Effect of Inlet Airflow Variables on Internal Natural Air Velocity as a Tool for Reducing Infection with COVID-19

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Abstract:

Coronavirus (**COVID-19**) has affected day to day human lifestyle and also is slowing down the global economy of all countries. This pandemic has affected thousands of people, who are either sick, sitting in hospitals or are being killed due to the spread of this disease. This viral infection has forced people to stay at home most of the time, and do the majority of life requirements from home, such as work, education, shopping, etc. and hence nowadays, the main task for architects is to improve the quality of environment inside different architectural spaces for helping the users to do their needs and from other side for protecting them from this virus.

Achieving natural ventilation is one of the most important tools, which helps improving the air quality and hence providing healthy spaces for reducing the viral infection. Good designing of the air inlet is playing the main role of achieving the mentioned healthy environment. This paper, therefore, presents a detailed evaluation of the impact of the inlet openings variables on the ventilation performance of a single-zone isolated building. The evaluation is based on the induced airflow velocity.

High-resolution coupled 3D steady Autodesk CFD simulations of cross-ventilation are performed for shape (rectangular and square shape); building slop angle (0, 15, 30,45,60,75 and 90 degree); Wall to Floor Ratio (WFR) (10, 15, 20%) and Wall to Wall Ratio (WWR) (20, 25, 30%) of inlet openings.

The results show that using rectangular window shape coupled with building slop 0 degree and WWR 30% represent the maximum ventilation ratio inside a building, while the square window shape represents an air flow ratio less than the rectangulr shape for the same window area, building slop degree, WFR and WWR. Additionally, the window shape effect on the variation in the airflow ratio of buildings with slope angel bigger than or equal 60 degrees, is too small that it can be ignored.

Keywords:

COVID-19; Natural Ventilation; Inlet variables; CFD Simulation

الملخص:

أثر فيروس كورونا (COVID-19) على نمط حياة الإنسان اليومي وايضا بطئ الاقتصاد العالمي لجميع البلدان. لقد أصاب هذا الوباء آلاف الأشخاص ، واصبحوا اما مرضى يقيمون في المستشفيات أو يقتلون بسبب انتشار هذا المرض. لقد أجبرت هذه العدوى الفيروسية الناس على البقاء في المنزل غالبية الوقت ، والقيام بمعظم متطلبات الحياة من المنزل ، مثل العمل والتعليم والتسوق وما إلى ذلك ، وبالتالي فإن المهمة الرئيسية للمهندسين المعماريين في الوقت الحاضر هي تحسين جودة البيئة في الفراغات المعمارية المختلفة لمساعدة المستخدمين على القيام باحتياجاتهم ومن ناحية أخرى لحمايتهم من هذا الفيروس.

يعتبر تحقيق التهوية الطبيعية من أهم الأدوات التي تساعد على تحسين جودة الهواء وبالتالي توفير مساحات صحية لتقليل العدوى الفيروسية. يلعب التصميم الجيد لفتحات دخول الهواء الدور الرئيسي في تحقيق البيئة الصحية المذكورة. لذلك ، تقدم هذه الورقة تقييمًا تفصيليًا لتأثير متغيرات فتحات المدخل على أداء التهوية لمبنى معزول في منطقة واحدة. ويعتمد التقييم على سرعة تدفق الهواء المستحث.

يتم إجراء محاكاة عالية الدقة مقترنة ثلاثية الأبعاد لـ Autodesk CFD للتهوية العابرة من الفتحات مختلفة الشكل (شكل مستطيل ومربع) ؛ زاوية الميل للبناء (0 ، 15 ، 30 ، 45 ، 60 ، 75 و 90 درجة) ؛ نسبة الجدار إلى الأرض (WFR) (10 ، 15 ، 20٪) ونسبة الجدار إلى الجدار (WWR) (20 ، 25 ، 30٪) لفتحات المدخل.

أظهرت النتائج أن استخدام شكل نافذة مستطيل مقرونًا بزاوية ميل المبنى 0 درجة و 30 WWR٪ يمثل نسبة التهوية القصوى داخل المبنى ، بينما يمثل شكل النافذة المربعة سرعة تدفق هواء أقل من الشكل المستطيل لنفس مساحة النافذة وزاوية ميل المبنى و WFR و WWR. بالإضافة إلى ذلك ، فإن تأثير شكل النافذة على التغيير في سرعة تدفق الهواء للمباني ذات زاوية ميل أكبر من أو يساوي 60 درجة ، يكون صغيرًا جدًا بحيث يمكن تجاهله.

الكلمات المفتاحية:
كوفيد-19، التهوية الطبيعية، متغيرات الفتحات، محاكاة CFD

1. Introduction:

A new virus named the extreme acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was reported as the cause of an outbreak of the disease that started in China in 2019. The disease is called coronavirus disease 2019 (COVID-19). The World Health Organization (WHO) had declared COVID-19 a pandemic in March 2020. Data have shown that the virus spreads between those in close contact (about 6 feet or 2 meters) from person to person.

World Health Organization (WHO) reported that: when an infected person coughs or sneezes (Fig.1), the COVID-19 virus spreads primarily through droplets of saliva or nose discharge, so it's important that everyone also follow respiratory etiquette. Avoiding crowded spaces (and not good ventilated) is one of the most important WHO guidelines for avoiding infection. [0 2020]

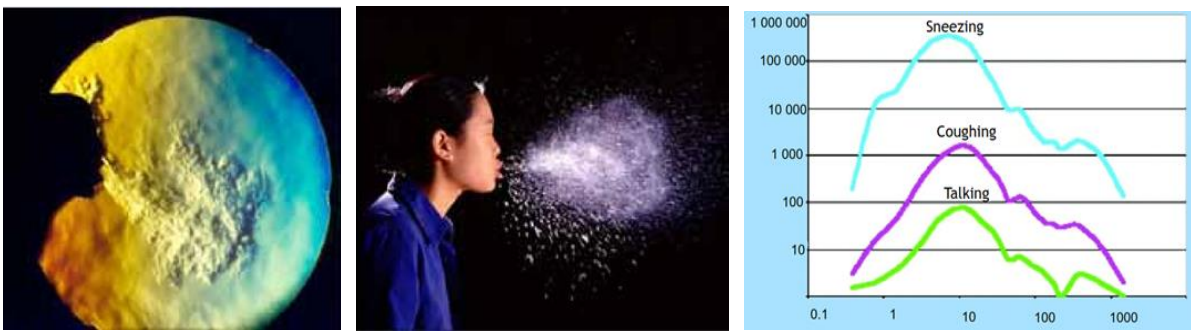


Fig. 1 (A) Visualization of human cough and sneeze. [□]
(B) Particle generation by sneezing, coughing and during talking (numbers and diameters). [□]

Natural air flow means the utilizing of wind and temperature variations to create airflows in, through and around buildings spaces. This airflow can be used for both achieving ventilation and as a tool of passive cooling strategies □, which leads to maximize the energy consumptions and reducing the infection. The main role of achieving sufficient amount of natural ventilation is essential to remove odor particles and volatile organic compounds (VOCs) as well as humidity, which are the most annoying indoor air quality disturbances to building users □. It is also necessary to dilute CO2, which can cause drowsiness for building users. Also, to remove excess heat that accumulates inside buildings [**Error! Reference source not found.**]

Ventilation involves bringing air from outside into a building or space and spreading it inside the building or the space. The general aim of the ventilation in buildings is to provide safe respiratory air by both diluting and eliminating contaminants from the building [**Error! Reference source not found.**].

The natural ventilation is essential tool for human comfort, health, and well-being. Sufficient providing natural ventilation inside building, can achieve all mentioned using less energy than mechanical ventilation systems. It removes heat through temperature - or wind-driven pressure differences (or a combination of both), while providing fresh air (good indoor air quality) □ by removing or diluting particle load, odors, humidity, and Volatile Organic Compound (VOC) concentrations [**Error! Reference source not found.** and Battaglia 2015]

By the seventeenth century, air had become a concern of physicians and health specialists due to the increasing of public buildings such as schools, universities, different types of recreational buildings and hospitals, in order to prevent the spread of diseases. Steven Connor, meanwhile, notes: “Buildings sweat, age, excrete and they respire.” [□2006] it became known that the major concerns for indoor air quality are the off- gassing of building material, users odors and the results of space users’ breathing. The need for healthy environment inside buildings became more important because of the spread of COVID-19 all over the world (**Fig.2**).

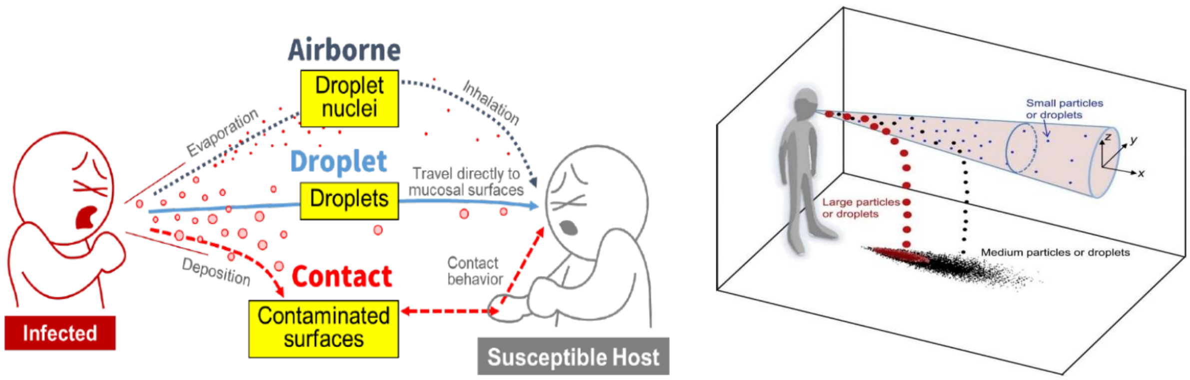


Fig. 2. Infection Methods with COVID-19

Experts say that remained in well-ventilated areas will prevent viral infection with the outbreak of deadly coronavirus in the world. Also experts further suggest that in addition to washing hands, people need to stop using the air-conditioners devices and start utilizing the fans or/and natural ventilation methods instead as getting fresh air and fans reduces the risk of the infection with the COVID-19 as earlier studies have shown that viruses can thrive in both dry and cool environmental conditions [□]

Lloyd Alter demanded that the design process be changed: "Architects can't just design a building and then turn the plans over to a construction engineer. The mechanical systems and the architectural design of the building are inseparable – how the air moves inside and around the building and how long does it take? Instead of designing for beauty or value or comfort, we

have to design for the human health and safety." We have to evolve the way of controlling internal air-quality, factoring not only the impacts on climate change and energy cost, but also aspects of human health more than they have been previously considered [Thorpe 2020]
Indoor spaces with human occupancy must be heavily ventilated, exclusively with fresh air, to minimize the concentrations of pathogens and viruses, in the event of potential contamination by suspended particles, and to reduce the risk of infection [□Da Silav 2020]
Eventually, the WHO publication and recommendations stated that: in practice, natural and mechanical ventilation systems can be equally successful in controlling infections. However, natural ventilation only works when natural forces, such as winds or breezes, are active and enough, and when apertures for inlet and outlet are good designed and are kept open. On the other hand, the difficulties of properly installing and maintaining the mechanical ventilation systems will lead to a high concentration of infectious droplet nuclei and eventually contribute to an increased risk of transmission of diseases. This method should be maximized where possible in current health-care facilities with natural ventilation, before considering other ventilation systems. This therefore relies on favorable climatic conditions for its use [□2009].

1.1 The Forces Causing Natural Ventilation

Natural ventilation needs natural forces to create the air movement and a three-dimensional flow path that leads fresh air inside functional spaces of the building. The main causes of natural ventilation are two major external forces based on the variation of pressure: wind (hydrostatic pressure variation) and the stack effect (density pressure variation) [□]
Natural forces (e.g. wind and thermal buoyancy forces due to variations of indoor and outdoor air density) push outdoor air through the building or space, building envelope openings. Purpose-built openings include windows, doors, solar chimneys, wind towers and wind catchers. The natural ventilation of buildings depends on the country environmental conditions, the design of buildings and human behavior.
Building spaces has to be designed and located to create a pressure difference between the two opposite sides of the building. It is necessary to provide a connection between the two sides to allow the right amount of air flow inside building. Ideally the amount of flow can be altered by changing the dimensions and/or direction of air inlets, which is depending on the space height. Interior space must take more than one climatic/seasonal condition into consideration, in order to take advantage of the physical properties of air – mass, pressure, temperature, and thus the air flow. All contributing factors need to be considered in the design process [□□ 2011]. The architects need to create an iterative parameter matrix and apply the principles of the relationship between air flow inside buildings and geometric shape, building slope angle, inlet proportion to wall and floor of each space. Also they need to examine integration of the architectural elements enhancing the air flow and natural ventilation inside building spaces, such as courtyards, domes and wind catches. Cooling the building's mass at night by the enhanced ventilation, enabled building elements to absorb heat from the ventilation air during sun-time hours, which leads to reduce the indoor day time temperature and improve the comfort for the building users all times.

Shakila P., Asanka R. and Rangika H. examined the effect of building form, building orientation and window to wall ratio on energy efficiency and internal thermal comfort of naturally ventilated houses in tropical climate, the practical part of the research was conducted by analyzing 300 different case studies, four WWR ratios and 24 building orientations were considered in this study by using Design Builder simulations software. The study concluded that: building shape and orientation do not play a clear effect on building thermal comfort [□]

G.M. Stavrakakis, P.L. Zervas, H. Sarimveis, N.C. Markatos, studied Optimization of window-openings design for thermal comfort in naturally ventilated buildings, (**Fig.3**) The results presented in this paper indicate that the South-East building orientation with utilizing two door-type openings is the best solution for almost activity levels. In case of combinations of two activity levels, it was found that a design of two door-type openings coupled with nearly South and South-East wind directions serve for the Standing-Seated and the Standing-Recumbent situation, respectively [□2012].

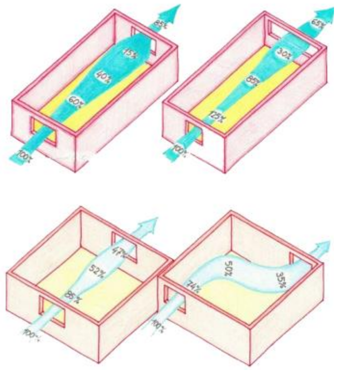


Fig. 3. The Effect of Window Design on Ventilation Ratio Inside Building

Building ventilation has three basic elements:

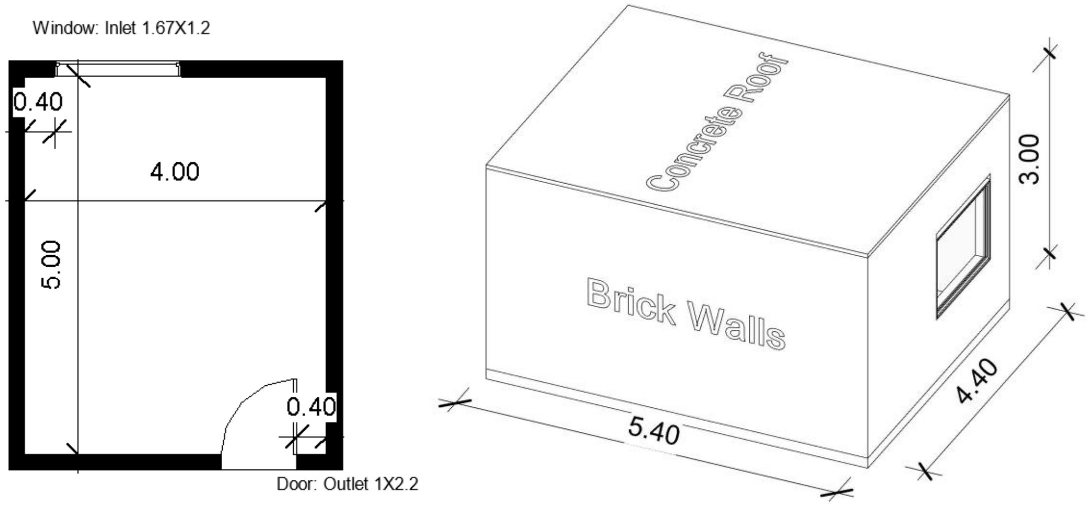
• Ventilation rate — the amount, volume and quality of outdoor air that is provided into the building spaces;

• The direction of airflow— the overall airflow direction in a building, which should be from clean spaces to dirty spaces; and air distribution or airflow pattern — the external air should be distributed to each space of the building in an efficient manner and the airborne contaminants produced in each space of the building should also be removed in an efficient manner.

2. Methodology

This research work is a numerical investigation of the ventilation performance in the buildings using Computational Fluid Dynamics (CFD) commercial code, Autodesk CFD 2019 with the following assumptions:

- The inlet air velocity is homogeneous through the cross section of all openings,
- Negligible temperature gradient between outside and inside building.
- All parameters for inlet flow are according to, [Masood, 2018]



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• **Fig. 4. Geometry of Reference Case. (Dimensions in meters)**

2.1 Reference model and variables

The dimensions of the reference room, considered for demonstration of the proposed methodology, are 5 m in length, 4 m in width, and 3 m height, the room wall thickness consists of two isolated brick layers of 20 mm width. The floor and the roof are made from concrete. The tested room contains 2 openings, which are located in 2 opposite walls, the first one is a window (air flow inlet) at the north wall, which will be considered the inlet. The window dimensions depending on the used ratio in simulation cases. The window sill height is fixed with height .9 m. The second opening (air flow outlet) is one door, which will be considered as outlet, with dimensions 1m width and 2.2 m height, it is located at the south wall (according to the origins sketched in **Fig. 4**) and the room is ventilated through these openings, while their distance from the east and west wall is 0.4 m.

Geometry of model with different slops, window shapes, Window to Floor Ratio (WFR) and Window to Wall Ratio (WWR) are shown in the following (**Table 1**) and (**Table 2**).

Inlet variables	**Rectangular Window Shape**						**Square Window Shape**					
	WFR %			**WWR %**			**WFR %**			**WWR %**		
	10	**15**	**20**	**20**	**25**	**30**	**10**	**15**	**20**	**20**	**25**	**30**
Window Area (m2)	2	3	4	2.4	3	3.6	2	3	4	2.4	3	3.6
Window Dimensions (m)	1.2 X 1.67	1.2 X 2.5	1.2 X 3.33	1.2 X 2	1.2 X 2.5	1.2 X 3	1.41 x 1.41	1.73 x 1.73	2 X 2	1.55 x 1.55	1.73 x 1.73	1.9 X 1.9

Table 1. Dimensions of inlet with different window shapes, Window to Floor Ratio (WFR) and Window to Wall Ratio (WWR)

		Slop 0	Slop 15	Slop 30	Slop 45	Slop 60	Slop 75	Slop 90
Rectangular Window Shape	**WFR 10%**	Case 01	Case 02	Case 03	Case 04	Case 05	Case 06	Case 07
	WFR 15%	Case 08	Case 09	Case 10	Case 11	Case 12	Case 13	Case 14
	WFR 20%	Case 15	Case 16	Case 17	Case 18	Case 19	Case 20	Case 21
	WWR 20%	Case 22	Case 23	Case 24	Case 25	Case 26	Case 27	Case 28
	WWR 25%	Case 29	Case 30	Case 31	Case 32	Case 33	Case 34	Case 35
	WWR 30%	Case 36	Case 37	Case 38	Case 39	Case 40	Case 41	Case 42
Square Window Shape	**WFR 10%**	Case 43	Case 44	Case 45	Case 46	Case 47	Case 48	Case 49
	WFR 15%	Case 50	Case 51	Case 52	Case 53	Case 54	Case 55	Case 56
	WFR 20%	Case 57	Case 58	Case 59	Case 60	Case 61	Case 62	Case 63
	WWR 20%	Case 64	Case 65	Case 66	Case 67	Case 68	Case 69	Case 70
	WWR 25%	Case 71	Case 72	Case 73	Case 74	Case 75	Case 76	Case 77
	WWR 30%	Case 78	Case 79	Case 80	Case 81	Case 82	Case 83	Case 84

Table 2. Model Inlet Variables shapes, Slops, (WFR) and (WWR)

2.2 Simulation program used

For practical part of the current research, the simulation program used is Autodesk CFD (**C**omputational **F**luid **D**ynamics). The engineers and analysts are using it to intelligently predict how liquids and gases will perform. It is a tool which can solve almost any heat transfer or fluid flow problem. Autodesk CFD helps eliminate the need for physical prototypes while offering a deeper insight into fluid flow design efficiency [□ 2020].

As the tested model is immersed in a fluid air, which called external volume for showing how the fluid air flows inside and around the model, so to analyze the flow, it is necessary to add a surrounding to the mentioned external volume of the model. The surfaces and edges of the volume cannot contact or intersect with any part of the tested room. The minimum scale factor is 5% greater than the geometry of all three Cartesian directions. The dimensions of this external volume is depending on the model dimensions, in our tested model; the resulting dimensions of the domain are 50 m length, 20 m width and 12 m. (**Fig. 5**)

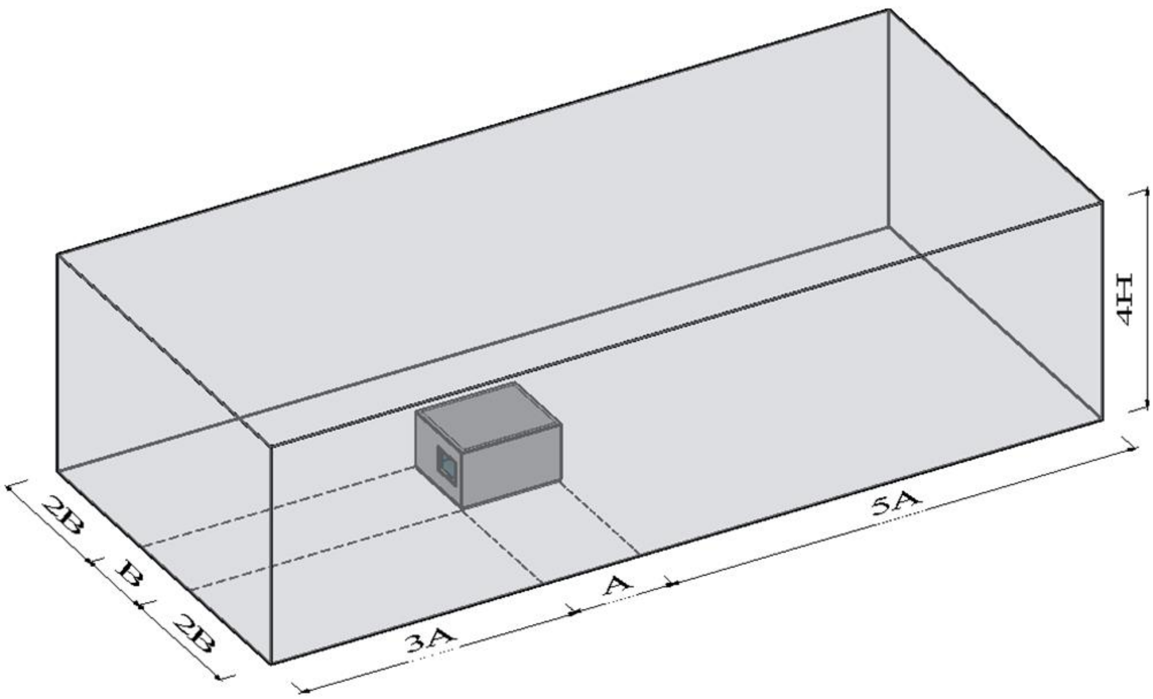


Fig. 5. Perspective View of Computational Domain (External Volume) and Reference Case

2.3 Outline of Simulation

The assumptions made are: heat transfer through radiation to the walls is ignored as the reflective insulation remains inactive in case of decreased solar irradiance during the late afternoon and night hours.

In addition, the heat transfer by conduction is ignored in the CFD model and is treated indirectly assuming that the amount of heat transferred between the inner wall surface and the inner air through convection is equal to that transferred through conduction through the brick wall.

The assigning materials for the tested model are: Concrete for floor; brick for walls and concrete for roof.

The boundary conditions (The design interacts with its surroundings, such as flow rate, pressure, and temperature to openings and other specific locations allow us to specify internal heat loading, such as heat dissipation often found in electronics thermal management simulations and define how the air flow enters or leaves the model) used for the tested model simulation are summarized as follows:

- Inlet average velocity from Egyptian code for ventilation at 5 m/s [Masoud 2018], it will be applied on the north side of the external volume.
- Inlet temperature is set to a fixed value 25 C.
- Outlet 0 pressure applied on the opposite south side of the external volume.

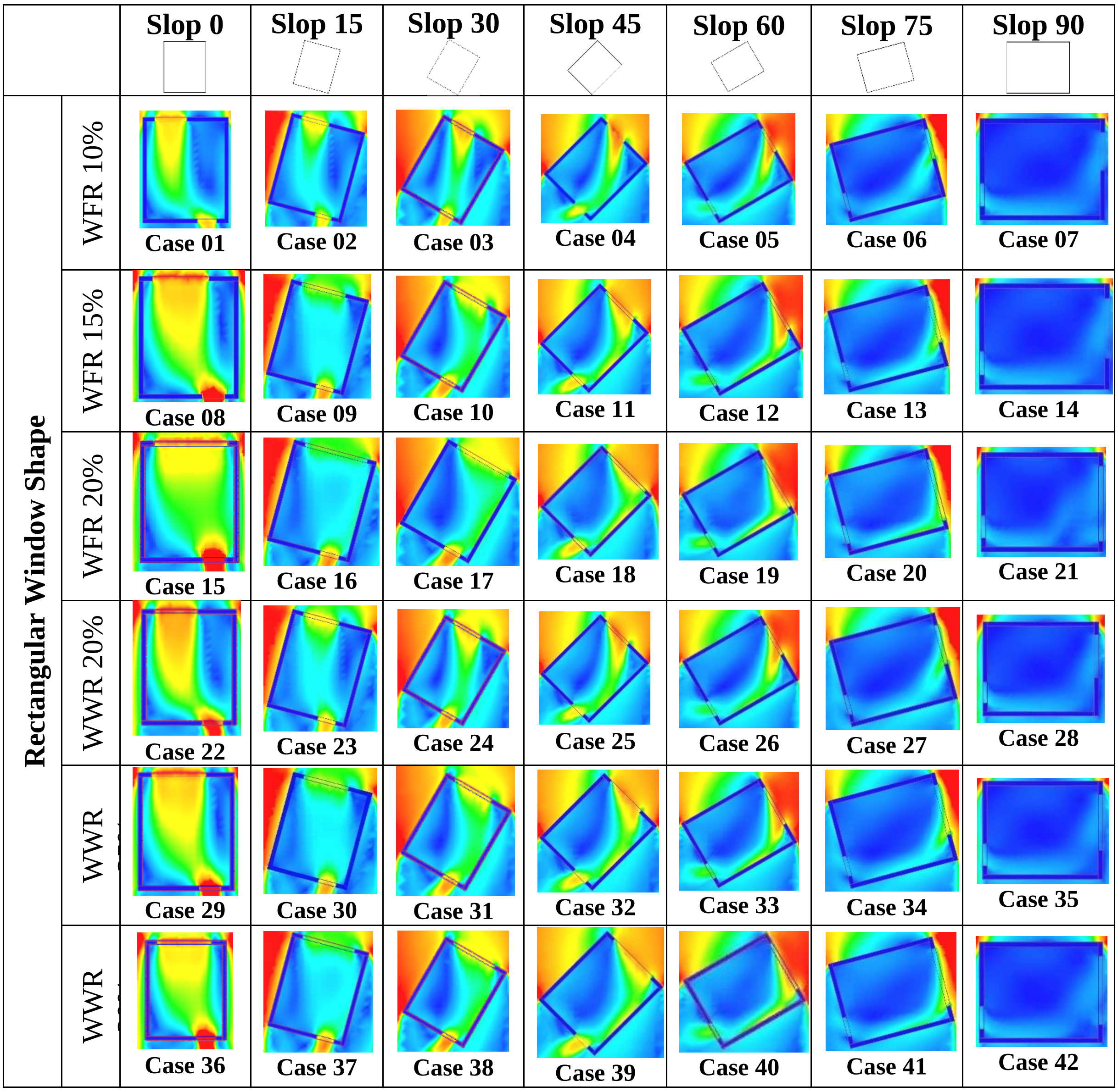
3. Results

The present section of the current research provides the results obtained after applying the procedure described in research methodology, produced using Autodesk CFD 2019 modeling for each case 1 up to 84. The results for rectangular window shape are visualized and summarized in (**Table 3,4**) while, the results for square window shape are visualized and summarized in (**Table 5,6**) where, for each combination of window shape (rectangular and square), different building slop (0,15,30,45,60,75,90 degree), different WFR (10, 15, 20 %) and different WWR (20, 25, 30 %). **Fig. 6-11** present the normalized airflow rate through the openings and the area-weighted average at the openings level for rectangular and square window shape using different WFR and WWR values. The following observations can be made:

- For WFR 10%, the highest induced airflow rate is achieved for Case_01 (rectangular window shape with 0 slope angle). In this case, the induced airflow rate is 40% from the outside air velocity, while the lowest rate is achieved for Case _49 (square window shape with 90 slope angle). In this case, the induced airflow rate is 4% from the outside air velocity.
- For WFR 15%, the highest induced airflow rate is achieved for Case_01 (rectangular window shape with 0 slope angle). In this case, the induced airflow rate is 45% from the outside air velocity, while the lowest rate is achieved for Case _49 (square window shape with 90 slope angle). In this case, the induced airflow rate is 4% from the outside air velocity. Also the induced airflow rate achieved for Cases _12 and Case _54 is equal for both window shape, with rate 21%.
- For WFR 20%, the highest induced airflow rate is achieved for Case_01 (rectangular window shape with 0 slope angle). In this case, the induced airflow rate is 48% from the outside air velocity, while the lowest rate is achieved for Case _49 (square window shape with 90 slope angle). In this case, the induced airflow rate is 4% from the outside air velocity. Also the induced airflow rate achieved for Cases _20 and Case _62 is equal for both window shape, with rate 13%, and for Cases _19 and Case _61 is equal for both window shape, with rate 20%
- For WWR 20%, the highest induced airflow rate is achieved for Case_01 (rectangular window shape with 0 slope angle). In this case, the induced airflow rate is 42% from the outside air velocity, while the lowest rate is achieved for Case _49 (square window shape with 90 slope angle). In this case, the induced airflow rate is 4% from the outside air velocity. Also the induced airflow rate achieved for Cases _23 and Case _65 is equal for both window shape, with rate 26%, and for Cases _26 and Case _68 is equal for both window shape, with rate 22%
- For WWR 25%, the highest induced airflow rate is achieved for Case_01 (rectangular window shape with 0 slope angle). In this case, the induced airflow rate is 45% from the outside air velocity, while the lowest rate is achieved for Case _49 (square window shape with 90 slope angle). In this case, the induced airflow rate is 4% from the outside air velocity. Also the induced

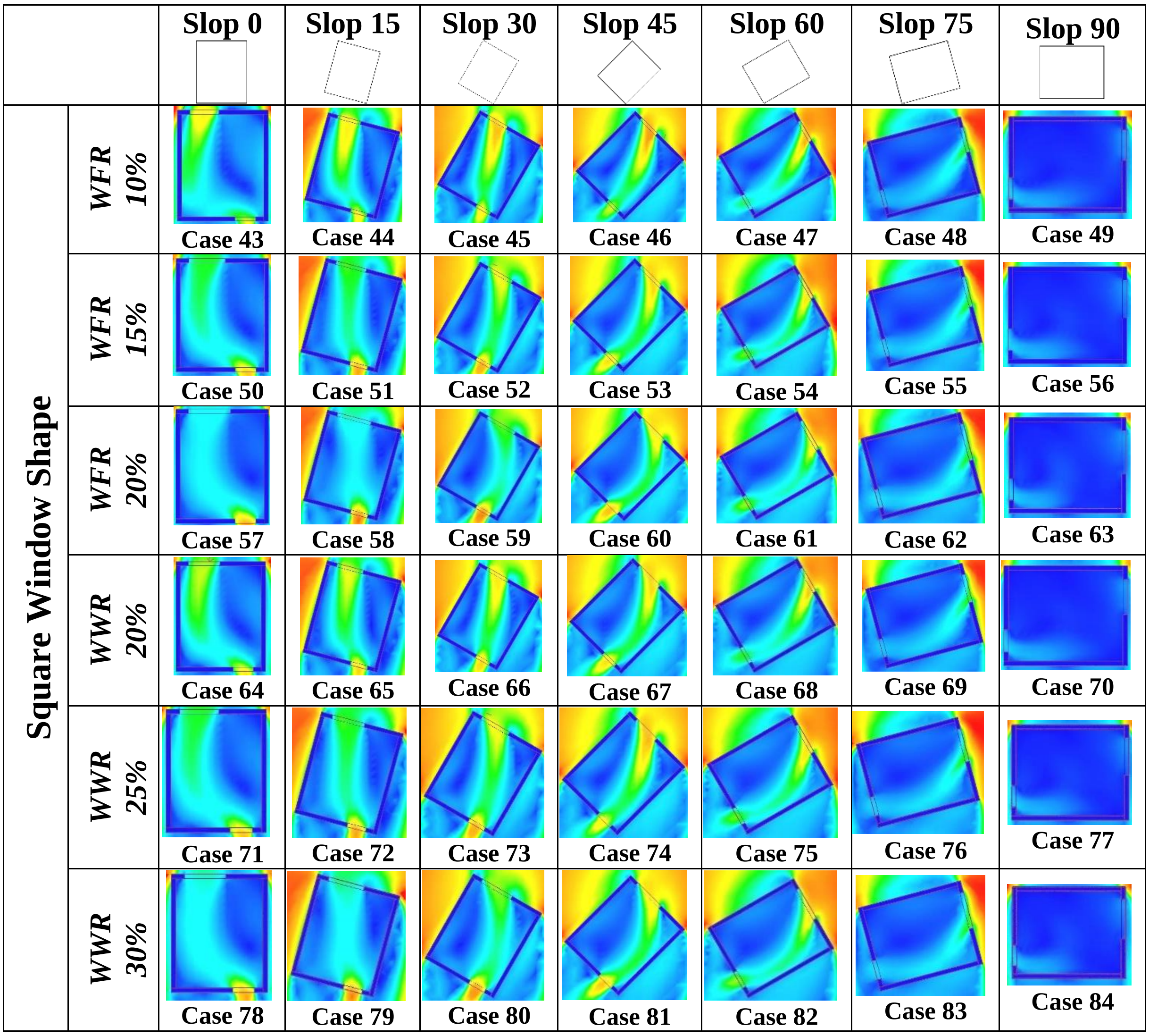
airflow rate achieved for Cases _33 and Case _75 is equal for both window shape, with rate 21%.

- For WWR 30%, the highest induced airflow rate is achieved for Case_01 (rectangular window shape with 0 slope angle). In this case, the induced airflow rate is 49% from the outside air velocity, while the lowest rate is achieved for Case _49 (square window shape with 90 slope angle). In this case, the induced airflow rate is 4% from the outside air velocity. Also the induced airflow rate achieved for Cases _40 and Case _82 is equal for both window shape, with rate 20%, and for Cases _41 and Case _83 is equal for both window shape, with rate 13%.
- For the rectangular window shape, the highest induced airflow rate is achieved for Case_01 (WWR 30% with 0 slope angle). In this case, the induced airflow rate is 49% from the outside air velocity, while the lowest rate is achieved for Case _07 (WFR 10% with 90 slope angle). In this case, the induced airflow rate is 10% from the outside air velocity.
- For the square window shape, the highest induced airflow rate is achieved for Case_44 (WFR 10% with 15 slope angle) and Case_ 45 (WFR 30% with 30 slope angle). In these cases, the induced airflow rate is 27% from the outside air velocity, while the lowest rate is 4% from the outside air velocity and achieved for Case _49, 56, 63, 70, 77, 84.



	WFR 10%	WFR 15%	WFR 20%	WWR 20%	WWR 25%	WWR 30%
0 Degree	0.397684	0.454716	0.482922	0.424474	0.45045	**0.487558**
15 Degree	0.255748	0.264806	0.256316	0.258438	0.264422	**0.2658**
30 Degree	0.278144	0.287138	0.26485	0.28964	**0.293326**	0.278392
45 Degree	0.272004	0.271308	0.244856	**0.280428**	0.269452	0.256214
60 Degree	0.21591	0.208466	0.204266	**0.217096**	0.210078	0.204474
75 Degree	0.1083752	0.1180448	**0.132982**	0.1124652	0.1173536	0.128164
90 Degree	0.0620944	0.0635854	**0.064893**	0.0638932	0.0633834	0.0644078

Table 3,4. The visualized and summarized results for rectangular window shape



Slop	WFR 10%	WFR 15%	WFR 20%	WWR 20%	WWR 25%	WWR 30%
0 Degree	0.246412	0.230156	0.200188	**0.249878**	0.23204	0.20827
15 Degree	**0.267768**	0.235112	0.20174	0.258632	0.233708	0.211708
30 Degree	**0.271902**	0.251558	0.223104	0.26405	0.251328	0.233106
45 Degree	**0.262016**	0.250696	0.228846	0.260972	0.250944	0.23593
60 Degree	0.216316	0.211094	0.1978128	**0.217864**	0.210902	0.202246
75 Degree	0.1198736	0.1254866	0.1255498	0.1229944	**0.1268694**	0.1254606
90 Degree	0.041262	0.0417538	**0.044651**	0.0411724	0.0419508	0.0423292

Table 5,6. The visualized and summarized results for square window shape **ximum value**

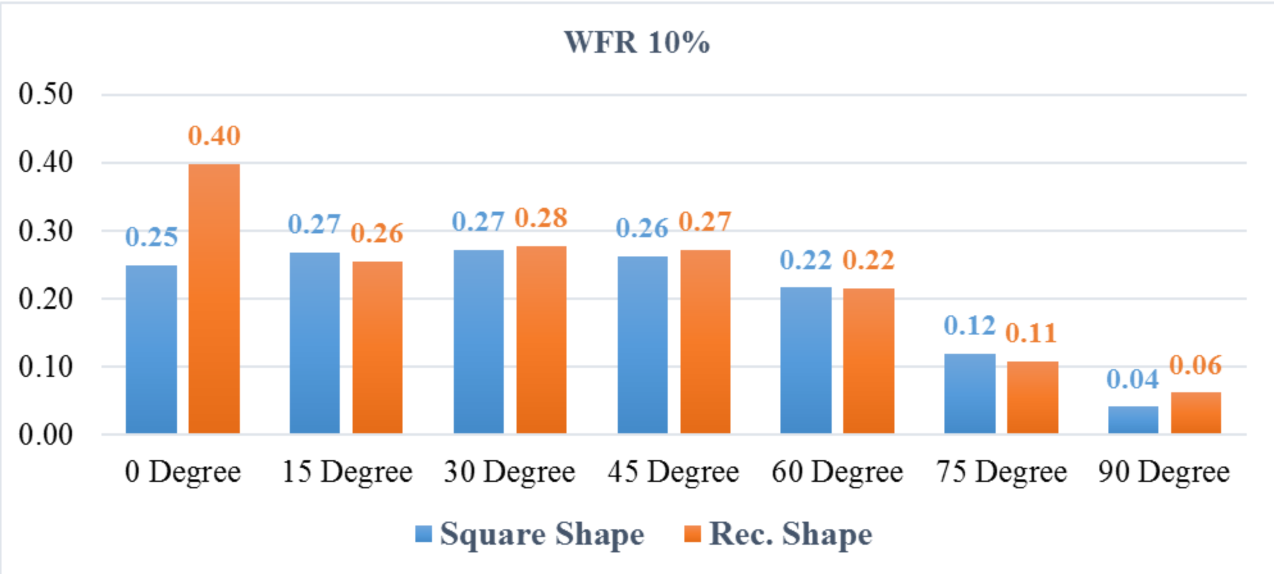


Fig. 6. Comparative air velocity efficiency between rectangular and square window shape (WFR 10%)

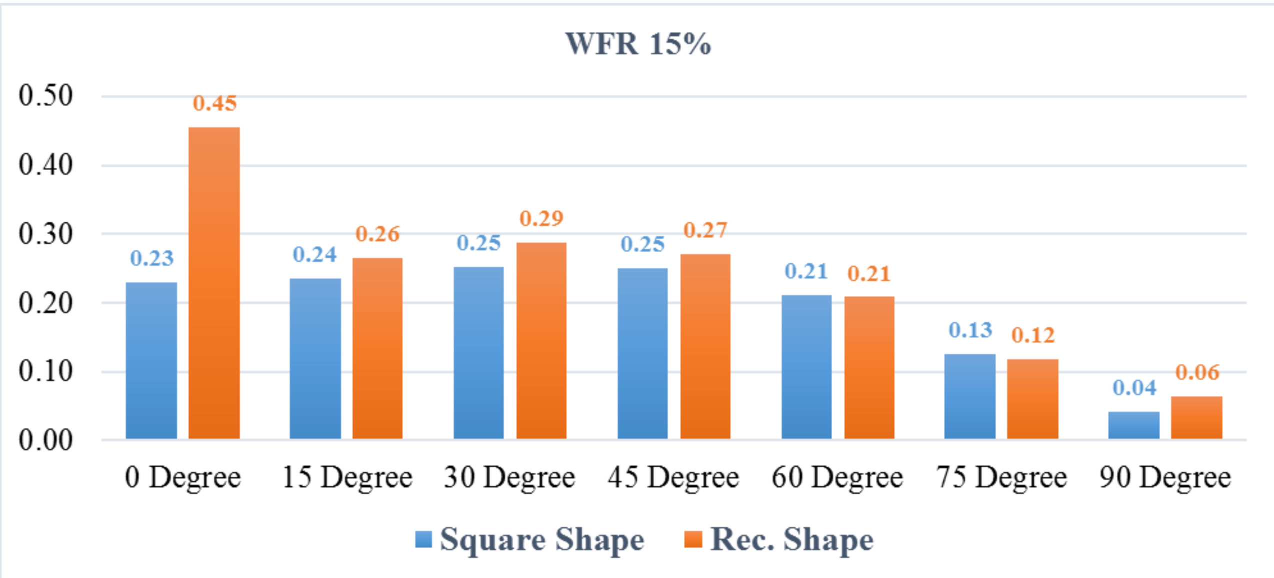


Fig. 7. Comparative air velocity efficiency between rectangular and square window shape (WFR 15%)

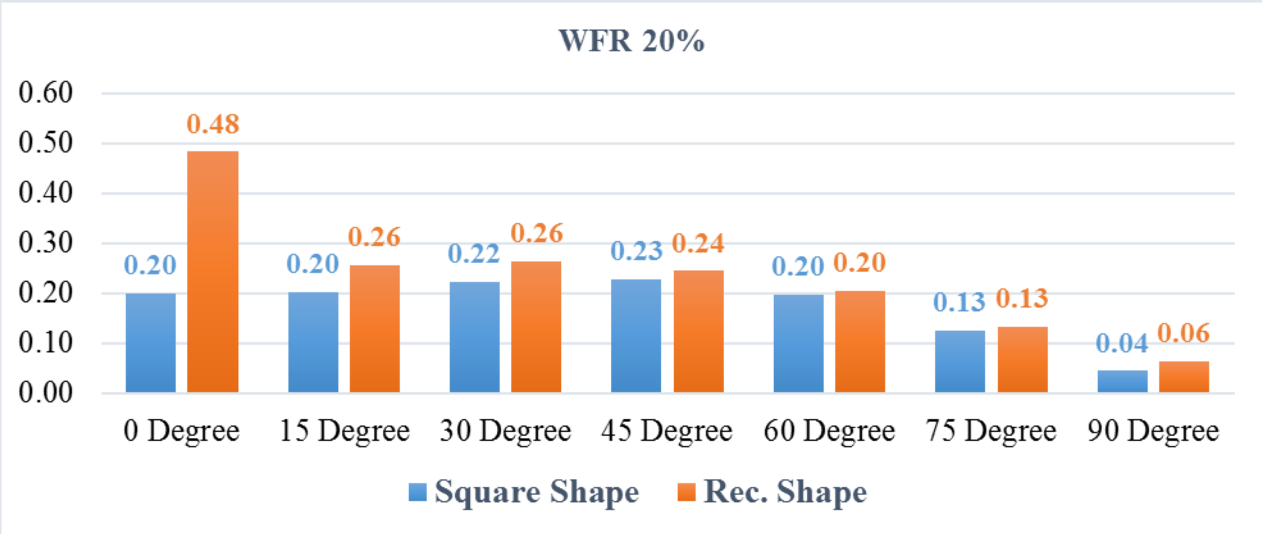


Fig. 8. Comparative air velocity efficiency between rectangular and square window shape (WFR 20%)

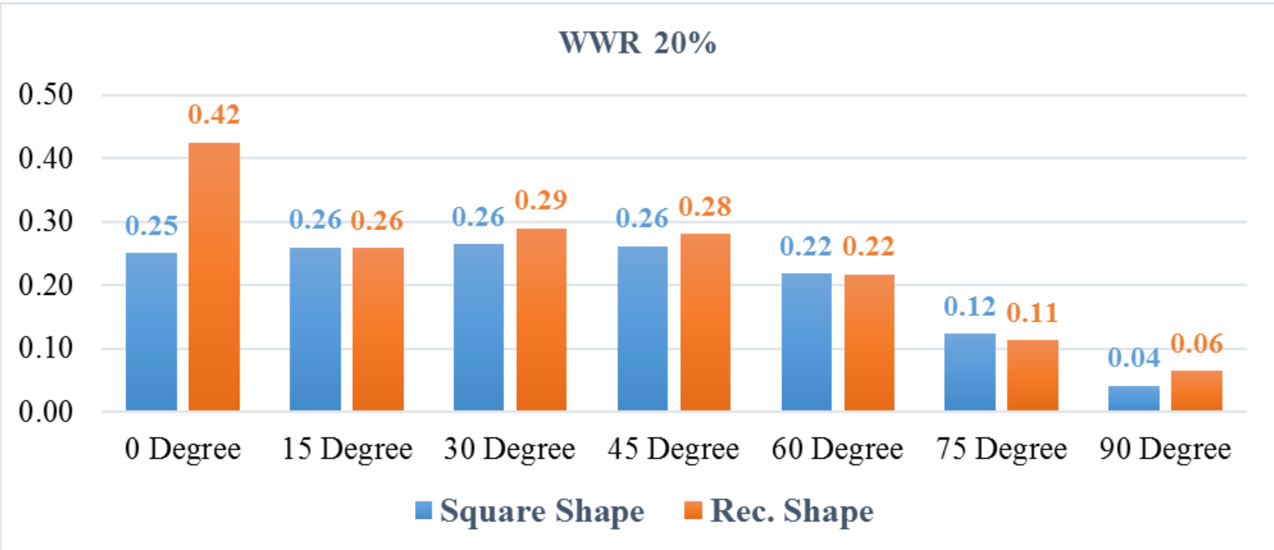


Fig. 9. Comparative air velocity efficiency between rectangular and square window (WWR 20%)

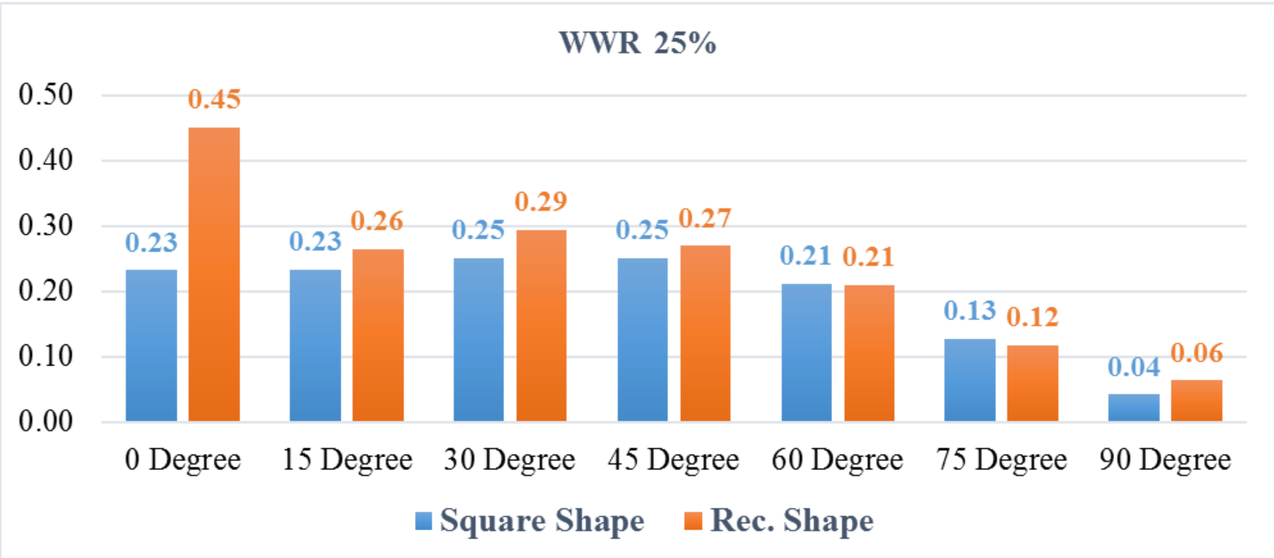


Fig. 10. Comparative air velocity efficiency between rectangular and square window (WWR 25%)

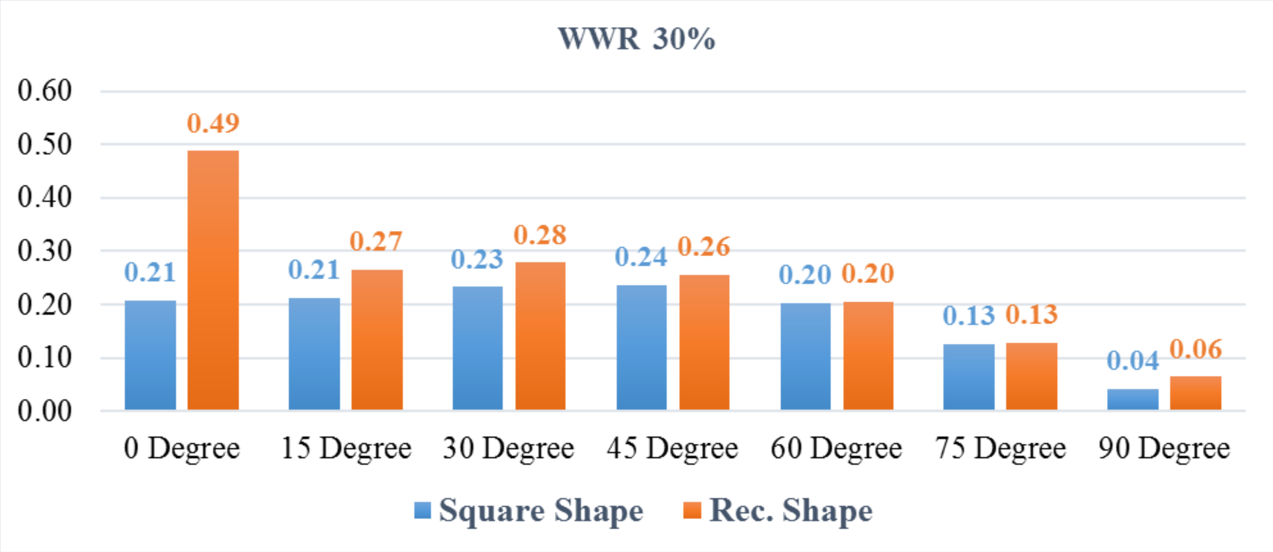
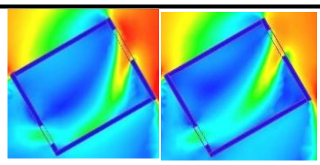
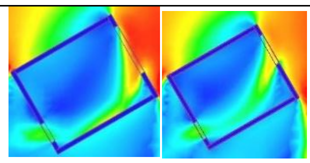
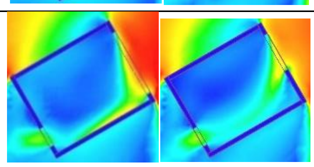


Fig. 11. Comparative air velocity efficiency between rectangular and square window (WWR 30%)

4. Discussion and Conclusion

The study in this article investigates different 84 ventilated window in shapes, slop with air flow direction and dimensions ratio in order to identify the optimum typology with regard to their air flow efficiency and hence achieving thermal comfort inside buildings. The following conclusions can be drawn:

- In summary, rectangular window shape coupled with building slop 0 degree and WWR 30% represent the maximum ventilation ratio inside building, and hence it helps reducing the infection with viruses in general due to the increasing of air velocity inside the building spaces.
- In addition, the square window shape represents an air flow ratio less than the rectangulr s hape for the same window area, building slop degree, WFR and WWR.
- Additionally, the window shape effect on the variation in the airflow ratio of buildings with slope angel bigger than or equal 60 degrees, is too small that it can be ignored
- It is also obvious that, rectangular and square window shape have the same air flow efficiency in the Cases shown in the following **table 7**.

Case no Rec, square	**Variables**			**Visualized Results**	**Air flow Ratio %**
	Slope	**WFR %**	**WWR%**		
Case 05,47	60	10	-		22
Case 12,54	60	15	-		21
Case 19,61	60	20	-		20

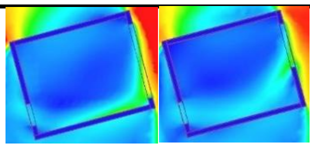
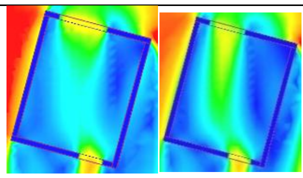
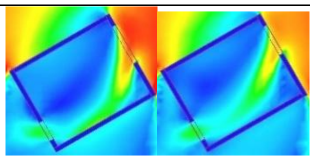
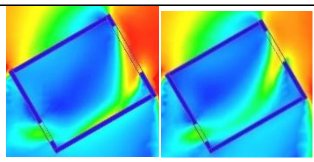
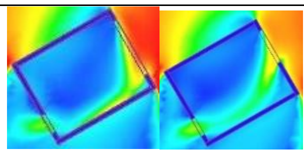
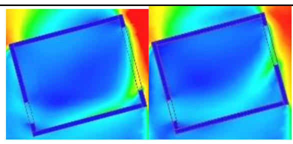
Case no Rec, square	**Variables**			**Visualized Results**	**Air flow Ratio %**
	Slope	**WFR %**	**WWR%**		
Case 20,62	75	20	-		13
Case 23,65	15	-	20		26
Case 26,68	60	-	20		22
Case 33,75	60	-	25		21
Case 40,82	60	-	30		20
Case 41,83	75	-	30		13

Table 7. Equaled air flow efficiency for rectangular and square window shape Cases

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