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Improving Single-Sided Room Ventilation by Using a Ceiling Fan.

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Abstract: *This study aims to improve one sided room ventilation by using a combination between a ceiling fan and a modified opening based on Pressure difference occurs due to ceiling fan movement, in order to exchange inner and outer air, as it is one of the recommendation strategies to achieve thermal comfort in hot humid Climates.*
Computer simulation CFD used in this study to analyze airflow and wall pressures to determine both maximum and minimum pressure positions due to fan movement in order to locate air outlet and inlet positions and find out a modified opening that allows inner and outer air to exchange.

Keywords: Ceiling fan, ventilation, CFD computational fluid dynamics, airflow, thermal comfort.

1. INTRODUCTION

Many studies of ceiling fans inside indoor spaces focused on how to achieve thermal comfort by sensation regarding the flow patterns resulted from ceiling fan movements and the coverage area of each fan [1] . Aynsley[2] analyzed the cone formed by the fan and found that the mounting heights of fans affect the limits of those cones.
Chiang [3] focused on the diameters of ceiling fan while the other studies by Schmidt[4] and Patterson focused on the shapes of fan blades, Rahman [5] simulated the different air velocities of ceiling fans and found that indoor air velocities equaled 1.5 m/s could achieve thermal comfort, Bassiouny[6] focused on the effect of air velocity on the human skin at the seating level.
Another trend in ventilation by Olegagy [7] , Givoni[8] and Abdin[9] studied the wind flow through openings and the relationship between inlet and outlet openings.
The previously outlined researches did not consider neither the relation between outside and inside air velocity in case of using a ceiling fan nor The integration between the design of opening and the flow patterns induced by a ceiling fan so these study aims to integrate between a ceiling fan's studies and cross-ventilation studies in order to Improve ventilation of a single-sided room by using a ceiling Fan.

2. MYTHOLOGY

This research studies the integration between façade openings and ceiling fan to improve ventilation Based on pressure distribution created by a ceiling fan on façade wall, several geometries of window openings were suggested and studied, the inlet air flow from a quiescent surrounding were used to evaluate opening geometry. Three steps are required to achieve the goal of this study:

I. First, is a survey of climatic conditions in several cities in order to define regions where the study would produce significant impact.
II. second step is a simulation of air flow pattern of a closed square room of typical dimensions and a ceiling fan, this step will lead to locate the positions of minimum and maximum pressures on façade wall where should be inlet and outlet opening.
III. Third step is modifying inlet and outlet openings design at the prescribed locations from step 2, and evaluate these designs based on the momentum of the induced flow.

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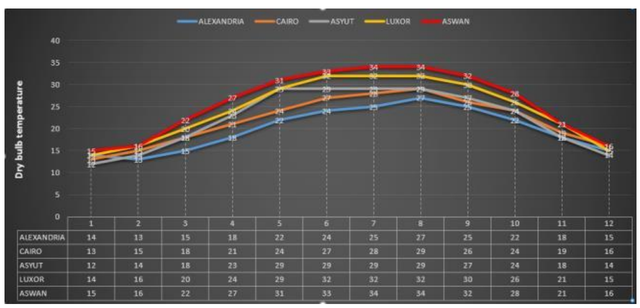
Table (1) Daily weather of Egypt's different regions

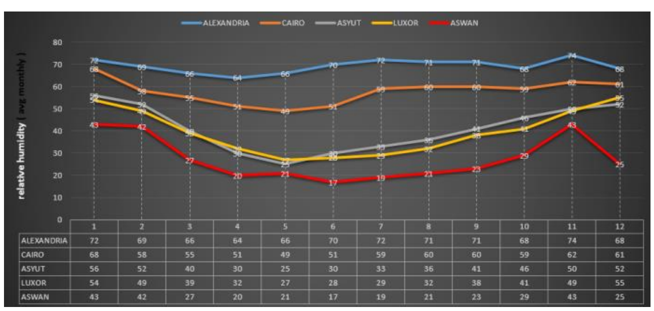
Regions	Weather elements	Day hours											
		0 am	2	4	6	8	10	12 pm	2	4	6	8	10
Northern Egypt	Temperature °C	20	18	20	23	25	29	30	30	29	27	25	22
	Wind velocity m/s	2	2	2	3	3	4	5	7	5	4	3	2
	Relative humidity %	80	80	80	77	75	70	60	60	65	70	75	80
Middle Egypt	Temperature °C	25	23	24	25	30	32	35	35	32	30	30	25
	Wind velocity m/s	1	1	2	2	2	3	4	5	4	3	3	1
	Relative humidity %	60	60	60	55	50	40	30	30	40	45	50	60
Southern Egypt	Temperature °C	32	28	27	28	31	35	40	41	43	40	38	36
	Wind velocity m/s	1	1	1	1	1	2	2	3	3	3	2	2
	Relative humidity %	20	24	28	30	20	18	13	17	10	13	16	18

3. DISSCUTION

Excess energy of human body transferred either by convection to the ambient air, radiation to the room walls, or evaporation of sweat from body surface [E1]. Thermal Comfort is affected by three factors: temperature1, humidity2, and air velocity as shown in (table-1,2,3)



(table-1)



(table-2)

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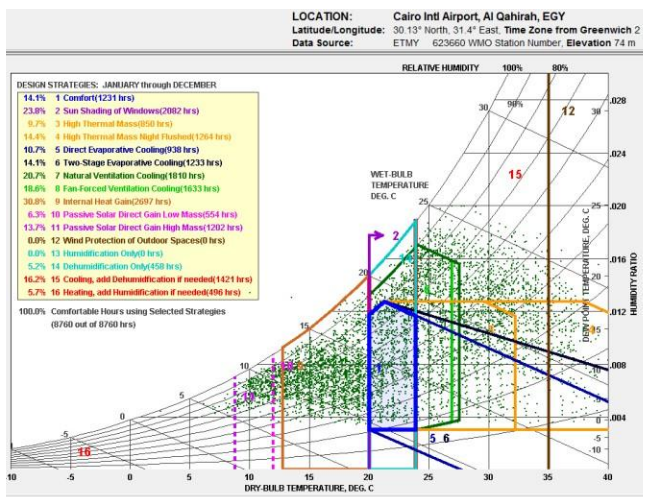
(table-3)

3.1 Climate consultant® is an open access software that plots weather data, including temperatures, wind velocity, sky cover, percent sunshine, beam and horizontal irradiation, to create psychometric charts, timetables of bioclimatic needs, temperature, wind speed, and related climatic data and is cross- referenced to bioclimatic design practices presented in Watson and Labs (1993). It can be down-loaded at no cost from the World Wide Web [10].

Climate consultant® used to analyse weather data, it reports and ranking design strategies that ensure thermal comfort by passive and active means, (pic-1) indicates a typical bioclimatic chart generated by Climate Consultant, indicating an annual summary for Cairo and in the upper left, the percentage that bioclimatic strategies needed to achieve thermal comfort.



(pic-1)

3.1.1 weather in certain cities in Egypt for example (pic-2) could be comfortable for specific hours of the year but these comfort hours could be increased by using suitable means like direct evaporative cooling, two stage evaporative cooling, natural ventilation, and finally fan forced ventilation (table-4) .

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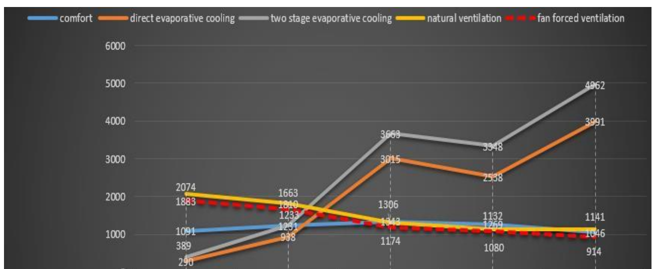
(pic-2)

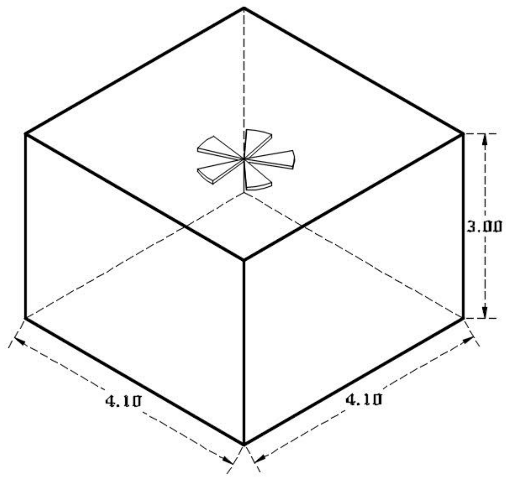


	ALEXANDRIA	CAIRO	ASYUT	LUXOR	ASWAN
comfort	1091	1231	1343	1269	1046
direct evaporative cooling	290	938	3015	2538	3991
two stage evaporative cooling	389	1233	3663	3348	4962
natural ventilation	2074	1810	1306	1132	1141
fan forced ventilation	1883	1663	1174	1080	914

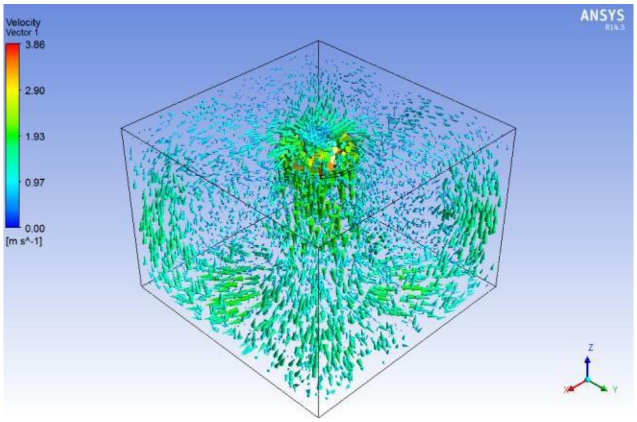
(table-4)

3.2 This step focuses on ceiling fan behaviour in a closed room to deliver a suitable forced air in order to archive thermal comfort according to suggested design strategy. In order to figure out ceiling fan behaviour it is important to analyse the cone formed by the ceiling fan and pressure distribution on façade wall, to locate air inlet and outlet suitable positions.

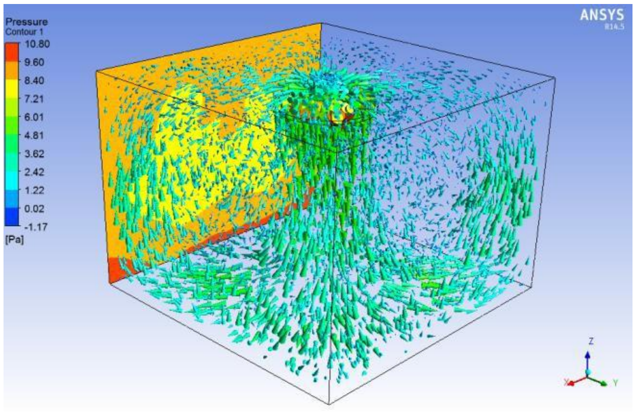
3.2.1 Air movement simulated inside a geometry shown (figure2), The continuity and momentum equations are solved using AnsysFluent software, boundary conditions are set to walls (no slip) boundaries on the wall and fan boundary is set to fan surface, k-ε was chosen to simulate turbulence.



(figure -1)



(figure -2)



(figure -3)

3.2.2 In order to deliver Natural ventilation cooling and air forced ventilation according to environmental

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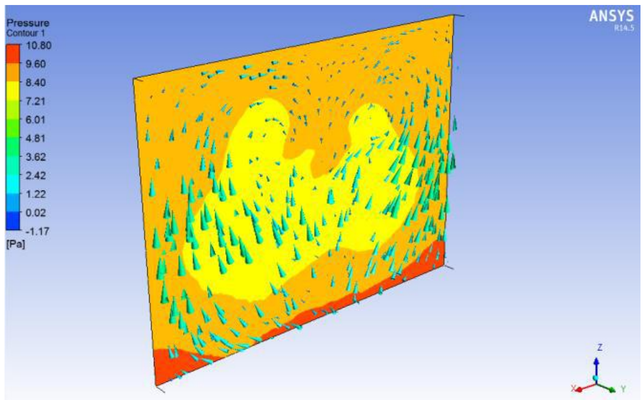
design strategies and psychometric chart, this study focuses on magnifying the performance of a ceiling fan that deliver air forced to work also as a delivery fan to get the outdoor cool air inside the room space as a natural ventilation cooling as shown in (table-4).

Airflow patterns created by ceiling fan movement in a closed space by dimension 4.1 m x 4.1 m x 3 m height are analysed to locate a suitable positions of inlet and outlet openings at external wall according to stagnation positions (figure -4).



(figure -4)

3.2.3 This study based on the hypothesis that the pressure values of the stagnation positions resulted from a ceiling fan movement, can determine both the positions and the shapes of the openings at the external wall, to deliver outdoor cool air inside a space according to natural ventilation cooling design strategies.

The suggested hypothesis of this study divides into three stages in the simulation experiments due to stagnation condition.

- The first stage is how to determine the suitable positions of the openings.
- The second stage is how to design the louvers of the openings.
- The third stage tests the modified openings. Choosing suitable positions of the openings on the wall requires determining the different positions of velocities

and pressures because of the central ceiling fan movement inside a closed space as shown in Figures (2) and (3), this hypothesis depends on the values of velocities, pressures and stagnation conditions to determine the type of the openings inlet or outlet.

3.2.4 The inlet opening requires a minimum position of air pressure or stagnation condition, while the outlet opening requires a maximum position of air pressure or stagnation condition, Figures (4) shows both the maximum and minimum stagnation position of the wall.

- Minimum stagnation in the middle of the wall mirrored to the centre of the room where inlet opening could be allocated Figures (5).
- Maximum stagnation at the bottom of the wall and around the minimum stagnation area. (figure -5)

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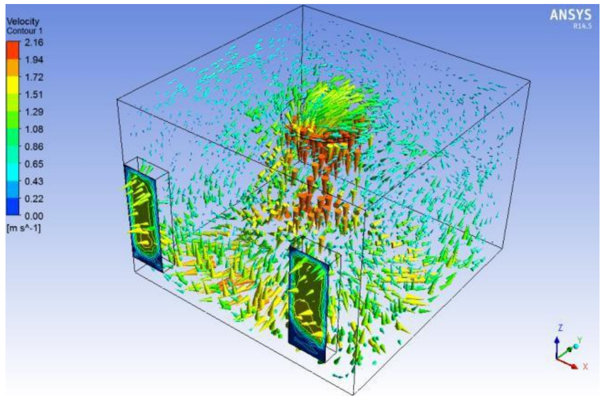
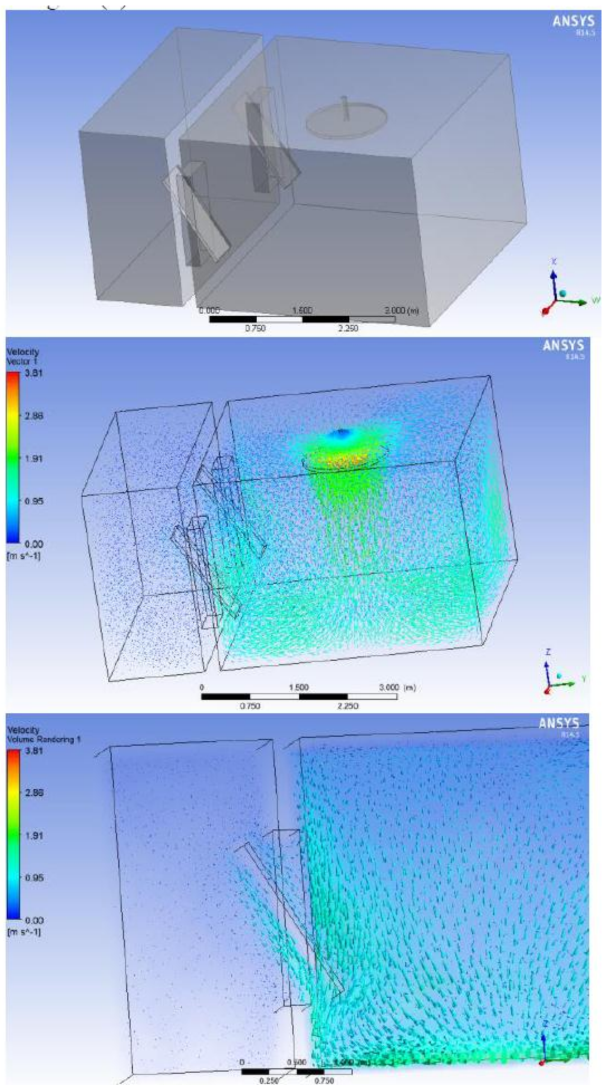


(figure -5)

3.2.5 Designing the louvers requires determining the velocity and direction of air flow due to fan movement, maximum airflow at the corner of the room gets an up direction at a high pressure area which louvers could strike airflow to improve outlet opening figure like shown at figure (6) .



(figure -6)

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Figure (6) shows the direction of the louvers in the modified openings, the top open by 30° angle from the vertical axis of the louver is suitable type of the openings for inlet opening to achieve a maximum negative velocity or pressure inside a space. The down open by 30° angle from the vertical axis of the louver is suitable type of the openings for outlet opening to achieve a maximum positive velocity or pressure inside a space.

3.3. Simulation shows these two-sloped louvers opening at the top and at the bottom with velocities of air movement improving ventilation.

Negative velocities at the inlet can enter the still cool air inside a space and positive velocities at the outlet can exit the warm air outside a space. Figure (6) shows these louvers deals with the air movement resulted from a ceiling fan, the velocity of air movement increases at the bottom of a space and raises up touching the opening wall then the air movement obstacles with the bottom sloped louvers to achieve a maximum stagnation condition resulting the warm air exits from the bottom outlet opening.

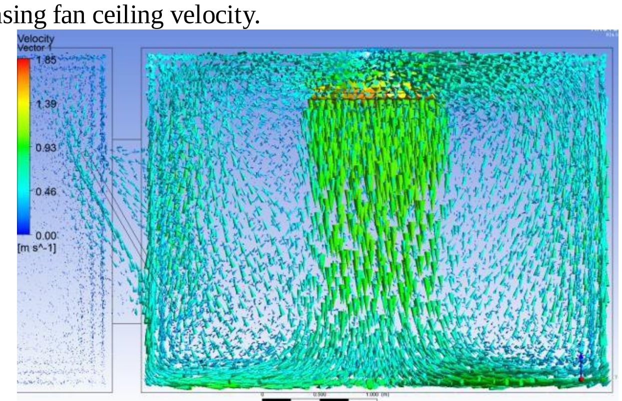
The velocity of air movement at the top inlet opening decreases to be a negative value of velocity causing the cool air enter from outside to inside a space, the air movement records **-** 1 m/s at the inlet top opening and +

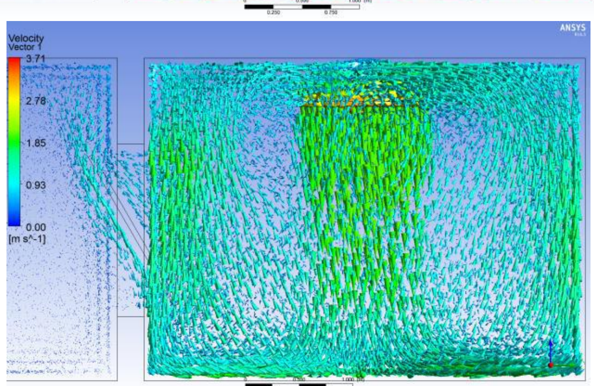
1.25 m/s at the outlet bottom opening.

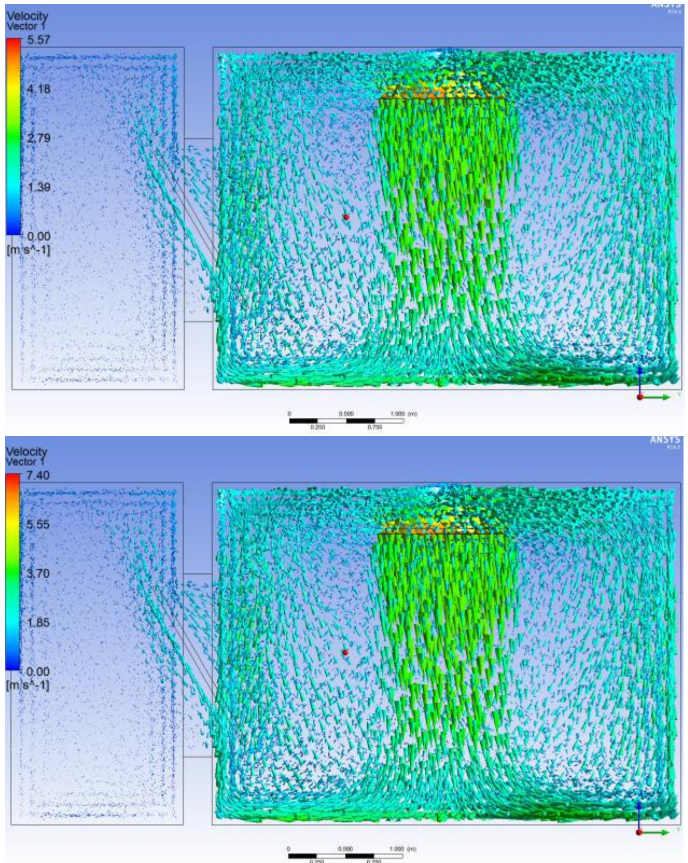
The arrows of the air movements direct to both inside a space at the top inlet opening and outside a space at the bottom outlet opening, Figure (6) details how the arrows of air movements direct to inside a space, Figure (5) shows the performance of the openings without the sloped louvers, the minimum area of the bottom opening can enter the still cool air with low velocity 0.22 m/s.

3.4. in order to increase natural ventilation cooling, fan velocities and different angles of sloped louver will be tested to develop louvers design:**-**

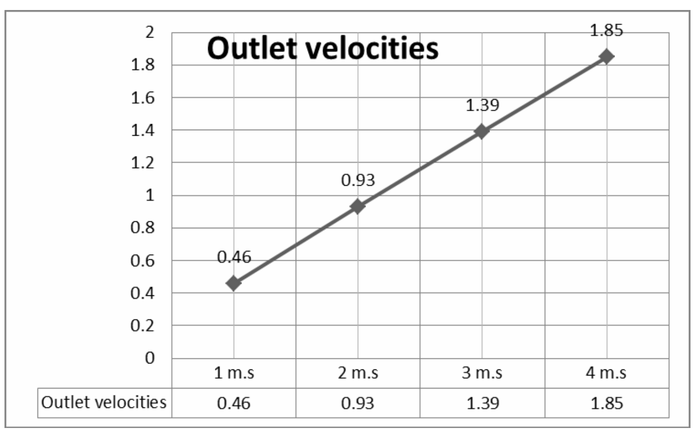
3.4.1 Fan velocities 1,2,3,4 m/s will be simulated as shown in figure 7 to observe the increasing of outlet air velocity according to increasing fan ceiling velocity.







(figure -7)



(table-5)

Table 5 shows that increasing fan ceiling velocity directly increasing outlet air velocity

3.4.2 louver slope angle 15,30,45,60,75,90 degree will be simulated as shown in figure 8 to observe the increasing of outlet air velocity according to increasing louver slope angle

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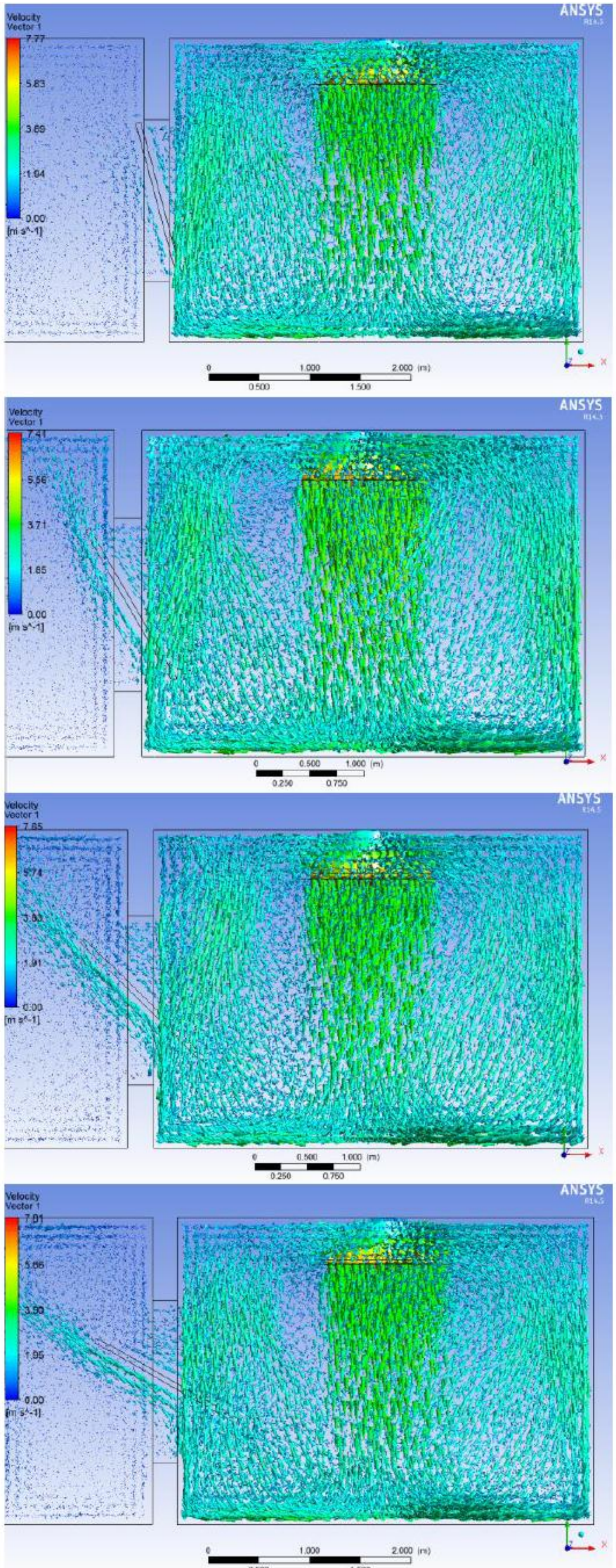

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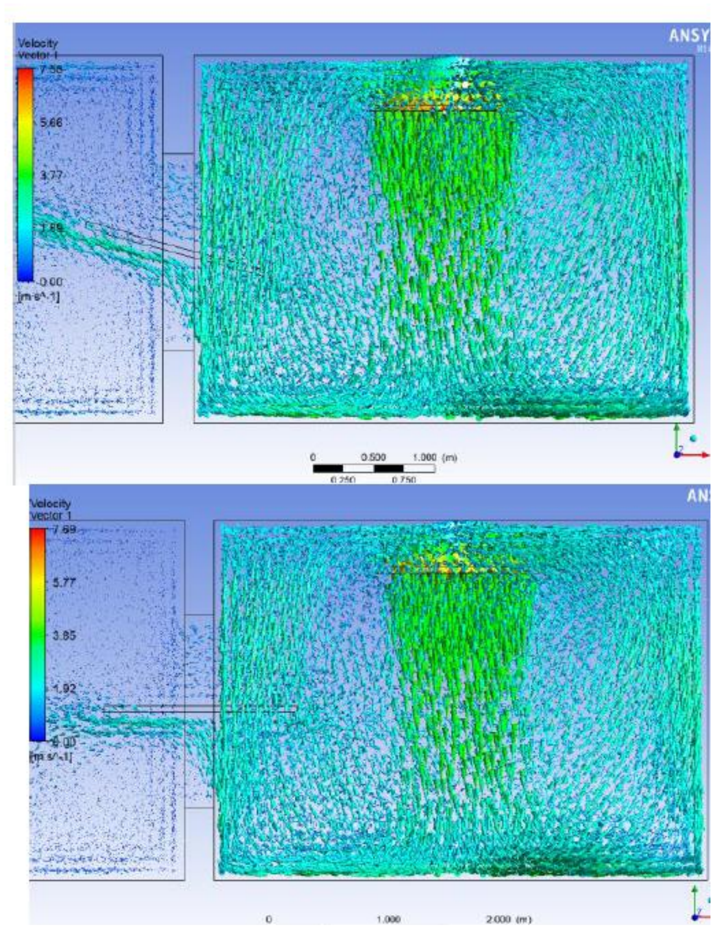
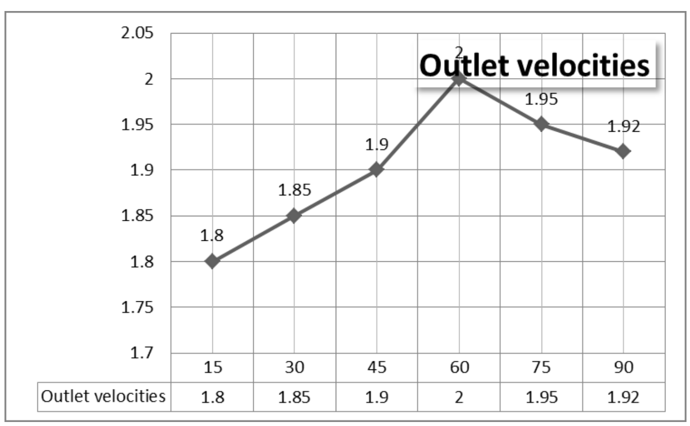


(Figure-8)



(Table-6)

Table 6 shows that increasing louver slope angle up to 60 degree directly increasing outlet air velocity

4. CONCLUSIONS

In order to deliver natural ventilation cooling according to environmental design strategies, a regular movement of a ceiling fan and a modified opening with a sloped louver used to improve one-sided room ventilation and exchanging the warmer air from inside the space with a cool air from outside.

The experiments are simulated in a cubic space volume with a central ceiling fan that its diameters of blades are equaled to achieve a regular movement, experiments showed that increasing fan ceiling velocity directly increasing outlet air velocity, that increasing louver slope angle up to 60 degree directly increasing outlet air velocity.

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