Port Said Engineering Research Journal
Faculty of Engineering – Port Said University
Volume (21) No. (2) September 2017 pp. 19:27

Achieving Energy Performance in Buildings Using Natural Ventilation as Passive Cooling Technique

(Housing Building in Port Said as Case study)

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Abstract

In the present time, scrupulous use of energy is a challenge for the world population especially in Egypt. This period, Egypt is attesting creation new communities and our needs for energy will increasing, so we need a new way to design this communities and buildings with less energy. Use the passive techniques in buildings for cooling will be more harmonious with the nature and will achieve energy efficiency. This Paper will examine the Natural Ventilation Technique as one of passive cooling techniques for hot humid climate. It also will confirm that this passive cooling technique has attainable gains through analyzing its effect on Housing Building in port said climate using Design builder simulation program. The findings of this study will help to explore new approach of design energy efficient buildings for sustainable development in the present era and Egypt future using passive cooling techniques.

Key words: Passive Cooling, Natural Ventilation, Energy Performance, Predicted Means Vote

Introduction

In recent years, the rapid economic growth in some of the thickly populated nations has stimulated the utilization of sustainable energy sources and energy conservation methodologies considering environmental protection. Globally, buildings are responsible for approximately 40% of the entire world‘s annual energy consumption. Most of this energy is for the provision of lighting, heating, cooling and air-conditioning. Modern architects are merely thinking about lowering down the temperature of internal spaces without any mechanical system. This paper will analysis Natural Ventilation technique as it is one of passive cooling techniques suitable with hot humid climate. Natural forces (e.g. winds and thermal buoyancy force due to indoor and outdoor air density differences) drive outdoor air through purpose-built, building envelope openings. Purpose-built openings include windows, doors, solar chimneys, wind towers and trickle ventilators. This natural ventilation of buildings depends on climate, building design and human behavior. [1] The ventilation principle indicates how the exterior and interior airflow are linked, and hence how the natural driving forces is utilized to ventilate a building. Furthermore, the ventilation principle gives an indication on how the air is introduced into the building, and how it is exhausted out of it. Infiltration through the building envelope can also play a certain role, depending on the air-tightness of the building envelope. This form of ventilation is, however, usually both unintended and unwanted. [2] It adopts simulation study as the main investigatory method. Energy simulation software – namely Design Builder – will

used to assess the performance of the building. The aim of this study is to apply the most effective passive cooling strategies to improve thermal performance and to reduce energy consumption of residential buildings in hot humid climate, thus reduce energy consumption.

1 – Passive Cooling

Passive cooling can be defined like using natural methods to remove heat from buildings by convection, radiation and conduction, making the buildings cool. Passive cooling is the least expensive means of cooling a home in both financial and environmental terms. It also means using outside air to ventilate and cool a building without the use of a powered system. [3]

2 – Natural Ventilation Technique

Natural ventilation is the result of differential wind forces on various building surfaces and temperature difference between outside and inside air. [4] Natural forces drive outdoor air through purpose-built, building envelope openings. Purpose-built openings include windows, doors, solar chimneys, wind towers and trickle ventilators. This natural ventilation of building

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depends on climate, building design and human behavior. [5]

2 - 1 Cross Ventilation

Wind-driven cross ventilation occurs via ventilation openings on opposite sides of an enclosed space. Figure 1 shows a schematic of cross ventilation serving a multi-room building, referred to here as global cross ventilation. [6] The term cross ventilation is also referred to when considering a single space where air enters one side of the space and leaves from the opposite side**.** In this case the ventilation principle on the system level can be either cross- or stack ventilation. As the air moves across an occupied space, it picks up heat and pollutants**.** [7]

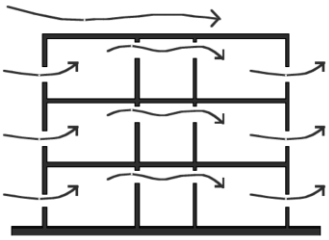

Figure 1 : Schematic of wind-driven cross

2 - 2 Single-Sided Ventilation

Single sided ventilation relies on openings on only one side of the ventilated enclosure. Fresh air enters the room through the same side as used air is exhausted. Ventilation airflow in this case is driven by room-scale buoyancy effects, small differences in envelope wind pressures, and/or turbulence. Consequently, driving forces for single-sided ventilation tend to be relatively small and highly variable. Compared to the other alternatives, single-sided ventilation offers the least attractive natural ventilation solution but, nevertheless, a solution that can serve individual offices. [8]

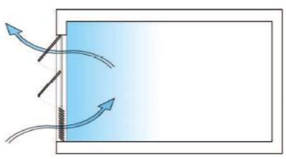

Figure 2 : Schematic of single-sided ventilation

2 - 3 Stack Ventilation

Stack ventilation uses temperature differences to move air. Hot air rises because it is lower pressure. For this reason, it is sometimes called buoyancy ventilation. The advantage of stack ventilation is that it does not need wind, it works just as well on still, breezeless days when it may be most needed. Stack ventilation effect can be combined with cross-ventilation as well. Cool air is sucked in through low inlet openings and hotter exhaust air escapes through high outlet openings. The inlet openings should be adjustable with operable windows or ventilation louvers. [9] Due to its physical nature, the stack effect requires a certain height between the inlet and the outlet. This can be achieved by e.g. increasing the floor to ceiling height, tilting the profile of the roof, or applying a chimney or an atrium. By its nature, stack ventilation resembles cross ventilation as far as some individual spaces are concerned, in that air enters one side of the space and leaves from the opposite side. [10] In winter when cooling is not required, vents in passive ventilation systems can be closed (fully or partially). Passive stack ventilation systems use very little energy but care must be taken to ensure the occupants' comfort in all seasons, taking into account predicted increases in summer temperatures with climate change. [11]

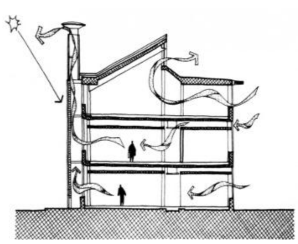

Figure 3: The stack effect: hot air rises due to buoyancy, and its low pressure sucks in fresh air from outside

2 - 4 Wind Towers

Wind towers are building elements designed to take advantage of the wind potential. They can be placed on or next to the roof of the building, or as a separate structure, connected to the building via e.g. an embedded duct. Unlike chimneys, they often have openings on several sides. [12] Wind flowing around a building cause's separation of flow which creates a positive pressure on the windward side and a negative pressure on the leeward side of the building. Airflow follows the pressure gradients within the structure and exits through purposely designed openings and as well as through the leeward side of the tower. The size and location of openings (e.g., windows, doors, etc.) and distribution of internal party walls have a great impact on encouraging cross flow and mixing of the indoor air. Orientations of wind towers are different according to the blow of main desired wind. [13] The inlet and outlet of rooms induce cool air movement. When an inlet is provided to the rooms with an outlet on the other side, there is a draft of cool air. It resembles a chimney, with one end in the basement or lower floor and the other on the roof. The construction materials used for wind towers depend on climate. The choice of materials is made to ensure that the wind tower

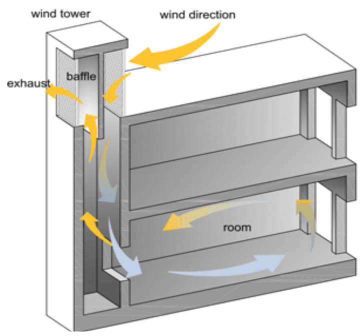

Figure 4: Air Circulation in Wind Tower

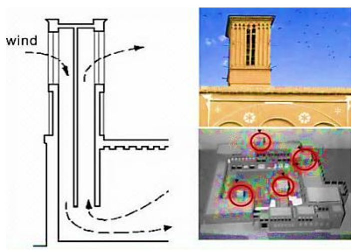

Figure 5: Wind Catcher

operates effectively as a passive cooling system. [14]

2 - 5 Atrium and chimney

An atrium or chimney can help to increase the natural ventilation potential. An atrium or chimney type of natural ventilation system can be a side-atrium or chimney type, or a central atrium or chimney type, depending on the relative position of the wards, and the atrium or chimney. [15] The most usual function is to extract the ventilation air, in which case they provide an increased buoyancy effect. e. The simplest design is an open top. This will ensure negative pressure and provide suction in all wind directions due to the Bernoulli Effect. To avoid ingress of rain, a cover can be placed above the top. [16] Solar chimneys having a relatively low construction cost, can move air without the need for the expenditure of conventional forms of energy, and can help achieve comfort by cooling the building structure at night. [17]

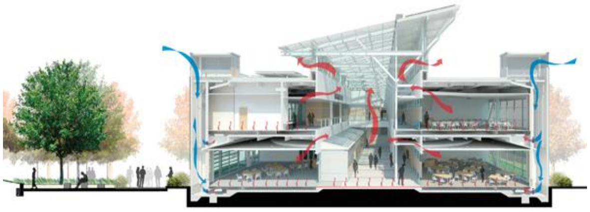

Figure 6: Cool air enters through the towers and eventually exits through the atrium skylight, creating a natural chimney effect. In addition, the atrium flooring uses radiant heat to supplement buoyancy return

2 - 6 Inlet and Outlet Sizes and Locations

Generally, the inlet and outlet size should be about the same, since the amount of ventilation is mainly a function of the smaller opening. However, if one opening is smaller, it should usually be the inlet, because that maximizes the velocity of the indoor airstream, and it is the velocity that has the greatest effect on comfort. Although velocities higher than the wind can be achieved indoors by concentrating the airflow, the area served is, of course, decreased the inlet opening not only determines the velocity, but also determines the airflow pattern in the room. [18]

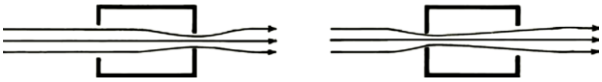

Figure 7: Inlets and outlets should be the same size. If they cannot be the same size, the inlet should be smaller to maximize the velocity

The location of the outlet, on the other hand, has little effect on the air velocity and flow pattern. Inlet openings should be located in positive pressure zones and outlet openings in negative pressure zones.

That provides the best conditions for maximum air movement through the building. [19]

3 – Definitions

Thermal Comfort: [20]

- It occurs when body temperatures are held within narrow ranges, skin moisture is low, and the body’s effort at temperature regulation is minimized.
- One of the primary functions of buildings is to help create thermal comfort. By understanding human comfort needs and the four conditions of the environment that affect comfort (i.e., temperature, RH, air speed, and MRT), the architect can better design buildings that are comfortable, yet use a minimum of mechanical equipment and little energy. Because climate determines many of the specific architectural strategies that should be used.

The predicted means vote (PMV) [21]

- The most widely used method in the assessment of human thermal comfort is through the indices Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD), developed by Fanger.
- This model combines six conventional indexes (air temperature, mean radiant temperature, water vapor pressure, air velocity, occupant’s clothing insulation and metabolic rate) Our approach was to accept one of the underlying assumptions of Fanger’s PMV/PPD indices, namely that a group mean thermal
- Sensation between the limits of -0.85<PMV<+0.85 corresponds with a predicted percentage dissatisfied (*PPD*) of 20%.

Air temperature (°C):

- Temperature of the air surrounding the occupant
- The comfort range for most people extends from (20°C) in winter to (25°C) in summer. In high humid climate it is up to 27 °C

4 - Area of Study and Building Analysis

Port-Said, Egypt is at 31°16'N, 32°14'E, 6 m (20 ft.). it has a hot desert climate (BWh) Arid Desert hot arid according to Köppen climate classification, but blowing winds from the Sea greatly moderates the temperatures, typical to the northern coast of Egypt, making its summers moderately hot and humid while its winters mild and moderately wet when sleet and hail are also common. [22]

4 – 1 Project Data

The building which will be studied is from the buildings that will be implemented for housing by the government in the new cities and communities that will be created. The government designed one model that will used everywhere, so we need to study it to reduce the energy use by using one of the passive cooling techniques.

Table 1 Showing Main Data for Building [23]

Item	Data
Use	Residential Building
Total Block Area	300 m2
Number of Floors	5 levels (Ground + 4 Repeated)
Number of Flats	4 flat in each Floor (Total 20 flat in all building)
Each flat Items	3 Bed Rooms + Reception + 1 Kitchen + 1 Bathroom
Total Area for each Flat	75 – 90 m^2

4 – 2 Analysis the Standard Building / Month before using passive technique

Table 2 Showing Comfort Results / Month using Design Builder simulation Program [24]

Temperature °C / Month	Air Temperature	Outside Dry Bulb Temperature	Relative Humidity (RH)%	PMV
May.	29.09	23.88	38.44	0.24
Jun.	31.72	26.62	39.98	1.59
Jul.	34.27	29.22	43.59	2.98
Aug.	34.61	28.88	42.95	3.31
Sep.	32.00	26.36	46.26	1.84
Oct.	29.46	23.13	45.09	1.15

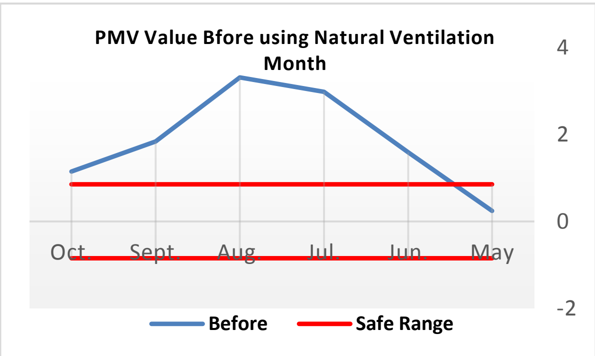

Figure 8: Showing PMV values / Month after using passive cooling technique

- According to the table above the temperature is very high compared with the Outside Dry Bulb Temperature, it needs to be modified.
- The relative human in all month is acceptable as RH < 60 %
- The PMV is acceptable in May as PMV comfort Range - 0.85 < PMV < + 0.85 but in other months is not acceptable.

Table 3 Showing Cooling Loads / Month results using Design Builder simulation Program

Month	May	Jun.	Jul.	Aug.	Sep.	Oct.
Total Cooling (MWH)	- 12.25	- 18.10	- 29.44	- 28.80	- 21.97	- 14.60

4 – 3 Analysis the Building after using Natural Ventilation Technique / Month

As Nature Ventilation is very effective in more cases and achieves comfort for building especially in hot humid climate like this building climate, chimney can be used to increase the natural ventilation potential through the windows by the stack (or buoyancy) effect.

Table 4 Showing Comfort Results / Month After Using (Natural Ventilation)

Temperature °C / Month	Air Temperature	Relative Humidity (RH)%	PMV
May.	25.52	47.51	- 0.59
Jun.	28.15	49.05	0.59
Jul.	30.78	52.75	1.85
Aug.	30.61	53.69	1.79
Sep.	28.02	57.94	0.63
Oct.	24.93	58.51	0.23

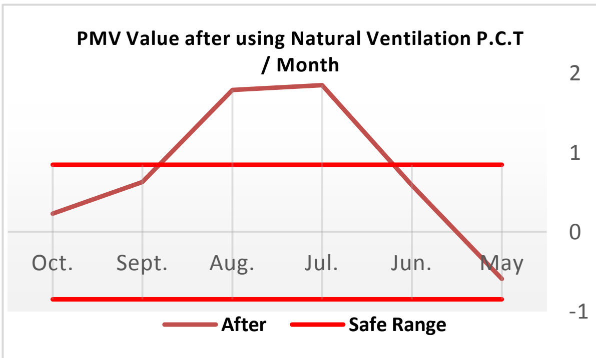

Figure 9: Showing PMV values / Month after using passive cooling technique

Relative Human (RH) is also in normal range RH < 60 %. There is a decrease in PMV value and reached to the safe range 0.85 < PMV < + 0.85 in 4 months. But it is not in 2 months.

Table 5 showing Cooling Loads / Month (M/Wh) After Using (Natural Ventilation)

Month	May	Jun.	Jul.	Aug.	Sep.	Oct.
Total Cooling (MWH)	- 32.92	- 71.19	- 138.20	- 126.49	- 73.88	- 27.22

4 – 4 Comparison between the results before and after using the Natural Ventilation Technique / Month

Table 6 showing comparsion for Comfort Results / Month before and after using passive cooling technique

Month	Air Temperature °C		PMV Value	
	Before	After	Before	After
May.	29.09	25.52	0.24	- 0.59
Jun.	31.72	28.15	1.59	0.59
Jul.	34.27	30.78	2.98	1.85
Aug.	34.61	30.61	3.31	1.79
Sep.	32.00	28.02	1.84	0.63
Oct.	29.46	24.93	1.15	0.23

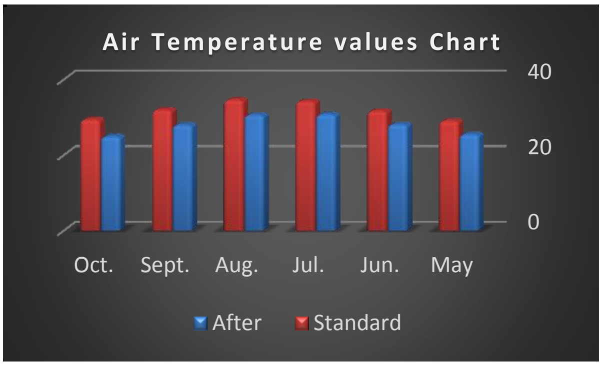

Figure 10: showing comparsion for air temperature after and before using passive cooling technique

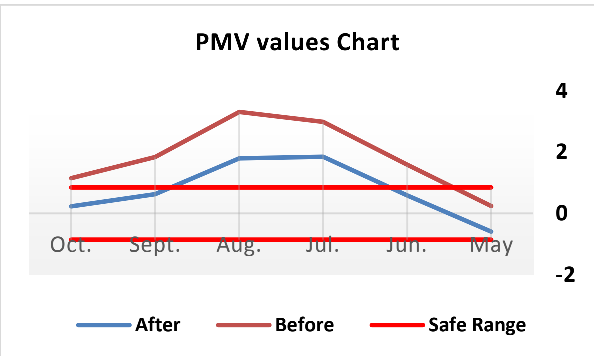

Figure 11: showing comparsion for PMV after and before using passive cooling technique

Table 7 showing comparsion for cooling loads Results / Month before and after using passive cooling technique

Month	May	Jun.	Jul.	Aug.	Sep.	Oct.
Total Cooling (MWH) Before	- 12.25	- 18.10	-29.44	-28.80	- 21.97	- 14.60
Total Cooling (MWH) After	- 32.92	- 71.19	- 138.20	- 126.49	- 73.88	- 27.22

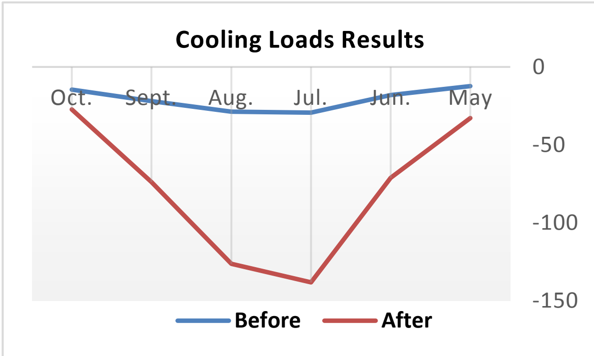

Figure 12: showing comparsion for Cooling Loads Results after and before using passive cooling technique

- The tables and charts above shows that there is a decrease in air temperature up to 6 degrees when using natural ventilation and the PMV decreased and reached to the safe range - 0.85 < PMV < + 0.85 in 4 months and it means that the comfort was achieved and it will have great effect to achieve energy efficiency.
- In Spite of the passive cooling techniques have a medium effect in the Peak season (Jul. and Aug.) but the PMV was decreased to 46 % to be closed from the safe range and also the temperature was decreased to 15 % and it means that the comfort become more better Even if it was not in the safe range. It will have good effect to achieve energy efficiency.
- Cooling loads are decreased compared with before using natural ventilation around month which means that the energy performance will be achieved

4 – 5 Analysis the Standard Building / Day before using passive technique

Table 8 Showing Comfort Results / Day 11 / 6 before using passive technique using Design Builder simulation Program

Comfort / Hour	Air Temperature °C	Relative Humidity (RH)%	PMV
6 am	29.44	43.39	0.75
7 am	31.32	40.07	1.00
8 am	32.07	39.48	1.45
11 am	31.04	35.33	1.19
12 pm	31.15	28.69	1.14
1 pm	31.24	26.03	1.13
2 pm	31.49	26.20	1.18
9 pm	31.79	40.54	1.68
10 pm	31.48	41.37	1.56
11 pm	30.34	43.91	1.34

Table 9 Showing Comfort Results / Day 24 / 9 before using passive technique using Design Builder simulation Program

Comfort / Hour	Air Temperature °C	Relative Humidity (RH)%	PMV
6 am	29.48	52.04	0.84
7 am	31.22	47.74	1.07
8 am	31.87	46.20	1.47
11 am	31.38	46.86	1.44
12 pm	31.56	46.52	1.57
1 pm	31.13	47.68	1.55
2 pm	30.74	48.44	1.40
9 pm	32.03	45.47	1.71
10 pm	32.02	45.85	1.72
11 pm	31.08	48.08	1.58

4 – 6 Analysis the Building after using Natural Ventilation Technique / Day

Table 10 Showing Comfort Results / Day 11 / 6 After using Natural Ventilation using Design Builder simulation Program

Comfort / Hour	Air Temperature °C	Relative Humidity (RH)%	PMV
6 am	23.45	59.99	- 0.81
7 am	24.17	61.48	- 0.71
8 am	24.82	61.94	- 0.46
11 am	28.10	31.59	0.10
12 pm	28.68	24.71	0.29
1 pm	29.37	24.58	0.40
2 pm	30.20	29.04	0.71
9 pm	28.12	49.31	0.73
10 pm	27.38	51.62	0.52
11 pm	26.41	54.59	0.27
			24

Table 11 Showing Comfort Results / Day 24 / 9 After using Natural Ventilation using Design Builder simulation Program

Comfort / Hour	Air Temperature °C	Relative Humidity (RH)%	PMV
6 am	23.37	72.89	-0.86
7 am	24.17	70.28	-0.75
8 am	25.04	67.42	-0.50
11 am	29.08	54.49	0.52
12 pm	29.33	52.74	0.80
1 pm	28.47	55.47	0.72
2 pm	28.14	55.76	0.52
9 pm	27.10	59.98	0.41
10 pm	26.89	60.89	0.31
11 pm	26.00	63.80	0.12

4 – 7 Comparison between the results before and after using the Natural Ventilation Technique / Day

Table 12 showing comparsion for Comfort Results / Day 11 / 6 before and after using Natural Ventilation technique

Month	Air Temperature °C		PMV Value	
	Before	After	Before	After
6 am	29.44	**23.45**	0.75	**- 0.81**
7 am	31.32	**24.17**	1.00	**- 0.71**
8 am	32.07	**24.82**	1.45	**- 0.46**
11 am	31.04	**28.10**	1.19	**0.10**
12 pm	31.15	**28.68**	1.14	**0.29**
1 pm	31.24	**29.37**	1.13	**0.40**
2 pm	31.49	**30.20**	1.18	**0.71**
9 pm	31.79	**28.12**	1.68	**0.73**
10 pm	31.48	**27.38**	1.56	**0.52**
11 pm	30.34	**26.41**	1.34	**0.27**

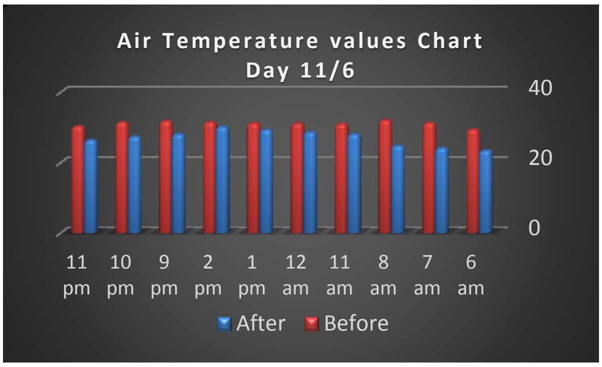

Figure 13: Showing comparsion for air temperature after and before using Natural Ventilation Technique / Day 11 / 6

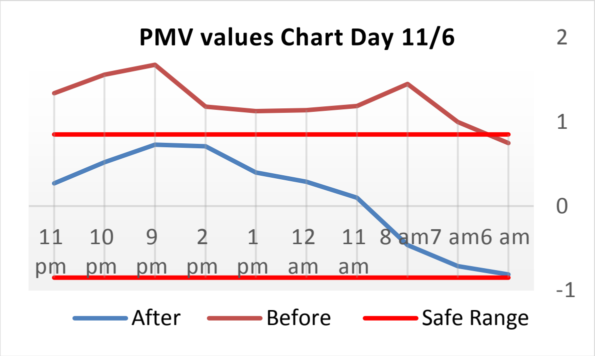

Figure 14: showing comparsion for PMV after and before using Natural Ventilation technique/Day 11/6

Table 13 showing comparsion for Comfort Results / Day 24 / 9 before and after using Natural Ventilation technique

Month	Air Temperature °C		PMV Value	
	Before	After	Before	After
6 am	29.48	**23.37**	0.84	**-0.86**
7 am	31.22	**24.17**	1.07	**-0.75**
8 am	31.87	**25.04**	1.47	**-0.50**
11 am	31.38	**29.08**	1.44	**0.52**
12 pm	31.56	**29.33**	1.57	**0.80**
1 pm	31.13	**28.47**	1.55	**0.72**
2 pm	30.74	**28.14**	1.40	**0.52**
9 pm	32.03	**27.10**	1.71	**0.41**
10 pm	32.02	**26.89**	1.72	**0.31**
11 pm	31.08	**26.00**	1.58	**0.12**

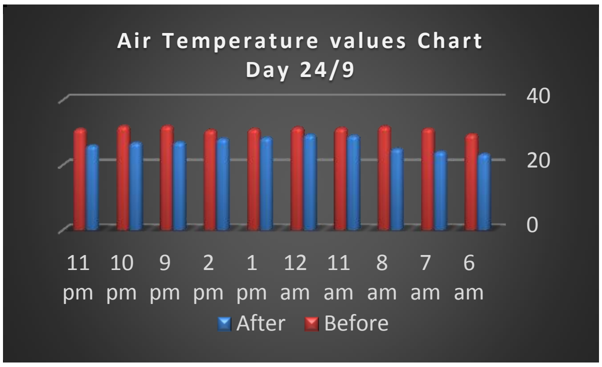

Figure 15: Showing comparsion for air temperature after and before using Natural Ventilation Technique / Day 24 / 9

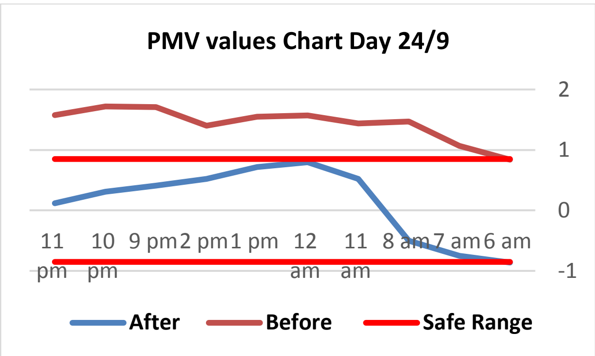

Figure 7: Showing comparsion for PMV after and before using Natural Ventilation Technique / Day 24 / 9

- The tables above showing comparison around two various days after and before using natural ventilation, there is a decrease in air temperature up to 7 degrees (23% decrease percent) when using Natural ventilation the comfort will be achieved.
- The PMV decreased and reached to the safe range - 0.85 < PMV < + 0.85 to great extent when using Natural Ventilation around various hours in two various days and it means that the comfort was achieved around the day.

4 – 8 Air behavior in wind chimney for Natural Ventilation Technique

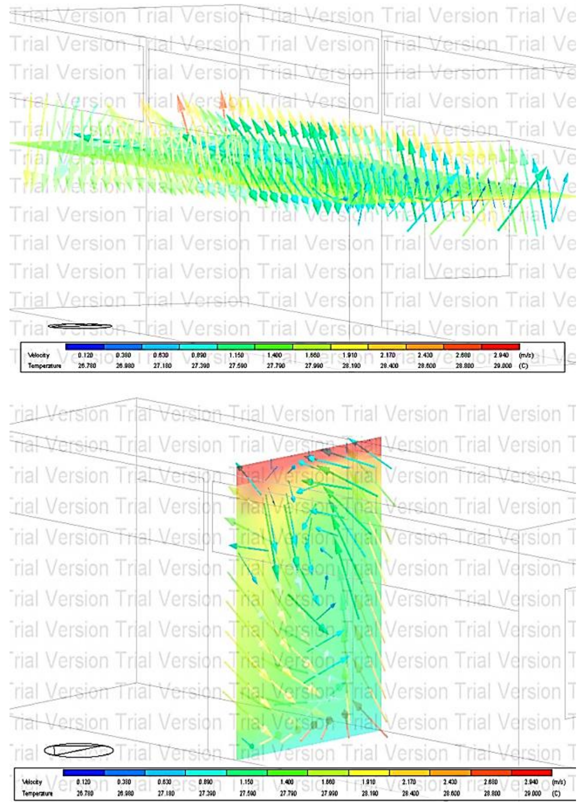

Figure 16: CFD from design builder simulation Showing air circulation, air speed in wind Chimney at 11 am 11 – 6 after using Natural Ventilation

The above drawings show the air circulation at specific moment in wind chimney, the wind chimney pulls up the cold air from the others spaces in the building from various openings – as it is the hottest area and the warm air moving up.

4 – 9 The Proposed Design using the Natural Ventilation Technique [25]

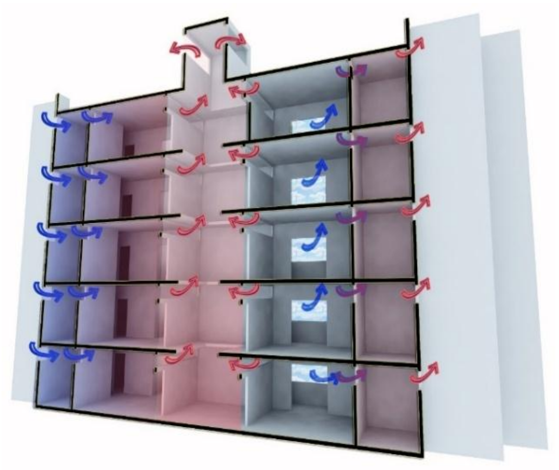

Figure 17: The section (A-A) shows the wind chimney for the building after using Natural Ventilation Technique

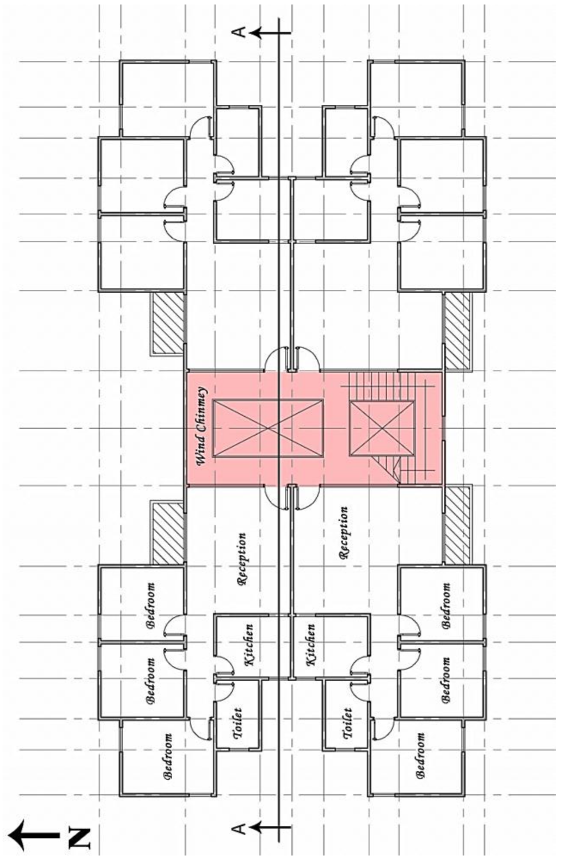

Figure 18: The plan for the building after using Natural Ventilation Technique

This design will achieve energy efficiency because it will not need to use more mechanical system in cooling thus, we will able to use it in new communities and cities with less energy use and that will reduce the energy crisis in Egypt. (23)

4 - Conclusion

Passive cooling means using outside air to ventilate and cool a building without the use of a powered system. Passive cooling techniques can reduce the peak cooling load in buildings, thus reducing the size of the air conditioning equipment and the period for which it is generally required. Natural ventilation: Two natural forces can be used to drive air through a building: wind chimney and buoyancy, which lead, respectively, to two main natural ventilation strategies: cross ventilation and stack ventilation. The effective passive cooling technique and cheapest one in the housing building is Natural Ventilation using Wind chimney in the building with cross ventilation, it will decrease the temperature level up to 7 C° (20 %) and achieve the human comfort to be in normal level. The ministry of housing and New Urban Communities Authority should take into account the importance of using passive cooling technique – Natural Ventilation Technique – when designing the new housing building model. The Proposed Design that offered in this paper reduces the overall energy consumption by including passive design concepts and achieving energy efficiency in Egypt.

5 - References

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