that they help the outflow of wind when closed.
5. Providing measures for using a window on the southwest front of the building and the designing window so that it prevents dust and insects and while it helps the lightning of room.
6. Designing details for the ventilation valves to achieve the natural ventilation potential for proper air conditioning and reduce the building temperature, inspired by native methods can be considered for future research.

Table 6. Meshed models in Gambit Software

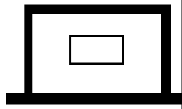
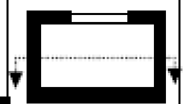
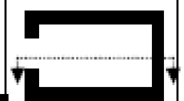
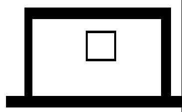
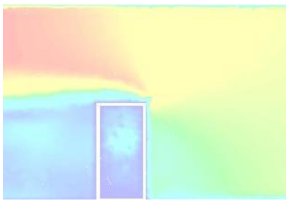
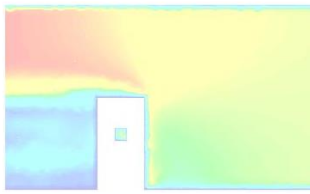
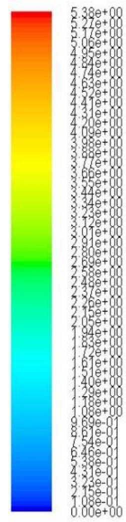
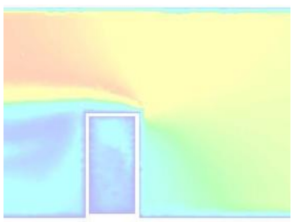
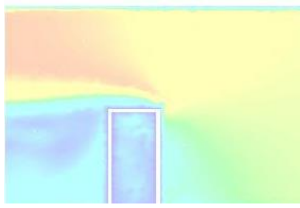
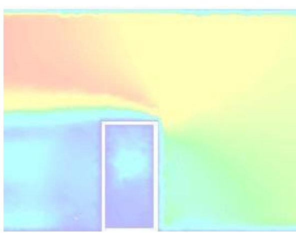
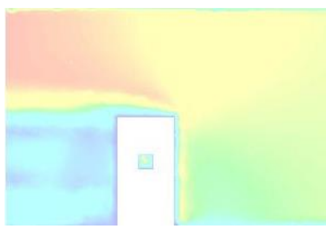
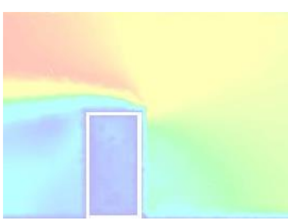
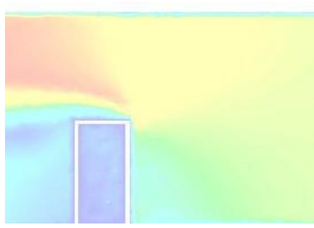
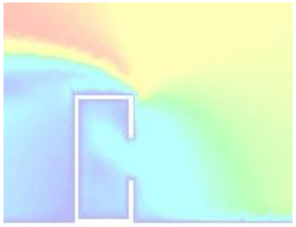
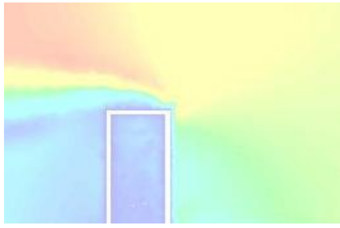
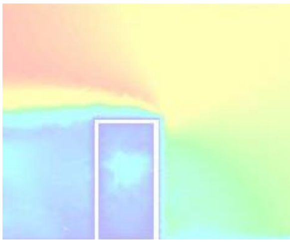
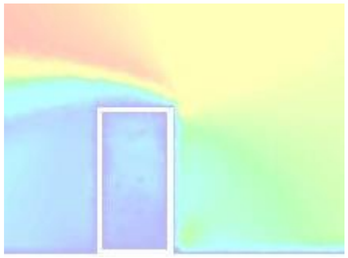
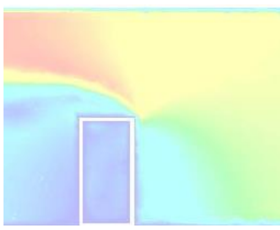
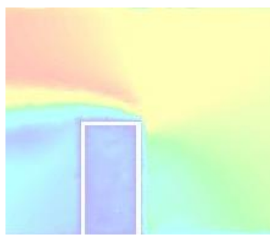
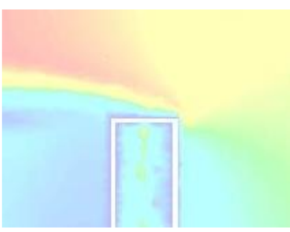
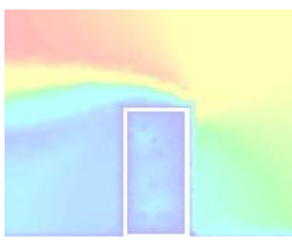
Distance of openings to the ground	Diameter of openings (meter)	Number of suction windows	Number of openings(in the direction of wind)	Direction of room	Section (in the direction of wind)	Plan	Model
0.9	Main opening: 1*1 Suction: 0.4*0.4	1	1	Northeast-southwest			1
0.9	Main opening: 1*1 Suction: 1*1	1	1	Northeast-southwest			2
0.9	Main opening: 1*1 Suction: 0.4*0.4	1	1	Northeast-southwest			3
0.9	Main opening: 1*1 Suction: 0.4*0.4	1	1	Northeast-southwest			4
0.9	Main opening: 0.4*0.4 Suction: 0.4*0.4	2	3	Northeast-southwest			5
0.9	Main opening: 1*1 Suction: 0.4*0.4	1	2	Northeast-southwest			6
0.9	Main opening: 1*1 Suction: 0.4*0.4	2	2	Northeast-southwest			7
0	Main opening: 1*1 Suction: 0.4*0.4	1	1	Northeast-southwest			8

Table 7. Analysis of wind behavior in selected models.

Model	Wind speed in plan Wind direction	 Wind speed at the cross-sections	Description	Wind Speed Spectrum Guide
1			Wind with an average speed of 3 m/s enters from the main opening, the main flow of the wind reaches at a speed of between 1-2 m/s to the wind outlet (suction window) and leaves the room at 2 m/s. On the sides of the central axis of the room there is a wind speed of 0-2 m/s.	 Blue Spectrum: From 0 to 3 m / s. Green and yellow spectrum: from 3 to 4.75 m / s. The red spectrum: from 4.75 to 5.8 m / s.
2			Wind with an average speed of 3 m/s enters the room but with regard to the suction window positioning along the main opening axis and the absence of an additional opening, the wind current flows only in the center of the room at a speed of 2-1 m/s and in the corner of the room it is 0 m/s.	
3			Wind with the average speed of 3 m/s enters through an opening of the perpendicular to the wind flow, but due to the suction window near the main opening, there is only some flow on the left side of the of room at the speed of 1-2 m/s and in other parts of the room, wind flow is 0 m/s. This model can be selected for the office and help mechanical cooling devices for air conditioning.	
4			Wind with an average of 3 m/s enters through the main opening and due to the smaller dimensions of the suction window than the main opening, there has been almost a wind current in the whole room at speeds of 1-2 m / s.	

5			Wind with an average of 3 m/s enters the room from 3 openings in the southwest. Due to the dispersion of the openings, the air flow is available at entire room that is suitable for sitting.	
6			Wind with an average of 3 m/s enters the room through two main openings embedded in the southwest front, and given that the suction windows are only located in one of the sides of the room, the flow is almost in the center of the left side of room at the speed of 1-2 m/s. But in the other two corners of the room on the right, wind speeds range from 0 to 0 m/s.	
7			Wind with an average of 3 m/s enters through the two main openings on the Southwest front, and given that two suction windows are located in the sides of the room, the wind current in the room is at a speed of 1-2 m/s, and when it reaches the opposite wall, which is s partition, it flows in all parts of the room.	
8			Wind with an average of 3 m/s enters through the main opening. In this model, since the main opening is an entire one and the suction window is near the ceiling, the air flows in the whole room at a speed of 1-2 m/s and, which is an optimal model.	

REFERENCES

[1] K. Tommy, **"Natural Ventilation in Buildings: Architectural Concepts, Consequences, Possibilities, "** Norwegian University of Science and Technology, International government publication: Manuscript, pp. 86, 2003.

[2] E. Kabir and A.B. Moradchelleh, **"Natural Ventilation in Educational Building of Moderate and Humid Climate (Case study: Gorgan), "** *International Conference on Civil Engineering* Architecture and Urban Infrastructure, pp. 1-12, 2015.

[3] A. Abbasnejad, S. Zahabnazouri, Z. Alibakhshi and H. Afsharmanesh, **"Determination of Buildings Direction in Order to Optimize Energy Consumption (Case of study: Gorgan)), "** *The First Conference on Climate, Building and Energy Efficiency*, pp. 141-156, 2011.

[4] M. Modiri, Z. nazouri., Z. Alibakhshi, H. Afsharmanesh, M. Abbasi, **"Investigation of the Proper Position of Buildings Based on Sunlight and Wind Direction (Case study: Gorgan), Quarterly, "** Journal of Geography and Regional Planning, Vol.2. No. 2, pp. 141-156, 2012.

[5] W.A. Burgess, **"Recognition of Health Hazards in Industry, "** New York: Wiley, p. 5, 1995.

[6] J. L. Kevin, **"Architectural Design of an Advanced Naturally Ventilated Building Form, "** Energy and Building, No. 39, pp. 166-181, 2006.

[7] M. Amidpour, **"Consideration of the Effects of No Chimney Stoves on Indoor Air Quality, "** Khaje Nasir Toosi University. Tehran, 2008.

[8] S. Asfour, B. Gadi, **"A Using CFD to Investigate Ventilation Characteristics of Vaults as Wind-inducing Devices in Buildings, "** Journal of Applied Energy, No. 85, pp. 1126-1140, 2008.

[9] D. Gribble, **"Natural Ventilation, Harnessed by New Kingdom Egyption Tomb Builders, may Explain the Changed Floor Levels in the Valley of the Kings Tomb kv5, "** Journal of Tunneling and Underground Space Technology. No. 24, pp. 62-65, 2009.

[10] G. C. Da Graca, N. R. Martins, and C.S. Horta, **"Thermal and Airflow Simulation of a Naturally Ventilated Shopping Mall, "** Energy and Buildings, No. 50, pp. 177-188, 2012.

[11] M. Hazbei, Z. Adib and F. Nasrollahi., **"Natural ventilation Effect on Shavadoons in Dezful by Applying CFD Modeling, "** The scientific Journal of NAZAR Research Center (Nrc) for Art, Architecture & Urbanism, Vol.11, No.30, pp.43-54, 2014.

[12] Heydari, **"Study and Analysis of Native Methods of Wind Use in order to Modeling and Modifying the Architecture of Rural Housing in Sistan, "** PH.D. Thesis. Iran University of Science & Technology, Iran, Tehran, 2016.

[13] R. Badiei, **"Detailed Geography of Iran, "** Eghbal Publication, Tehran, Iran, 2000.

[14] M.Y. Kiani, **"Overview of Urbanization and Urban Development in Iran, "** Islamic Guidance Publication, Tehran, Iran, 1987.

[15] M.Y. Kiani, **"Iran Cities, "** Vol. 4, Jahad daneshgahi Publication, Tehran, Iran, p. 206, 1992.

[16] Moeini, **"Geography and Historical Geography of Gorgan and Plan, "** Book Printing Corporation, Tehran, Iran, p. 83, 1966.

[17] Saeidian, **"Land and People of Iran, "** Science and Life Publication, Tehran, Iran, 1991.

[18] M. Kasmaei, **"Climate and Architecture, "** Khak Publication, Isfehan, Iran, 2006.

[19] Golestan Province Meteorological Department, 2017.

[20] Iran Meteorological Organization, 2005.

[21] M. Tahbaz, Sh. Jalilian, **"Principles of Architectural Design with Climate in Iran by Approach of Mosque Architecture, "** Shahid Beheshti University Publication, Tehran, Iran. Vol.2. p.43, 2011.