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SIMULATION COMPARISON BETWEEN NATURAL AND HYBRID VENTILATION BY FANS AT NIGHT TIME FOR SEVERE HOT CLIMATE (ASWAN, EGYPT)

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ABSTRACT

The computer simulation measures the effect of ceiling and wall fans in decreasing air temperature during night time. The indoor temperature exceeds the thermal comfort through overheated period in Aswan. High time lag of envelope at the day time increase the indoor temperature at the night time. As a result, the indoor temperature becomes higher than the outdoor temperature at the night time of the overheated period.

The simulation study consists of three models according to ventilation conditions (types). The first model that depends on cross ventilation only is called natural ventilation model. The second model is hybrid ventilation that consists of natural ventilation (cross ventilation) and mechanical ventilation (ceiling fan). The third model is using wall (side) Fan instead of ceiling fan. The boundary conditions are put according to Aswan weather in overheated period (July).

Simulation results of hybrid ventilation models decreased indoor temperature from 2 ºC to 4ºC. The wall (side)(average indoor air velocity in case of wall fan equals 1 m/s) is better than ceiling fan)(average indoor air velocity in case of ceiling fan equals 0.86 m/s) according to decreasing indoor temperature (4ºC) and air flow is well-distributed inside the room at sitting level.

Keywords: Comfort ventilation, nocturnal ventilation, night cooling, cross ventilation, fans: ceiling and side, and CFD models.

1. INTRODUCTION

1.1. Previous studies

In case of ceiling fan according to Kadiri's study, the main factors of increasing air flow at indoor are the distance from fan the velocity of fan. At the distance 1 m from the ceiling fan that the air velocity of the ceiling fan equals 2.5m/s, the air velocity at I m from the ceiling fan equals the same velocity of the fan 2.5m/s. At the distance 5 m from the ceiling fan that the air velocity of the ceiling fan equals 2.5m/s, the air velocity at 5 m from the ceiling fan decreases up to 1m/s(40% from the fan's velocity).

1.2 .Aswan problem

1.2.1. Visual-doe application at Aswan

Visual-doe is used to calculate the rate of energy consumption in different ventilation conditions (natural ventilation, natural ventilation and mechanical ventilation by using fan, and air conditioning). Table (1) shows that the air conditioning achieves comfort temperature (outdoor temperature in sun 48ºC, indoor temperature 25ºC) with extreme high energy consumption (1879 W hr) while fan decreases around 5ºC with low energy (165 W hr) in cross ventilation condition.

Table (1) Aswan outdoor temperature with ventilation types

No	Ventilation condition	Air temperature ◦C											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1	Outdoor temp. in sun	31.2	34.3	37.8	40.9	45	48	47.5	47.3	46.5	46	42	36.3
2	Cross ventilation	26.3	27.8	32.7	35.6	40.2	43.2	42.8	43	40.6	39.1	35.6	32.2
3	Fan +cross ventilation	26.1	27.6	32.5	35.4	40	43	42.6	42.8	40.5	39	35.3	32.1
4	Air-conditioning	22.5	22.5	22.6	23	24.7	24.9	24.6	25.1	24.9	24.9	22.1	22

1.2.2. Air temperature

Givoni's equation no-1 predicts indoor temperature according to outdoor temperature.

T max = G T avg. + Del T +K (T avg. – G T avg.)

T max = maximum indoor temperature (ºC)

GT avg. = Grand average of outdoor temperature, equals 7ºC in summer and 4ºC in winter.

Del T = Depends on mass, shading, and ventilation condition (type), equals 12 ºC in non-ventilation condition, 8-10 ºC in ventilation condition.

K = Depends on mass level, equals 0.5-0.8.

T avg. = maximum outdoor temperature + minimum indoor temperature/2

T max at Aswan =7+12+ 0.5 (41+28/2 – 7) = 38ºC.

Figure (1) shows the chart of outdoor air temperature in shade and suggested indoor temperature according to equation no-1 through a full day of hot July at Aswan, the chart shows also the hours that are effectiveness according to cooling natural ventilation.

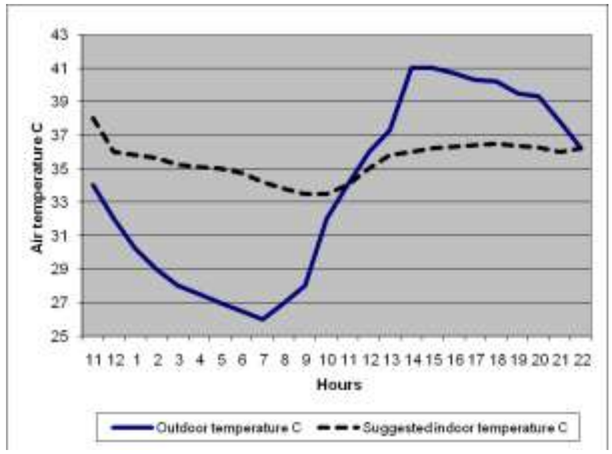


Figure 1 Outdoor and suggested indoor temperature

Table (2) shows outdoor temperature in shade through a day all over the year. 50% of hot period is suitable to ventilation especially at night time because of low temperature that isn't over 32ºC, Night ventilation can be achieved when night outdoor temperature is lower than indoor temperature and night out door temperature isn't over 32ºC according to thermal comfort of hot climate's people.

Table (2) : Maximum / minimum outdoor air temperature , the critical ventilation hours, and the night ventilation hours for upper Egypt region (Aswan).

Time	Hours											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
0	13.7	13.8	19	25.4	28.4	30.1	31.9	31	29	26	20	14.4
2	12	12.5	18	23.6	27	28.1	30.2	29.2	27.3	24.4	18	13
4	11.4	11.8	16.6	22.5	25.4	26.6	28.9	28.2	26.1	23.1	17.1	12.5
6	11.6	11.6	16.5	22.8	25.8	27	29	28.3	26.4	22.5	16.8	12.1
8	11.4	12.3	18.3	23.8	28.6	30.6	32.3	31.4	28.7	24.7	17.9	13.3
10	15.3	16.2	22.8	28.3	32.2	34.4	36.1	35.2	32.1	29.3	22.1	18.2
12	19.6	19.5	26.1	31.4	35.4	38.1	38.2	38.8	36.5	32.5	25	21.2
14	22	21	28.4	33	37.2	39.8	40.7	40.5	38.7	34.8	26.7	23.4
16	21	21	28	32.7	36.2	39.5	40.3	40	38.5	34.5	26.1	22.2
18	20	19.7	26.3	31.6	35.4	38.1	39.5	38.8	36.7	32	25.2	20
20	17.4	17.7	23.5	28.9	32.1	35.1	36.5	35.5	33.5	29	22.7	17.7
22	15.5	15.6	21.4	27.2	30.3	32.7	33.9	33	31	27.2	22.1	16

1.2.3. Wind

Table (2) shows wind velocity, direction, and temperature (wind chill) at night of July, Freemeto.com [5]. Wind velocity ranges between 0.8-2 m/s at 5 meter height (low wind velocity. Wind direction ranges between north and west (constant direction). Wind temperature ranges between 21-29 ºC.

Table (3) Wind environment at night of July

Local time	Wind		
	Velocity m/s	Direction	Temperature ◦C (Chill)
8 pm	0.8	NNW	27
11 pm	2	WNW	29
2 am	1.4	N	25
5 am	0.8	NNW	21

2. <u>SIMULATION EXPERIMENTS</u>

2.1. ANSYS

ANSYS FLOTRAN computational fluid dynamic (CFD) (three dimensions)- is used for measuring the patterns of both air flow and air temperature.

2.2. Air properties

Air properties at 305º K (32ºC) are: Specific heat=1004 GL/ ºK, thermal conductivity= 0.025 W/m^2, dynamic viscosity = 1.87 *10^{-5}, density = 1.1614 KG/m^2, static pressure = 10133 Pascal, gravitational acceleration = 9.81m/s^2, pressure coefficient at windward side = 1.4, loss coefficient 1.5 m/s.

2.3. Case study

Test model is a single room with dimensions that are 6 m length, 4 m width, and 3.5 m height as shown in figure (2). Inlet and outlet openings dimensions are 1 m width and 2 m height. Model consists of two types of fans, the first fan is central (ceiling) fan and the other is side(wall) fan. Diameter of fan is 1 m. Position of ceiling fan is at the center of roof and its height is at 3.2 m from ground level. Position of side fan is at the center of side wall and its height is at 1 m from ground level. Temperature and flow are measured at 1 meter from ground level (sitting level).

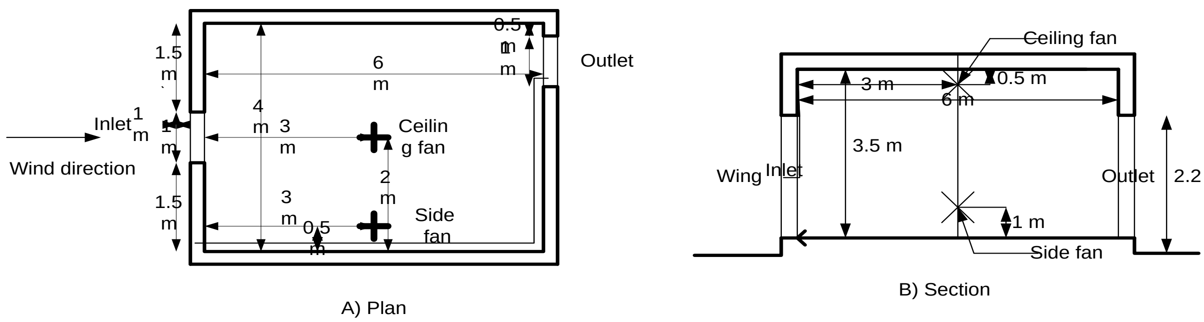


Figure 2 Description of test model

2.4. Case studies and ventilation conditions

Table (3) shows main three types of analyzed model due to ventilation characteristics.

2.4.1. First model (cross ventilation model)

First model (no-1)- basic model depends on inlet at center of windward side that can achieve maximum positive pressure according to wind pressure, Lstiburek ,[6].

2.4.2. Second model (ceiling(central) fan model)

Second model (no-2) is to measure the effect of adding ceiling fan to enhance indoor ventilation and decrease temperature.

2.4.3. Third model (wall (side) fan model)

Third model (no-3) is to compare the effect of ceiling (central) fan and wall (side) fan in increasing velocity and decreasing temperature.

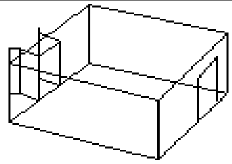
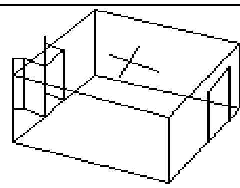
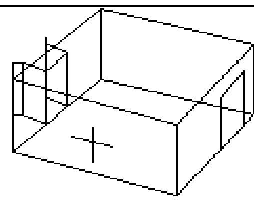
2.4.4. Fan height and velocity

Ceiling fan is at 2.5 m and wall fan is at 1 m from ground level in order to enhance ventilation rate at sitting level (1 m height from ground level) . Kadiri ,[2], shows that the effectiveness velocity of air would be at the first meter from fan's position, the velocity decreased when the subject position fared from fan to achieve half of fan's velocity at the second meter . Both ceiling and wall fans velocity equal 1.5 m/s.

2.4.5. Boundary conditions

Wind velocity at inlet opening equals 1 m/s and the night wind temperature is 300ºK (28ºC). Night indoor temperature is 312ºK (38ºC) due to outdoor temperature in the day 315ºK (43ºC) - weather conditions, Givoni's equation no-2, and figure (1).

Table (4) Experimental conditions

NO OF MODEL	MODELS DUE TO VENTILATION	DESCRIPTION OF MODELS BY DRAWINGS	DESCRIPTION OF MODELS	BOUNDRY CONDITIONS
Model no 1	Natural cross ventilation due to wind pressure through inlet and outlet openings		Models contain two openings (inlet and outlet). Inlet equals outlet. Inlet is characterized by wings.	- Intake wind velocity = 1 m/s. - Outdoor Intake wind temperature = 301°K., 315°K - Indoor temperature = 312°K.
Model no 2	Natural cross ventilation + Mechanical ventilation by ceiling fan.		As previous description, model contains ceiling fan at mid roof and at 2.5 meter from ground level.	- Type of fan: Ceiling or central fan. - Diameter of fan = 1 m. -Velocity of fan = 1.5 m/s
Model no 3	Natural cross ventilation + Mechanical ventilation by side fan.		As basic model side, adding fan at mid wall instead of ceiling fan and at height 1 m from ground level.	Type of fan: Wall or side fan. - Diameter of fan = 1 m. - Velocity of fan = 1.5 m/s

3. RESULTS AND DISCUSSIONS

Figures (3, 4) show the plan of air temperature and velocity patterns.

According to decreasing reference indoor temperature (312ºK), figure (3) and table (5) show the performance indoor temperature pattern in three models. Model 1- cross ventilation model decreases 5ºK as shown in figure (3-1). Model 2- ceiling (central) fan model decreases 7ºK as shown in figure (3-2). Model 3- wall (side) Fan model- decreases 8ºK as shown in figure (3-3).

According to reference outdoor air velocity (1 m/s), figure (4) and table (5) show average of indoor air flow (velocity) pattern in three models. Model 1 – cross ventilation model – achieves 45% (0.45m/s). Model 2– ceiling (central) fan model – achieves 86 %(0.86m/s). Model 3- wall (side) fan model- achieves 100% (1 m/s).

Table (5) shows both temperature and flow patterns of nine measurement points inside room. The both minimum air temperature and maximum air velocity is at the center of room's long axis. Increasing temperature and decreasing velocity the long axis's measurement point is fare from inlet opening.

According to night ventilation cooling, high indoor air flow (velocity) can achieve low indoor temperature. The maximum air velocity (1.2 m/s) in model 3 can decrease 8ºK. The minimum air velocity (0.52m/s) in model 1 can decrease 5ºK.

Figure (6) shows the comparison between air velocity and air temperature of three models.

Results can be summarized: Aswan climate problem is increasing air temperature in heavy mass of buildings in night time 312 ºK (38ºC) (+2-+3 according to predict mean vote). Cross ventilation can decrease 5ºK. Adding fan can decrease more than cross ventilation (7-8 ºK). Decreasing of indoor temperature depends on the position of fan according to sitting level.

Table (6) and figure (6) show the different between night ventilation (low intake wind temperature:300ºK (28ºC)) (+0.5 according to predict mean vote (slightly warm)) and day ventilation (high intake wind temperature:315ºK (43ºC)) (+4 according to predict mean vote) on air temperature pattern. Night ventilation is preferable at night and isn't preferable at day. At the center of long axis, night ventilation decreases indoor temperature 10ºK and day ventilation increases indoor temperature 4ºK according to reference indoor temperature (312ºK(38ºC)). Fan is more effective in a night time (13ºK) than a day time (1ºK). These results are only in over-heated period at hot dry climate such as Aswan that is characterized by high temperature (315ºK (43ºC)) and low temperature (300ºK (28ºC)).

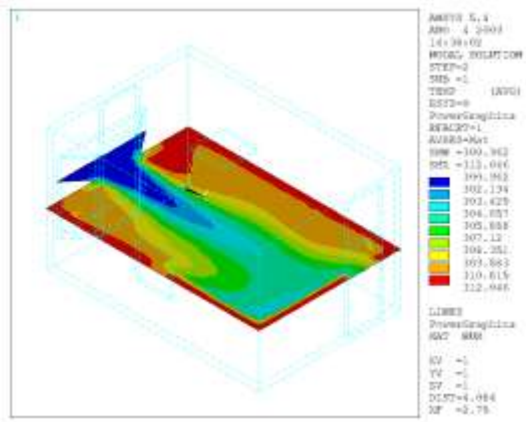


Figure (3-1) Model 1 pattern of air temperature

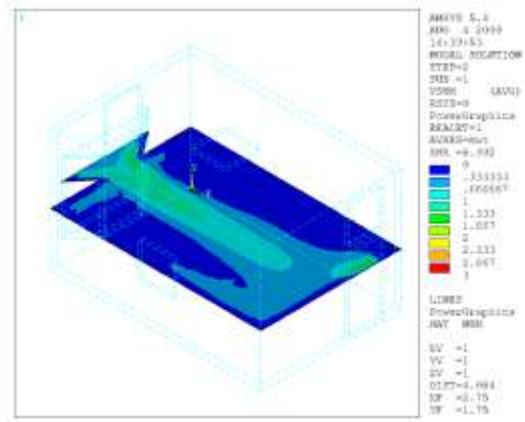


Figure (4-1) Model 1 pattern of air flow

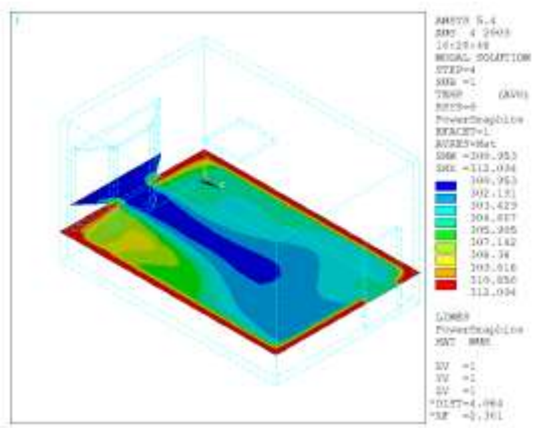


Figure (3-2) Model 2 pattern of air temperature

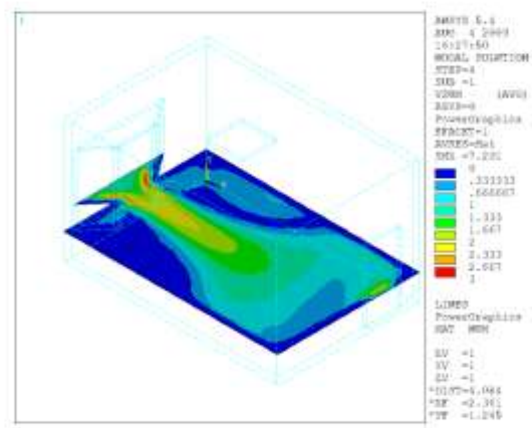


Figure (4-2) Model 2 pattern of air flow

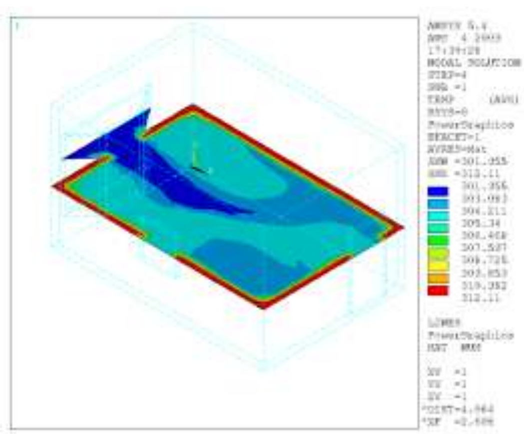


Figure (3-3) Model 3 pattern of air temperature

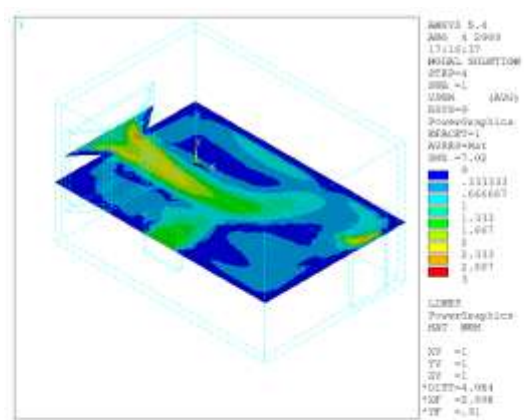
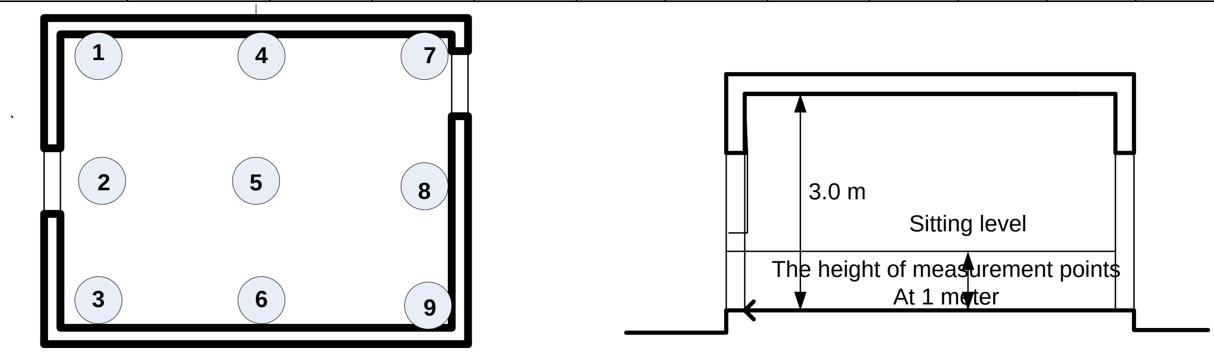


Figure (4-3) Model 3 pattern of air flow

Figures (3, 4) Air temperature and air flow patterns

Table (5) Air temperature and air flow patterns of nine measurement points inside room

Number of model	Temp.(ºK) & flow (m/s)	Measured points									
		1	2	3	4	5	6	7	8	9	Avg.
Model 1	Temp.	311.43	301.57	310.2	310.2	302.8	309	310.2	304	305.2	307.17
	Flow	0.15	1.15	0.15	0.15	0.88	0.2	0.8	0.8	0.45	0.52
Model 2	Temp.	306.5	301.57	307.67	305.3	301.57	307.67	304	302.8	302.8	304.43
	Flow	0.45	2	0.47	0.5	1.8	0.3	2	1.15	0.8	1.05
Model 3	Temp.	304.5	302	304.5	303.5	302.5	304.5	307.6	303.5	303.5	303.5
	Flow	0.5	2.15	0.45	0.83	1.85	1.8	2.3	0.45	0.45	1.2



A) Plan shows 9 measurement points

B) Section shows level of measurement points

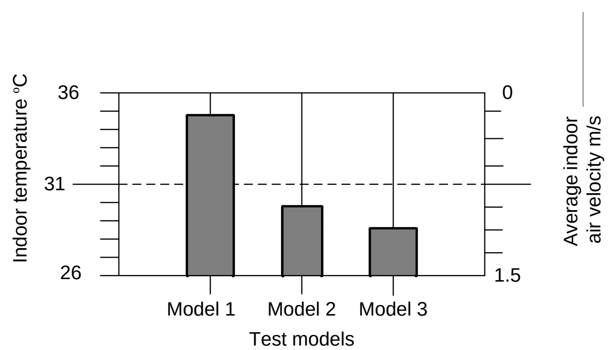


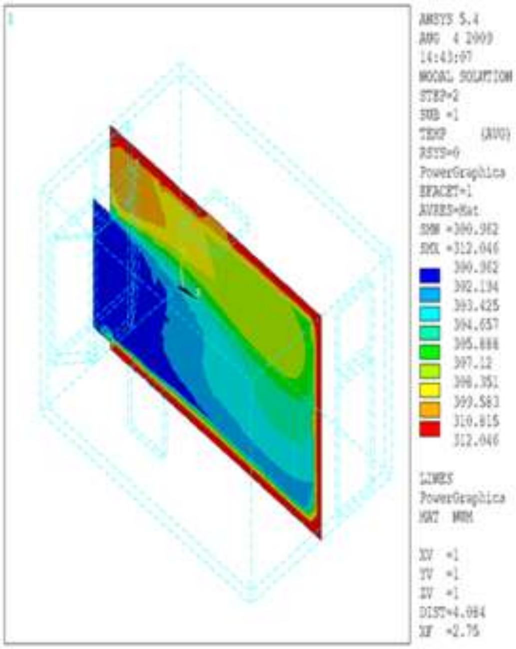
Figure (5) Comparison between air velocity and air temperature of three models.

Table 6 shows the different between ANSYS measurements and wind tunnel measurement According to points 2, 5, and 8 of cross ventilation model – model 1. Table 6 shows the ANSYS measurements is slightly higher than wind tunnel measurements.

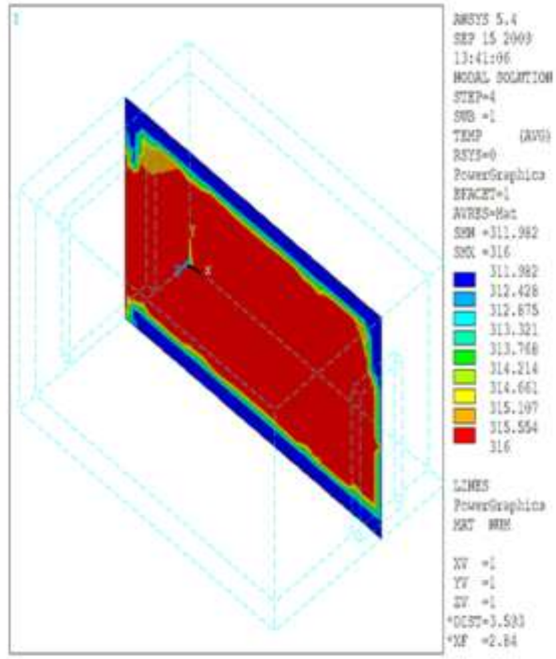
Table 6 validation of results between ANSYS simulation and wind tunnel experiments

Tool	Measurement points		
	2	5	8
ANSYS measurements	115%	88%	80%
Wind tunnel measurements	100%	80%	65%

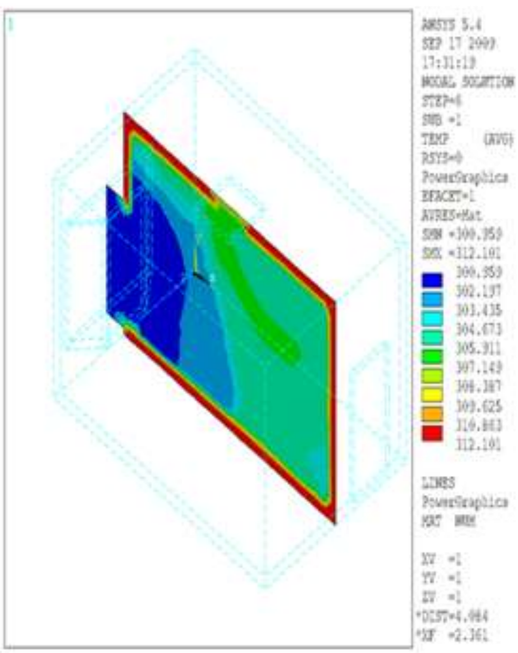
a, b model 1 – cross ventilation model c, d model 2 – ceiling fan model



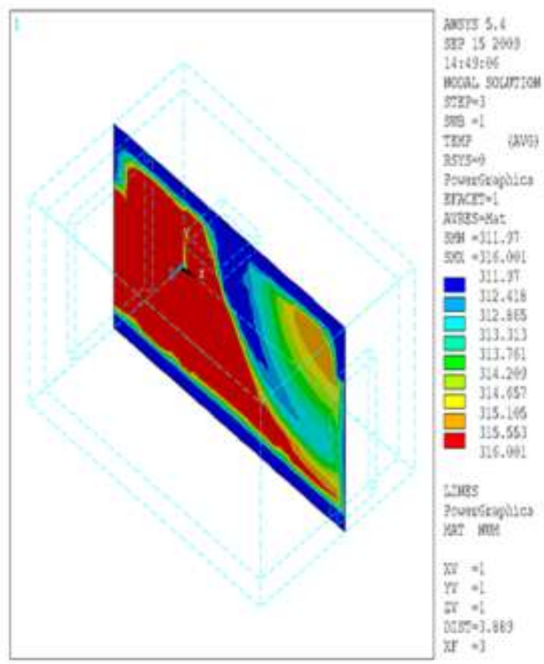
a) Intake wind temperature 300°K



b) Intake wind temperature 315°K



c) Intake wind temperature 300°K



d) Intake wind temperature 315°K

Figure (6) Comparison between low intake wind temperature and high intake wind temperature

Table (7) Comparison between low and high intake wind temperature (night and day ventilation)

Model	Boundary conditions	Measurement points at long axis of room ºK				Reference indoor temperature ºK
		2	5	8	Avg.	
Model 1	Low intake wind temperature (300 ºK)	301.57	302.8	304	302.79	312
	High intake wind temperature (315 ºK)	316	316	316	316	312
Model 2	Low intake wind temperature (300 ºK)	302	302.5	303.5	302.66	312
	High intake wind temperature (315 ºK)	316	316	314.65	315.5	312

4. CONCLUSION

1. Internal air velocity that equals 0.52 m/s can decrease 5^{o}K in the only condition that outdoor is less than indoor temperature and night outdoor isn't over than 32^{o}C.
2. Hybrid ventilation by fan is more effectiveness according to decrease temperature regularity inside room than only natural cross ventilation – paper's weather conditions.
3. Side fan is better than central fan.
4. The strong relationship is between increasing indoor air velocity and decreasing indoor air velocity. Well-ventilated model- model no-3- decreases indoor air temperature as shown in figure (3-3).
5. Fan isn't effective in the over-heated period. According to this paper, fan doesn't depend on velocity and distance only but also depend on intake temperature.

5. REFERENCES

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