Romanian Journal of Civil Engineering, Volume 12 (2021), Number 1

Evaluation of the potential of natural ventilation in different Algerian climates.

Meriem Mezouari [1], Naima Fezzioui [1], Mohamed El-mir [2], Roulet Claude-Alain [3].

[1] Laboratory of Mechanical Structures « LMS »
University of TAHRI Mohammed Bechar, Algeria
Meriem.m82@live.fr

[2] Energy Laboratory in Arid Zones ENERGARID
University of TAHRI Mohammed Bechar, Algeria
mir0562@yahoo.fr

[3] École Polytechnique Fédérale de Lausanne EPFL
Claude.roulet@epfl.ch

Abstract. *The purpose of our research is to test the effectiveness of some basic configurations of natural ventilation on the thermal comfort of occupants for different climates. The study focuses on the Algerian climate. Seven cities were selected from the new climate zoning of Algeria proposed by [1]. To evaluate the potential of the selected configurations and given the diversified nature of the Algerian climate, the study will focus on the mid-season period that includes the months of May September and October and the summer season for the months of June, July and August. The study was carried out through numerical simulations using the TRNSYS software coupled with the COMIS aeraulic software.*

The results of the simulations showed the contribution of natural chimney ventilation caused by the stairwell to improve occupant comfort Its integration, however, requires a judicious and permanent control to guard against the falls of temperatures or the risks of overheating.

Keywords: Algerian climate; natural ventilation, thermal comfort; TRNSYS- COMIS.

1. Introduction

The building sector is the largest consumer of energy, criteria used for heating, ventilation and air-conditioning (HVAC) systems have been found to account for almost 60% of the global energy consumption of the building sector [2].

The energy demand for buildings is growing steadily and may exceed 64% of energy consumption by 2100 [3]. The energy used for cooling takes an increasing part in the energy balance especially in the Mediterranean climate, due to the increasing use of mechanical conditioning devices [4]. Due in particular of climate change and global warming [5]. More, it is necessary to emphasize that concrete is the most used material in the construction of buildings.in the world. Thermal energy absorbed on hot days does not have enough time to dissipate at night. Also air conditioning is necessary to keep the occupants comfortable and therefore contributes to the increase in energy costs [6].

To remedy this situation, several authors have looked into passive cooling techniques which make it possible to reduce the level of consumption observed and to achieve an acceptable level of thermal comfort. Among these techniques, natural ventilation has been widely studied numerically by The Computational Fluid Dynamic (CFD): [7] examined natural ventilation for underground constructions in Spain. [8] Looked at the methodology and case study of optimizing the building's natural ventilation thanks to the simulation of the CFD wind environment in three aspects, namely site planning, building shape and building envelope, in order to propose ideas to remedy the inadequacy and the weak synergy between architectural design and technological analysis. [9] Used the unstable RNG k-ε model to determine the air flow around and inside the building. [10] Studied

The potential of natural ventilation in a traditional Iranian CFD strategy. [11] Assessed the air flow in a traditional building fitted with a bilateral Wind catcher using the standard turbulence model (k-ε). Ventilation has also proven its role in preserving the durability of building structures, indeed, the rate of condensation which can take place in winter in certain buildings contributes to the creation of building pathologies and to the degradation of its structure [12,13]. Other research has also shown that it is beneficial to use natural ventilation in an enclosed space for a humid climate for three reasons: promoting thermal comfort, air purification inside the building and lower energy consumption [10]. In addition natural ventilation intervenes in the reduction of carbon emissions [14] and energy costs, which increase by 40% for air-conditioned buildings compared to naturally ventilated buildings [15]. Algeria is no exception. The nature of its climate requires the use of air conditioning even in mid-season for the hot and dry climate and summer period for the semi-arid continental climate and high plateaus where the inhabitants are forced to use air conditioners, as indicated on the balance sheet of SONELGAZ [national electricity and gas company].

To remedy this situation in Algeria, several studies have been carried out on natural ventilation, among them that relating to the circulation of air which proved that this last strongly depends on the opening and their dimensions (windows, doors, orifices) and their location in the rooms [16-17]. More [18] have studied by digital analysis the impact of natural night ventilation in summer in a hot and dry climate in the east of Algeria by coupling between TRNSYS and CONTAM. Their results show the effectiveness of window dimensions in improving this ventilation.

Finally, the aim of our research work is to examine the contribution of natural ventilation on thermal comfort for basic configurations in different climates of Algeria.

2. Climate

The climate has a major impact on thermal comfort and on the energy consumption of buildings. Energy codes and standards are based on a clear definition of climate zones to meet the needs of manufacturers. Algeria which covers an area of 2,381,741 km2, has known three climatic zoning classifications: in 1962, 1984 and in 2015. The latter was developed in the work of [1] and is based on the analysis of climate data recorded by 60 weather stations over the period 1999 to 2008, by defining the Climate Zoning maps according to the thermal energy costs necessary for heating and cooling.

Starting from the fact that heating costs less in Algeria than air conditioning which is done by the use of electricity, the authors have come up with two maps as shown below: a map of the climatic zones of Algeria: for heating (A) and for cooling (B). Another map of climatic zones has been drawn up based on energy consumption costs. The latter will be used for the selection of the cities studied.

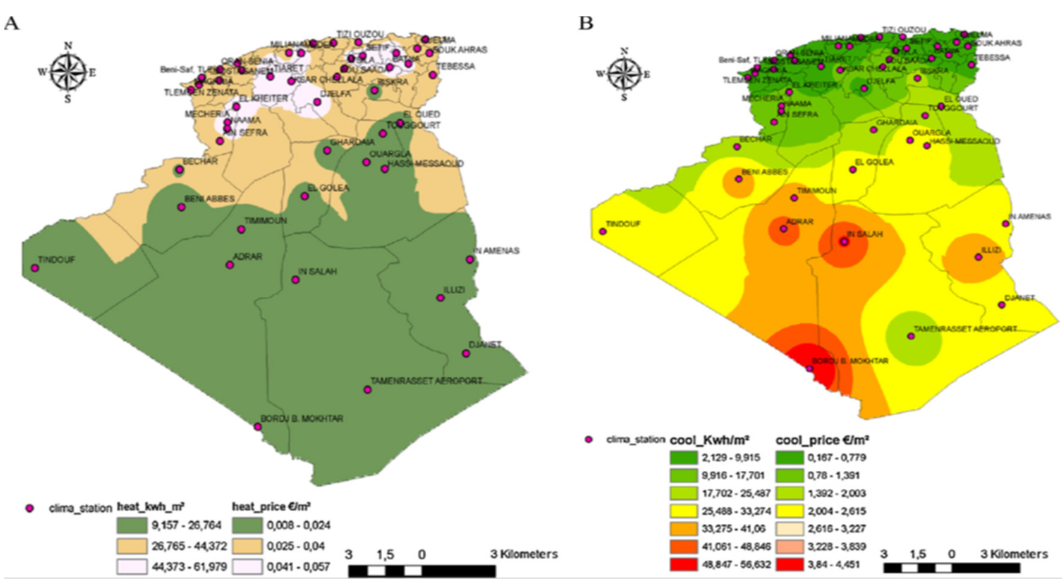


Fig. 1. Map of the climatic zones of Algeria: (A) for heating; (B) for cooling [1].

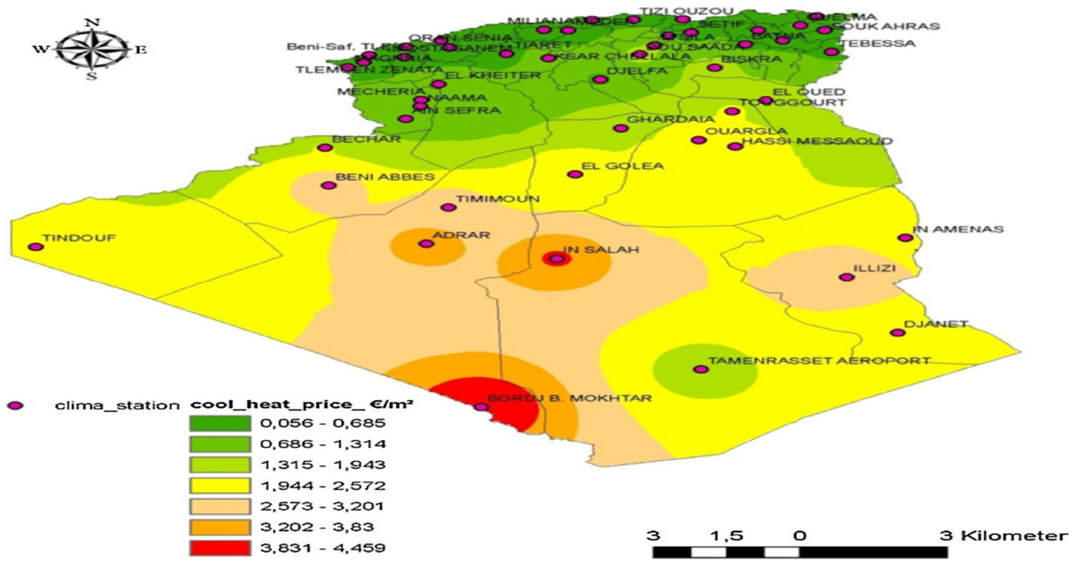


Fig. 2. Climate zones in Algeria according to energy consumption costs [1].

Several previous works have shown that the aridity of the Saharan climate requires the use of air conditioning in summer [19,20], and that achieving optimal comfort during this period really requires the combination of several passive cooling strategies. According to The psychrometric diagram for the city of Hassi Messaoud (Figure 3), the hottest and driest months are 2/3 of May as well as June to September, for this the solar control, the thermal mass effect (thermal inertia), and especially an evaporative cooling and night ventilation are the strategies recommended for this period in order to reintegrate summer comfort [21].

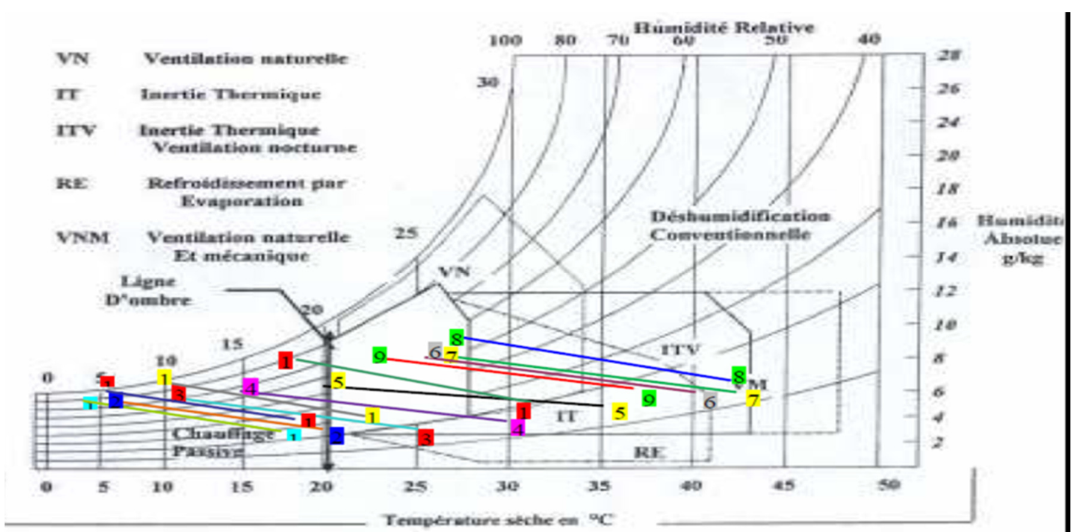


Fig. 3. GIVONI psychometric diagram with application to the city of Hassi Messaoud [21].

According to the psychrometric diagram of the city of Bechar (Figure 4). The thermal mass and natural ventilation can ensure an acceptable level of comfort during a good part of the months of May and September.

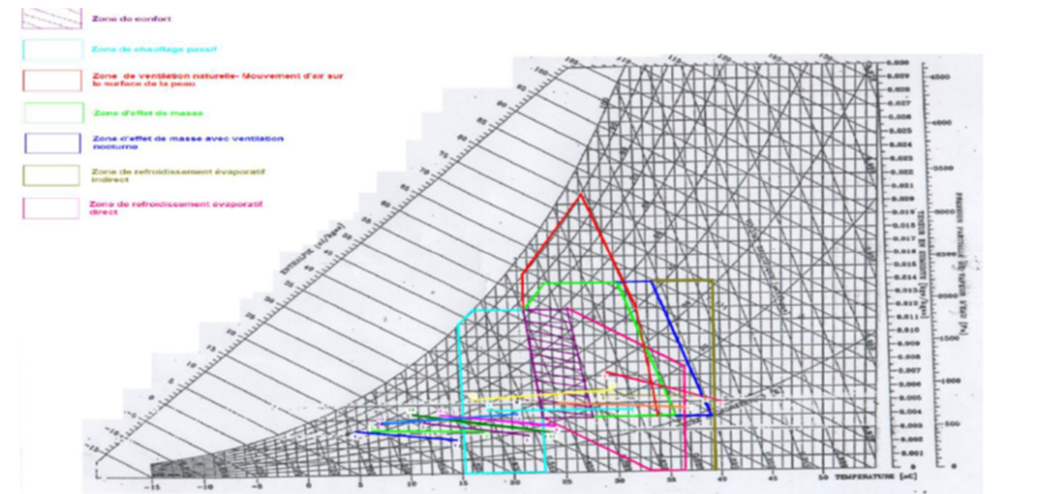


Fig. 4. The GIVONI psychometric diagram with application to the city of Bechar.

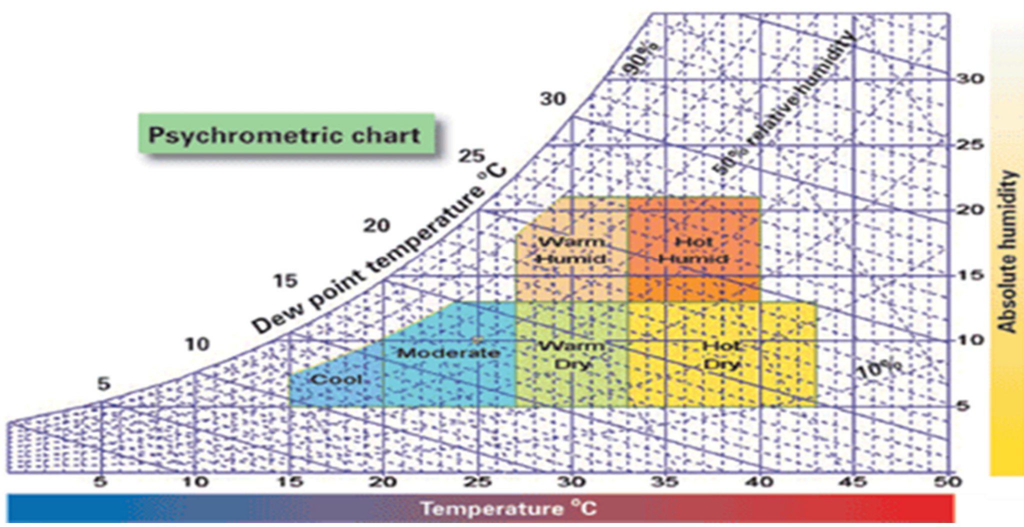


Fig.5. Szokoly diagram for hot and dry climate and Mediterranean climate

According to Szokoly's diagram, natural ventilation is not suitable for summers in hot and dry climates (Figure 5). However, for a Mediterranean climate, night ventilation contributes well to improving comfort in summer. For this reason and for the selected cities representative of each climate zone, we wanted to test the ventilation potential in summer for coastal cities in the north of the country, and the highlands. For the cities of the south of the country we limited our study to the midseason period.

Finally and to properly conduct our study, we selected seven cities according to the new climate zoning [1].

3. Description of the configurations studied

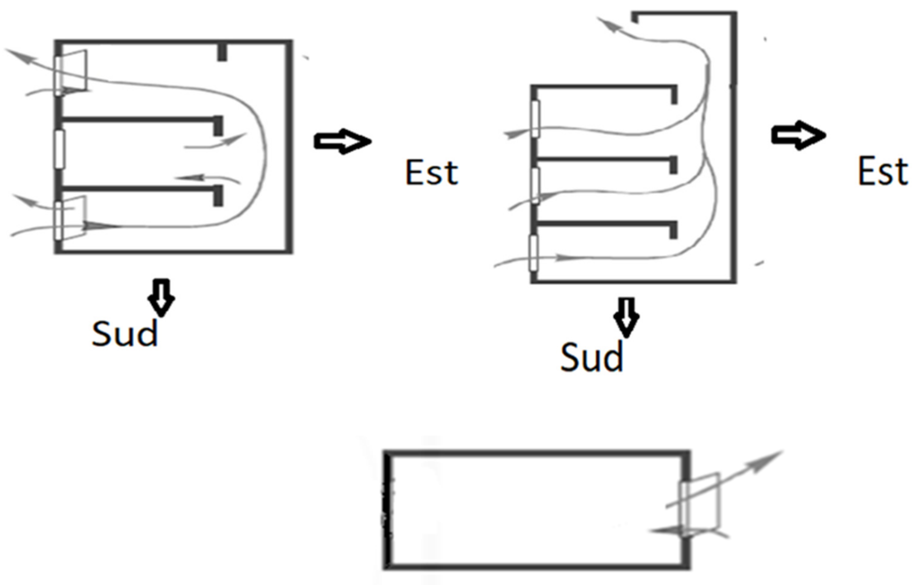


Fig.6. The three configurations to study: top right case A, top left case E, below case B

4. Description of the configurations studied

Our research concerns the analysis of three basic configurations of natural ventilation illustrated schematically in Figure 3.

4.1 Description of the reference case (mono zone)

The basic cell has an area of $20m^2$, a height of 2.8m. It has a single dimension window $(1.4X1.2)\ m^2$ facing west.

4.2 Configurations of the analyzed cases

Case "A": the block consists of a ground floor (Z3) and two floors, Z2 (1st floor) and Z1 (last floor). The zones are connected to a stairwell, zone 1 and zone 3 have a single window of the same size as the base cell $(1.4x1.2)\ m^2$, facing west.

Case "B": the cell consists of a single zone with two windows of dimensions $(1.4X1.2)$ m^2 located on two opposite facades.

Case "E": the block consists of a ground floor (Z3) and two floors, Z2 (1st floor) and Z1 (last floor) each with a dimension window $(1.4X1.2)$ m^2 and connected by a door of $(1X2)$ m^2 at the stairwell of dimensions $(2.10X9.2)$ m^2 equipped with a terrace opening of dimension $(1.5X1)$ m^2 and oriented towards the west.

Table 1

Composition of the cell envelope

Matériaux de construction			U[W/(m°2K)]
WALL	Constitution (from the inside to the outside)	Thickness	
wall OUTSIDE / INTERIOR WALL	Interior plaster	3 cm	0.637
	Red brick	10cm	
	Expanded polystyrene	3cm	
	Red brick	15cm	
	Exterior plaster	3cm	
ROOF roof Ext	Interior plaster	3cm	2.352
	hourdi 16	16cm	
	Concrete	4cm	
	Floor tile	3cm	
FLOOR BASIC	Floor tile	2cm	0.864
	Concrete	20cm	
	Expanded polystyrene	2cm	
	Pierre	40cm	
BETWEEN TWO FLOORS ROOF	Interior plaster	3cm	2.352
	Hourdi 16	16cm	
	Concrete	4cm	
	floor tile	3cm	

5. Internal Earnings and Occupancy Strategy

We assume that the internal inputs and the use scenarios of the buildings are similar for the different zones. The same likely scenario of occupation is applied to each zone. We then assume that each cell houses two people from 00h à 7h et de 17h à 00h. A person is supposed to be present between 12h à 17h. The level of metabolic activity is 1.5 met from 8h to 23h and 1met from 23h to 8h. Regarding the thermal resistance of clothing she is equal to 0.5 clo (summer outfit). The relative speed of air is equal to 0.1 m/s [16]

Another scenario concerning the use of artificial lighting and the use of computers and televisions has also been proposed and built-in simulations (table .2).

Table 2

devices

Apparatus	Time of use
TV	7-14 and of 17-23
computer	10-12 and of 17-23
The lighting	7-8 and 18-23

6. Night ventilation method used

Natural ventilation and simple exposure type, cross, transverse and by thermal draw It is created by opening the openings in the building [22]. Two types of windows characterize these configurations. We have those who are in contact with the exterior of the building and those who directly overlook the stairwell. In order to test the effectiveness of the natural ventilation potential generated by each configuration according to the nature of the climate, five scenarios are proposed The seven cities have been chosen and represent each climatic zone of Algeria.

Table 3

Door and window opening scenarios

Case	month	Towns	Opening on the outside		Sashes opening onto the stairwell	
			Opened	closed	Opened	closed
V1	May, September, October	Adrar, Bechar, Ilizi, Ourgla, Borj-Baji-Mokhtar-	-	24 h		24h
	Juin, juillet, aout	Oran, Djelfa				
V2	May, September, October	Adrar, Bechar, Ilizi, Ourgla, Borj-Baji-Mokhtar-	9h-19h (90%)	19h-19h	9h-19h (90%)	19h- 9h
	Juin, juillet aout	Oran, Djelfa				
V3	May, september, october	Adrar, Bechar, Ilizi, Ourgla, Borj-Baji-Mokhtar-	9h-19h (90%)	19h- 9h	Opened if Tcage< Tint	Closed if Tcage< Tint
	Juin, juillet aout	Oran, Djelfa				
V4	May, september, october	Adrar, Bechar, Ilizi, Ourgla, Borj-Baji-Mokhtar,	Opened if Tcage< Tint	Opened if Tcage< Tint	9h-9h (90%)	19h- 9h
	Juin, juillet aout	Oran, Djelfa				

V5	May, september, october	Adrar, Bechar, Ilizi, Ourgla, Borj-Baji-Mokhtar,	Opened if Text< Tint	Opened if Text< Tint	Opened if Tcage< Tint	Opened if Tcage< Tint
	Juin, juillet aout	Oran, Djelfa				

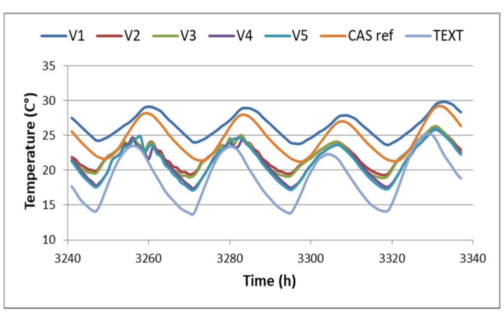
7. Numerical simulation

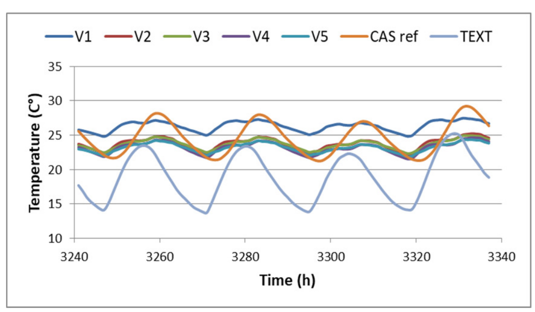
The thermal aeraulic modeling of each configuration is carried out by the TRNSYS software coupled with the COMIS software. The climatic data of the chosen cities comes from the METEONORM software. The soil temperature is determined by the simple type 77 describing the soil temperature. The values of the pressure coefficients (Cp) characterizing the effect of the wind on the facades and roofs of the building, are calculated on the basis of the (Cp) Generator tool [16]. The values of the discharge coefficients (Cd) which take into account the physical effects of the contraction of the flow and the frictional forces as well as the values of the flow coefficient for the cracks (Cs) and (n) exponent of the air flow were calculated with reference to the works of [16,23].

8. Results and discussion

Results are presented in terms of hours of hot and cold discomfort (HTC, HTF) obtained according to the standard EN-15257, In order to complete the thermal comfort of each configuration, to complete our analysis we used maximum and minimum temperatures (Tmax,Tmin). In order not to burden the manuscript we presented only the results that we think are the most interesting for all selected cities.

First of all, and as a first reading of our simulation results, we traced the evolution of the temperature during four days of mid-May for the cities of Oran, Djelfa and Adrar for the three zones and for the different configurations by comparing them with the reference case. The analyzes performed in Figures 7; 8; 9 lead to the following observations.





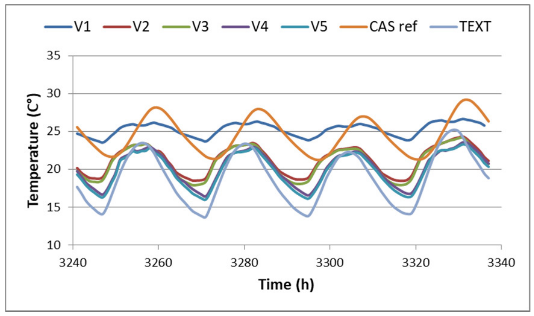


Fig.7. Case A, city of Oran at the top right (Z1), at the top left (Z2), at the bottom (Z3)

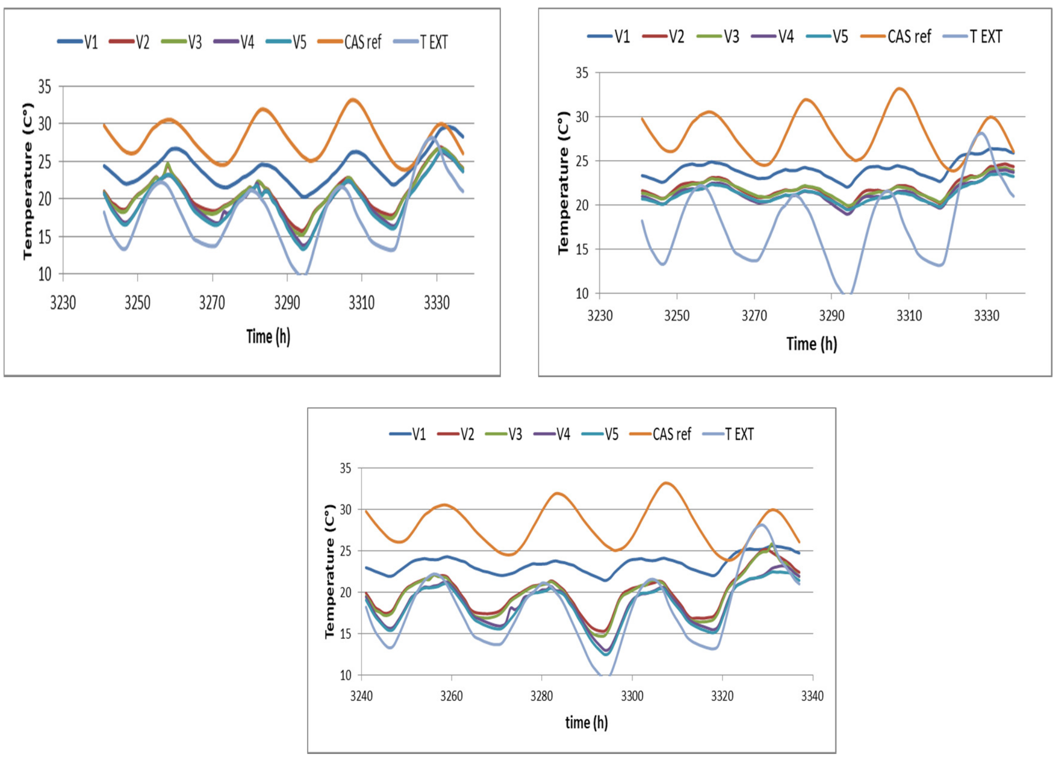


Fig.8. Case A, city of Djelfa top right (Z1) top left (Z2) bottom (Z3)

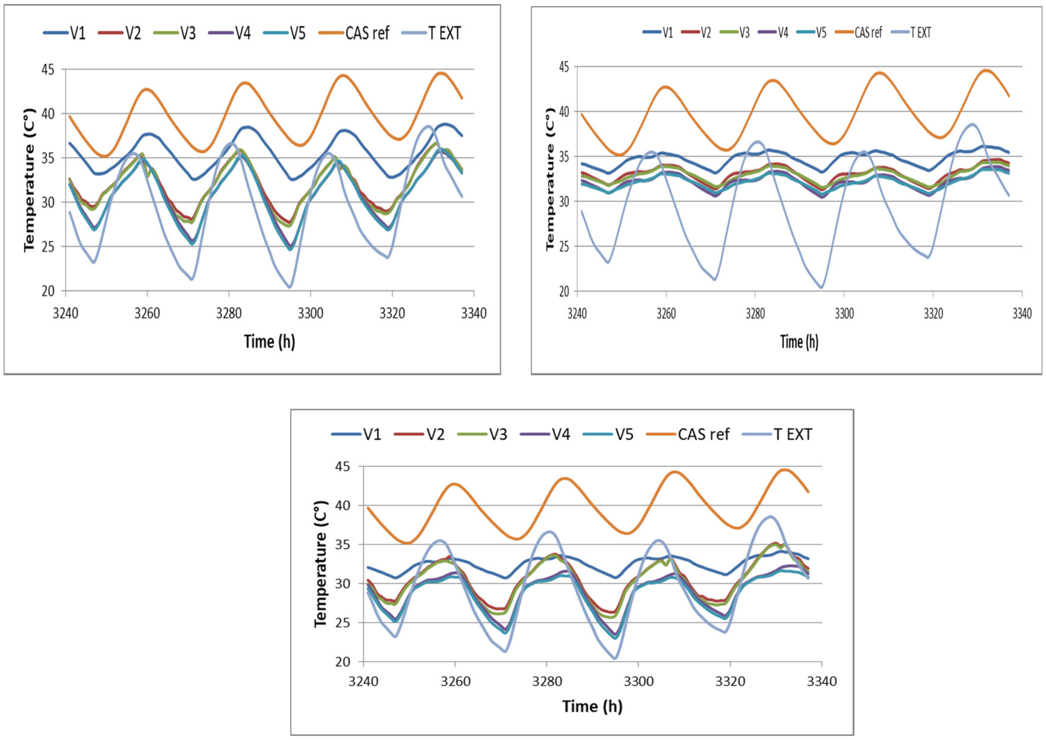


Fig.9. Case A, City of Adrar top right (Z1), top left (Z2) bottom (Z3)

The fluctuations observed in zone1 and zone3 for the cities of Oran, Djelfa, Adrar, are more pronounced than those in zone 2, mainly due to the level of air flow (figure 10). The one from zone 3 is the highest, The one from zone3 is the highest, followed by the level of zone1. The flow in zone 2 is insignificant. As we pointed out previously, the air circulation is between zone 3 and zone 1.

The temperatures recorded on the graphical representations of Figures 7; 8; 9 are all below the temperature of the reference case. But it's zone3 that benefited the most from natural ventilation since the night temperatures recorded in zone 1 are slightly higher than those from zone 3.

Analysis of Figures 7; 8; 9 also shows us that the V4 method is better than the V3 method due to the level of air flow displayed by a higher level for windows in contact with the exterior than the openings in contact with the stairwell.

In short, the V5 method seems to us to be the most efficient the fact that all the windows opening onto the stairwell and the exterior are open by condition ventilation.

For the city of Adrar (figure 9) the temperatures are all above 30° C which represents the limit temperature for summer comfort (EN 15257). The temperature of zone2 oscillates in an interval of 2.5 ° C while those of the top floor (Z1) and the ground floor (Z3) oscillate respectively in an interval of 13° C and 8° C. This difference in the thermal behavior of the three zones is the result of the position of each zone. Zone 1 is in direct contact with the roof which represents the part most exposed to direct and diffuse solar rays during the day [12]. The horizontal surface receives more sunlight than other surfaces, whether in summer or mid-season. However zone3 located on the ground floor benefits from the freshness of the basement. Even with windows closed, the rate of air infiltration in this area is considered relatively high.

On the other hand, natural night ventilation did not play its full role in zone 2 since the calculated difference is 9 ° C between the displayed temperature and the outside temperature during the night (especially around 4 a.m. when the outside temperature reaches its maximum for the month of May)

But an in-depth analysis of the thermal behavior of zone3 shows us that the temperatures from the variants V2 and V3 (opening onto the exterior or the stairwell are open from 7 p.m. and 9 a.m.) exceed the temperature of variant V1 (open during 24 hours), for a time that we estimated at 4 hours. . This situation leads us to think that natural ventilation cannot be considered as a technique which can provide an answer to the problem of controlling thermal comfort even during the mid-season in regions characterized by a hot and arid climate.

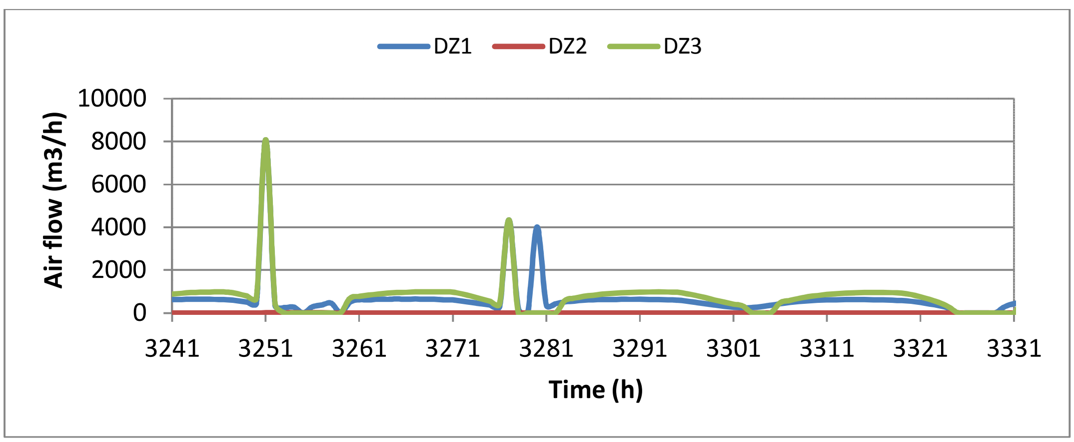


Fig.10. Variation of air flow in the three zones.

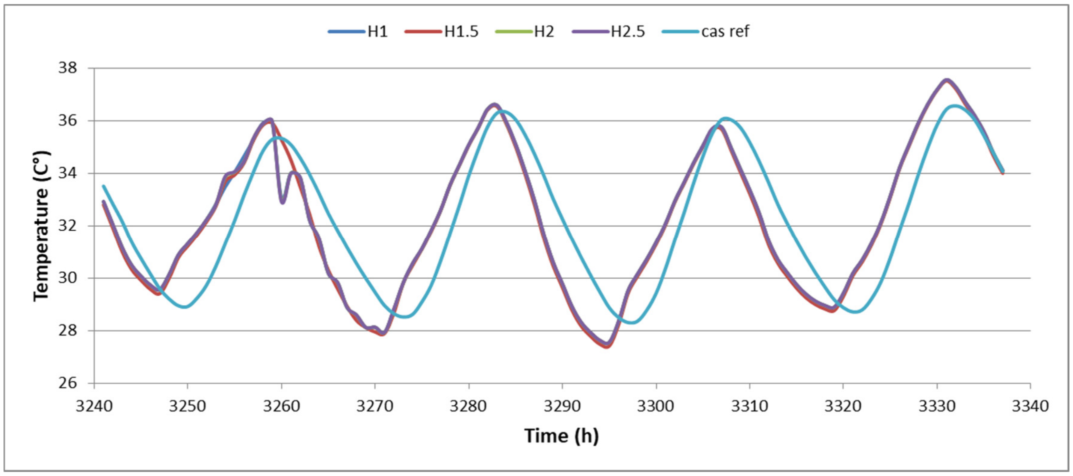


Fig.11. The influence of the variation of the height of the large high opening on the night temperature for the month of May for the city of Adrar.

Now let's see if increasing massive air flows is possible by increasing the height of the opening to be added to the building's terrace.

The graphical representation of Figure 11 shows the influence of the variation in the height of the night opening for the month of May. Note first that the graphs in Figure 11 have the same general appearance. The evolution of the temperatures shows that the representative temperatures of the heights register compared to that of the reference case an increase 1°C during the day and a decrease of 1 ° C in the evening.

It can therefore be said that the variation in height up to 6m did not register an improvement in the natural ventilation of zone 1.

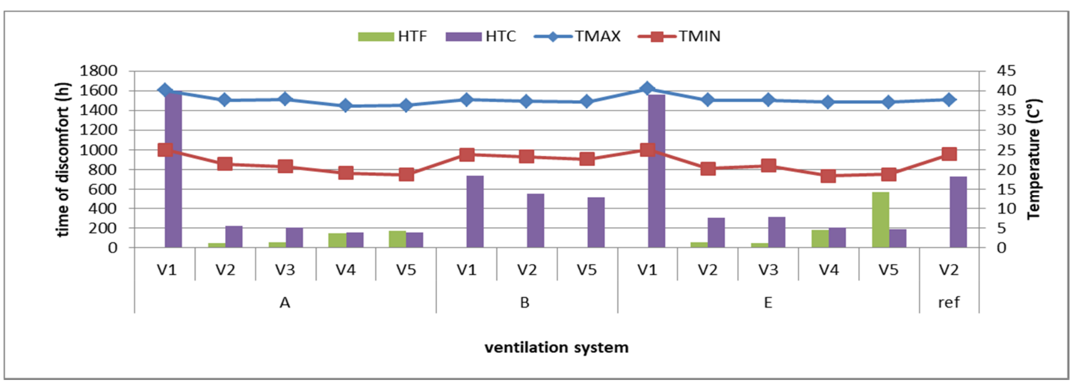


Fig.12. Variation in hours of discomfort and maximum and minimum temperatures as a function of time for the city of Oran

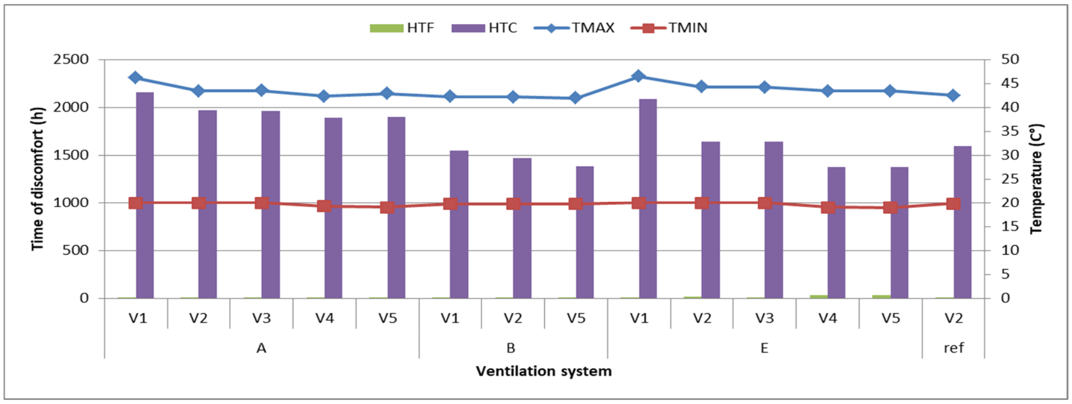


Fig.13. Variation in hours of discomfort and maximum and minimum temperatures as a function of time for the city of Adrar

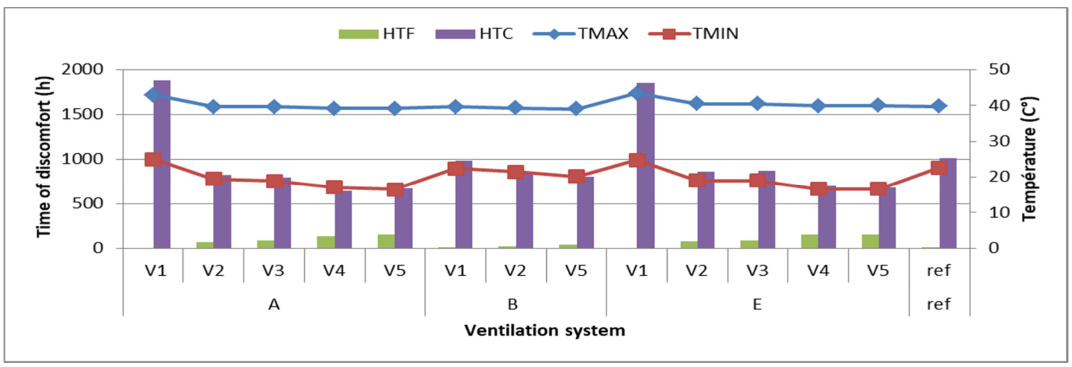


Fig.14. Variation in hours of discomfort and maximum and minimum temperatures as a function of time for the city of Djelfa

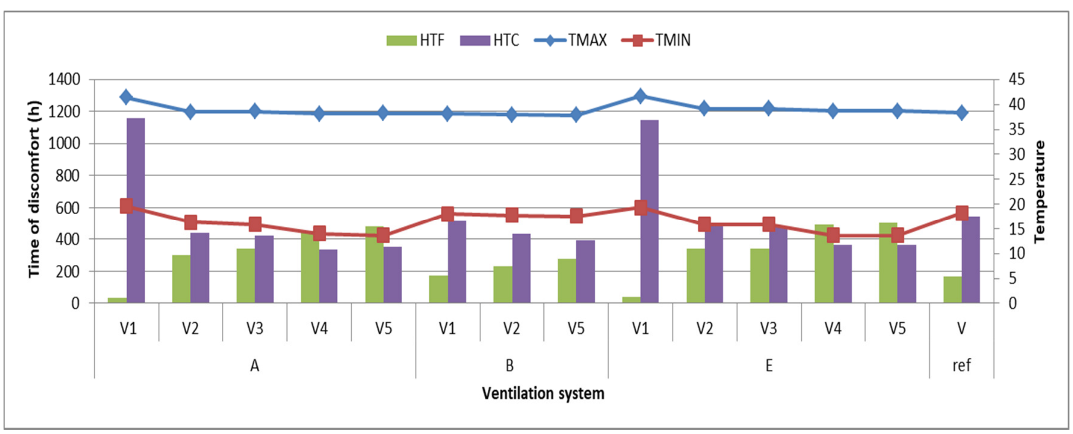


Fig.15. Variation des heures d'inconfort et des températures maximales et minimales en fonction du temps pour la ville de Bechar

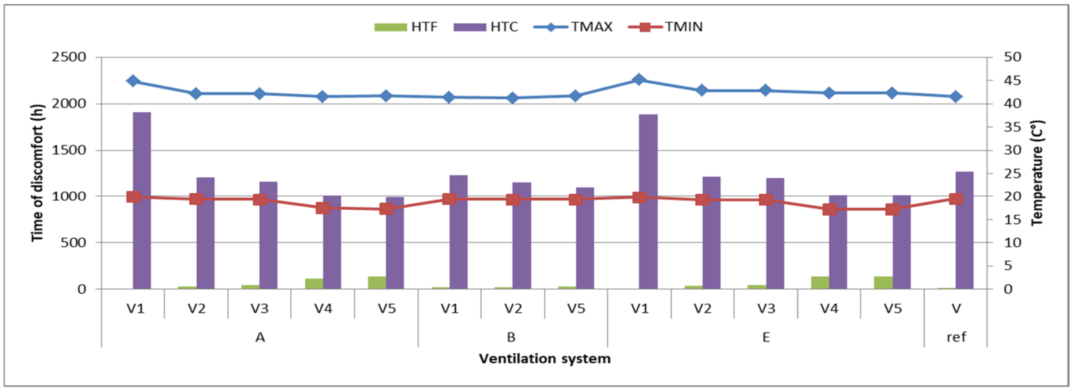


Fig.16. Variation des heures d'inconfort et des températures maximales et minimales en fonction du temps pour la ville d'Ouargla.

The analysis of the graphical representation of the hours of discomfort makes it possible to identify the most favorable case for ventilation. The analysis will relate only to the results of Z1 which represents the hottest zone such as we underlined it during the study of the results of the temperature curves by zone.

In order to complete our study it seems important to us now to analyze the results in terms of hot discomfort hours and cold discomfort hours obtained according to standard EN15257.

The results show first of all that scenario V5 represents the best performing scenario due to the level of HTF (hour of cold discomfort) and HTC (hour of hot discomfort) noted on the histograms of the figures. This observation is valid for all cities. Also our analysis will only relate to scenario V5.figure 12 shows that for the city of Oran, case B presents the level of HTF almost zero. More, we note for case E that case A presents better results. So, the level of HTC in case A and case E shows a decrease of 78.34% and 73.94% respectively compared to the level of the reference case. In addition, the Tmax (maximum temperature) corresponding to case E exceeds by 1 ° C that of case A. Case A seems to be the most favorable case, The level of Tmax is in the range between 35 ° and 40 ° for all of the cases studied. So, it seems to us that the opening method was not sufficient to decrease the temperature below 30°

The city of Adrar (figure 13) is characterized by a zero HTF level. But the level of HTC is considerable and far exceeds the level of other cities in the country. The level of HTC in case A exceeds by 19.22% that relating to the reference case. En revanche, le niveau de HTC dans le cas E a enregistré une baisse de 13,31% par rapport au niveau du cas de référence. This leads us to think that case E is the most favorable case. The fluctuation in Tmax is low and lies in the range between 43 ° C and 46 ° C, but the Tmax remains much higher than the temperature of the reference case. Tmin (minimum temperature) is between 19 ° and 20 °.

This analysis highlights the arid character of Adrar's climate even in mid-season. Despite our choice in favor of case E, analysis has shown us that the arid climate of the city of Adrar is an obstacle to the use of openings as a technique for improving the thermal efficiency of natural ventilation.

Zone 1 Djelfa:

Like other cities, the level of HTC is considerable and far exceeds the level of HTF which seems insignificant. The Tmin is located at 16 ° C while the Tmax displays a level above 40 ° C and considerably exceeds the level of the reference case. The appearance of the histograms shows us that the HTC and HTF of case A are at an equivalent level than those of case E. The choice in favor of case E would lead to an increase in the costs linked to taking charge of the upper opening.

Zone 1 bechar:

Analysis of the graphic representations of the city of Bechar shows us the high level of HTF compared to that found in other cities. As in the previous cases the level of HTC greatly exceeds the level of HTF. It then seems to us that case A is the most favorable case because it has a low level of HTC compared to that of case E.

Specify, otherwise, that natural ventilation by opening windows should be used with caution in cities with a temperate climate because and as we noted the mid-season period can present hours of hot discomfort but also hours of cold discomfort which requires careful control of the level of air flow induced by the opening of windows.

Zone 1 Ouargla:

The results obtained for the city of Ouargla are completely comparable to those of other cities. The level of HTC is much higher than that of HTF observed in Figure 13. The fluctuation of the maximum temperature is small the difference of 1 ° C between the Tmax of case A and of case E while the difference between Tmin of the 2 cases is located at 3 ° C. The decrease in the level of HTC in cases A and in case E compared to the level in the reference case was 21.92% and 20.03% respectively. This difference is not significant and does not allow one to choose one or the other.

9. Conclusion

This article presented a study aimed at testing the efficiency of natural ventilation on the thermal comfort of occupants by the application of different configurations in various climates in Algeria. Regarding the thermal behavior of the areas studied, it should be noted that whatever the ventilation scenario zone 3 benefited most from natural ventilation. On the other hand, zone 1 remains the hottest zone due to the high level of hot discomfort hours and cold discomfort hours. The study showed that it is the fifth scenario (V5) applied which gave the best results among all the opening scenarios proposed, especially in the regions from littoral and highlands. Even with the use of the top opening (case E) we did not see any improvement in results for all selected cities. Maximum temperatures have exceeded the 30 ° C threshold and lie in an interval between [43 ° -44 °] in Adrar, [35 ° -40 °] in Oran, [40 ° -45 °] in Djelfa, and [38-44] in Bechar. Minimum temperatures have dropped to 13 °Cin Bechar, 10 ° in Djelfa, 20 ° in Adrar. As a last resort, it seems that the natural ventilation created by the effect of air remains an applicable method in the regions from littoral and highlands provided it is carefully checked. On the other hand, natural ventilation is difficult to apply in regions characterized by extreme climatic conditions even in mid-season. Overheating of the interior environment of the building can occur and direct natural ventilation becomes unnecessary under these conditions. Wait for the recommended comfort temperature levels, alternatives need to be found by coupling natural ventilation with other passive cooling systems.

References

[1] *R. Ghedamsi, N. Settou, A. Gouareh, A. Khamouli, N. Saifi, B. Recioui, B. Dokkar*. "Modeling and forecasting energy consumption for residential buildings in Algeria using bottom-up approach." Building and Environment, vol. 121, no. 1, June. 2016, pp. 309-317.

[2] *G. Evola, V. Popov*. "Computational analysis of wind driven natural ventilation in buildings." Energy and Buildings, vol. 38, no. 5, May. 2006, pp. 491-501

[3] *M. Santamouris*. "Cooling the buildings – past, present and future." Building and Environment,vol. 128,no. 15, sept. 2016, pp. 617-638.

[4] *A. Rinaldi, M. Roccotelli, A.M. Mangini, M. Pia Fanti, F. Iannone*. "Natural ventilation for passive cooling by means of optimized control logics." In High- Performance Built Environment Conference – A Sustainable Built Environment Conference, Procedia Engineering, Ghrdaia, vol. 180, no. 2017, pp. 841-850

[5] *N. Saïfi*. "Contribution a la conception des batiments a faible consommation d'energie dans les zones arides.", PhD Thesis, Kasdi Merbah University of OUARGLA, 2015

[6] *J.L. Alvarado, W. Terrell, M.D. Johnson*. "Johnson Passive cooling systems for cement-based roofs." Energy and Buildings, vol. 180. no. 9, Sept. 2009, pp. 1869-1875.

[7] *C. Porras-Amores, F.R. Mazarrón, I. Cañas, P. Villoría Sáez*." Natural ventilation analysis in an underground construction: CFD simulation and experimental validation.", Tunnelling and Underground Space Technology, vol. 90, no. August. 2019, pp. 162-173.

[8] *W. Guo, X. Liu, X. Yuan*. "Study on Natural Ventilation Design Optimization Based on CFD Simulation for Green Buildings." 9th International Symposium on Heating, Ventilation and Air Conditioning and the 3rd International Conference on Building Energy and Environment, Chine, nol. 121, no. 2015, pp. 573-581

[9] *S. Liu, W. Pan, Q. Cao, Z. Long, Q. Chen*. "CFD simulations of natural cross ventilation through an apartment with modified hourly wind information from a meteorological station." Energy and Buildings, vol. 195, no. 15, July. 2019, pp. 16-25

[10] *S. Omrani, V. Garcia-Hansen, B. Capra, R. Drogemuller*. "Natural ventilation in multi-storey buildings: Design process and review of evaluation tools." Building and Environment, vol. 116, no. 1, May. 2017, pp. 182-194.

[11] *A. Zaki, P. Richards, R."Sharma*. "Analysis of airflow inside a two-sided wind catcher building." Wind Engineering and Industrial Aerodynamics, vol. 190, no. July. 2019, pp. 71-82

[12] M.Y. Ferroukhi. "Modélisation des transferts thermo-hydro-aérauliques dans les enveloppes de bâtiments : évaluation des désordres causés par l'humidité.", PhD Thesis, University of La

Rochelle, 2016.

[13] E. Kyritsi, A. MichaelAn. "Assessment of the impact of natural ventilation strategies and window opening patterns in office buildings in the Mediterranean basin." Building and Environment, no. 30, August. 2019, 106384

[14] *w. Feng, Q. Zhang, H. Ji, R. Wang, N. Zhou, Q. Ye, B. Hao, Y. Lid, D. Luof, S. Lauc*. "A review of net zero energy buildings in hot and humid climates."Renewable and Sustainable Energy, no. 114, October. 2019, 10930.

[15] *J.A. Castillo, G. Huelsz*. "A methodology to evaluate the indoor natural ventilation in hot climates." Building and Environment, vol. 114, no. March. 2017, pp. 366-373

[16] N. Fezzioui, "Analyse et Caractérisation du Bilan d'Energie d'un Habitat Traditionnel 'région Sud-Ouest", PhD Thesis, Tahri Mohamed University of Bechar, 2014.

[17] A. Belakehal, "Etude des aspects qualitatifs de l'éclairage naturel dans les espaces architecturaux. Cas des milieux arides à climat chaud et sec.", PhD Thesis, Mohamed Khider University of Biskra, 2006.

[18] *M. Hamdani, S.M.A. Bekkouche, T. Benouaz, R.Belarbi, M.K. Cherier*. "The Study Natural Ventilation by Using Buildings Windows: case study in a Hot Dry climate, Ghardaia, Algeria." In: Proceedings of International Conference On Materials And Energy, Tetouan, 2015, and the International Conference On Materials And Energy, La Rochelle, 2016, vol. 139, no. December. 2017, pp. 475-480

[19] *N. FEZZIOUI, B. DRAOUI, C.A Roulet*. "Etude du comportement aéraulique des maisons à ouverture zénithale." In: Proceedings of 1st International Seminar on the Apport of the Simulation in Technological Innovation, Ghardaïa, 2017.

[20] *M. M. Osman, H. Sevinc*. "Adaptation of Climate- Responsive Building Design Strategies and Resilience to Climate Change in the Hot/Arid Region of Khartoum, Sudan." Sustainable Cities and Society, vol. 47, May. 2019, 101429

[21] *A. DJOUIMAA*. "Realisation et verification de la performance thermique d'une tour a vent pour un rafraichissement passif dans les regions chaudes et arides . Cas DE HASSI MESSAOUD." PhD Thesis, Mentouri University of Constantine, 2008.

[22] *H. Sacht, L. Bragança, M. Almeida, and R. Caram*. "Study of Natural Ventilation in wind Tunnels and Influence of the Position of Ventilation Modules and Types of Grids on a Modular Façade System." In: Proceedings of SBE16 Tallinn and Helsinki Conference; Build Green and Renovate Deep, Tallinn and Helsinki, vol. 96, no. Sept. 2016, pp. 953-964.

[23] *C. FLORY-CELINI*. "Modélisation et positionnement de solutions bioclimatiques dans le bâtiment résidentiel existant.", PhD Thesis, University of Lyon 1 Claude Bernard of France, 2008.