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Bioclimatic approach of passive cooling techniques for the design of buildings in southern Algeria

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Abstract – *The bioclimatic approach looks into the opportunities for building conception under the local climatic conditions. The first bioclimatic chart has been developed by Olgyay which combines temperature with relative humidity to characterize the comfort zone. It is founded on outside climate conditions to identify attenuation measures such as solar radiation, wind speed, or shading to reach comfortable inside conditions. Givoni created also a bioclimatic chart founded on inside conditions using the physical and thermal properties of air. Bioclimatic approach strategies contribute to decreasing the building energy loads and increasing thermal comfort for its residents over the year. The principal aim of this research is to evaluate a bioclimatic approach to passive cooling for building design in Algeria's South using Givoni's Bioclimatic chart and Olgyay's Bioclimatic chart. Climate data of various locations (Ouargla, Ghardaia, and El Oued) within this area were collected and analyzed. Furthermore, an overview of appropriated conception strategies for the hot season for each zone is developed. The results show that the maximum average temperature from June to August at around 43.1°C. After applying passive cooling strategies, the temperature indoor can be decreased from about 26.1 to 31.4°C, which can be described as being in the comfort zone for the three studied locations. Finally, these findings can contribute to understanding the thermal behavior of residential buildings and offer guidelines to develop a convenient concept of what the building composition should look like in arid and hot climates.*

***Keywords**: Thermal comfort, passive cooling, bioclimatic approach, bioclimatic chart, hot climates.*

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I. Introduction

In recent years, electricity consumption in Algeria has accelerated with an unexpected increase especially in the commercial, and industrial and residential sectors [1]. It is very important to notice that one of the principal factors for this increase in energy consumption is the use of conventional cooling systems power consumption. Providing thermal comfort in architectural and building design is the subject of many types of researches that clarifies its significance especially in hot climates.

Since ancient times, people have been tried to adapt to their environment by creating new solutions to create suitable climate conditions indoor their dwellings [2]. In hot climates, excessive temperatures are the principal issue that should be taken into consideration in the selection of building passive thermal conception strategies. In these climates, natural ventilation is a significant process to maintain indoor temperature when the outdoor temperature cannot maintain thermal comfort.

The standard bioclimatic tools, which utilized in the building design analysis, are Olgyay's bioclimatic chart [3], and Givoni's psychometric chart [4]. These graphs are founded on dry bulb temperature and relative humidity for a given location according to the ASHRAE comfort zone. Numerous studies have been recorded in the world about the providing of thermal comfort in buildings by using bioclimatic charts of the passive cooling design. In Oman bioclimatic charts have developed for eight locations founded on Typical Meteorological Year (TMY) data [5]. This chart indicates that the high thermal mass parameter can be efficient in four months (March, April, October, and November). The climatic conditions of the Indonesian areas were examined by using the Olgyay's bioclimatic chart and the Givoni's bioclimatic chart [6]. These charts indicated that this climate needed air movement and shading to reduce solar gain entering the building. In the composite zone of India, bioclimatic charts have developed for 21 locations [7]. Results have shown a significant difference in passive conception potential even within the composite area. In Algeria, scientific research which attempts to improve the thermal performance of buildings remains rare and fragmented because thermal quality problems are not taken into account in the design of buildings to achieve thermal comfort.

In the hot climate of Algeria, the thermal behavior of bioclimatic buildings has assessed by applying wind towers [8]. Performance observing and in-site measurement of the system offered data that introduced in model validation. The results have been encouraging and still over the minimum demand of comfort zone in a hot season for a climate such as that of Ouargla. This study confirmed the advantage of the application of this passive cooling strategy in hot and arid climates.

In the hot climate of Adrar - South Algeria, a simulation of a hybrid passive cooling system composing of an Earth-to-Air Heat Exchanger (EAHE) which assisted by a wind tower has been realized [9]. The results have shown that the system can significantly favor natural ventilation and provide a suitable level of inside temperature lower than 32°C.. Other authors [10] have validated this model using both theoretical and experimental data.

Generally, looking through this study, clear comprehension of passive cooling in the bioclimatic charts is developed to improve both thermal performance and indoor comfort in hot climates in southern Algeria. In South Algeria, air conditioning is the most used compared to other electrical appliance. In the hottest three months (June, July, and August), energy consumption exceeds that of the rest 9 months of the year together. A good energy-saving opportunity at low or no additional cost could be offered by using passive cooling techniques.

The added value of this study is founded on providing a bioclimatic approach to evaluate the building conception potential in South Algeria. The recommendations for the bioclimatic design of passive cooling are validated by using the recent fifteen years of climate data (2004-2018) for Ouargla, Ghardaia, and El Oued cities created and made available by the US NOAA's Integrated Surface Database.

II. Methodology

This study tries to develop guidelines of a passive cooling standard for buildings in South Algeria that provides thermal comfort. The Olgyay Bioclimatic chart and Givoni Bioclimatic were used to examine and evaluate the climatic conditions of the selected areas. Generally, the construction passive thermal conception strategies are founded on the local climatic conditions and could be made using bioclimatic charts.

II.1. Case Study and data collection

Recent climatic data supported by (ATM) files for the three cities studied were used in this study. These climatic data were created and made available by the Integrated Surface Database of US NOAA [11].

Figure 1 indicates the locations of the three selected Provinces, and Table 1 presents their geographic location.

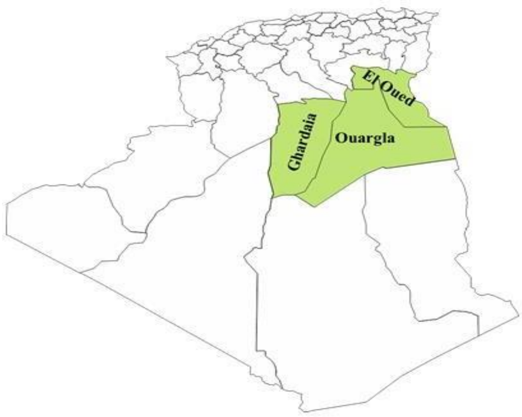

Figure 1. Algerian map showing the studied locations

Table 1. Geographic coordinates of the three provinces

Locations	Latitude	Longitude	Elevation (m)
Ouargla	31°55’N	05°24’E	141
Ghardaia	32°23’N	03°49’E	450
El Oued	33°30’N	06°47’E	69

II.2. Olgyay Bioclimatic Chart

This chart was one of the first chart that combined the relative humidity in abscissa with dry bulb temperatures in ordinate [6, 11]. In this chart, the comfort zone is situated at the center of the graph. Oglyay's chart has a constant comfort zone in the interval from 20 to 30°C. Olgyay bioclimatic chart envelops a wide range of temperature, humidity, wind speed, and solar radiation levels. [12].

II.3. Givoni Bioclimatic Chart

This chart is the most popular among the bioclimatic cards. It is based on the linear relationship between the temperature amplitude and vapor pressure of the external air. Givoni's chart identifies the convenient cooling concept founded on the outside climatic condition [13, 14]. Several specific zones are found on Givoni's chart such as Comfort Zone (CZ), Natural Ventilation (NV), High Mass (HM), High Mass with Night Ventilation (HMV), and Evaporative Cooling (EC) [5].

II.4. Adaptive Thermal Comfort

The ASHRAE adaptive comfort model (by ASHRAE Standard 55-2020) is the most well-known model that paved the way for significant energy saving allowing a wider range of temperatures in naturally ventilated buildings [15]. The relationship between indoor comfort temperature, T_{comf}, and outside temperature, T_{out} is given by the equation Eq. (1):

$$T_{comf} = 0.31 \times T_{out} + 17.8 \tag{1}$$

According to ASHRAE Standard 55-2020, there are two major acceptability limits in this approach:

- 80% acceptability limits = Operative temperature: 22.1 to 29.1 °C
- 90% acceptability limits = Operative temperature: 23.1 to 28.1 °C

The ranges of temperature for 80% and 90% of thermal acceptability are set as ±3.5 ºC and ±2.5 ºC respectively.

III. Results and discussions

Figure 2 shows the monthly minimum and maximum, temperatures in Ouragla, Ghardaia, and El Oued. The thermal amplitude is very important throughout the year; it reaches to 38°C, with the monthly mean minimum and maximum being around 5°C and around 43°C respectively in three locations. Relative humidity has been shown in Figure 3. It ranges between 14% and 86% in three locations. These values are used in section 4 in order to determine the proper passive cooling strategy to be used as shown on Olgyay bioclimatic chart and Givoni bioclimatic chart.

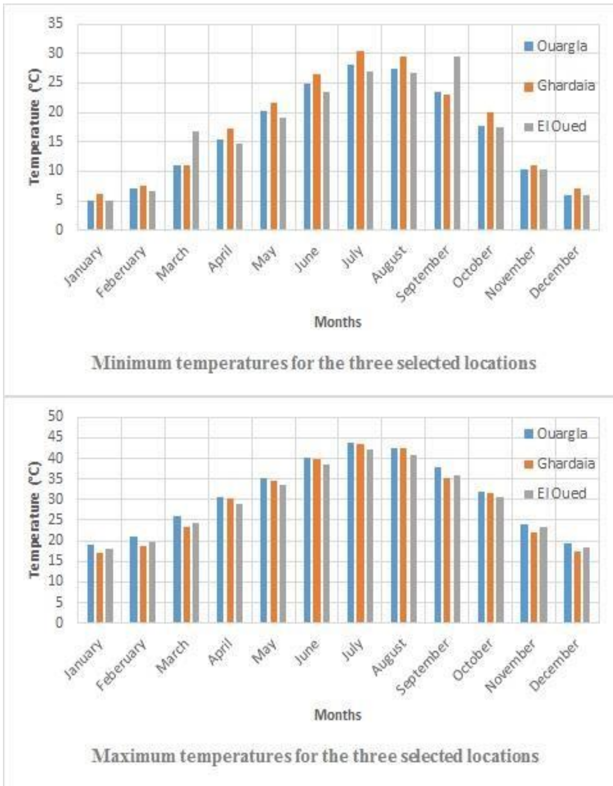

Figure 2. Minimum and maximum temperatures for the three selected locations

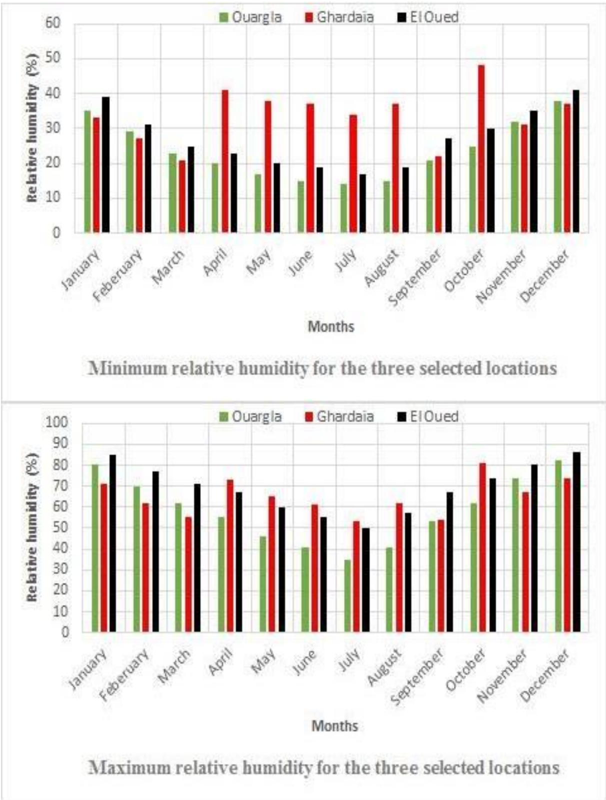

Figure 3. Minimum and maximum relative humidity for the three provinces

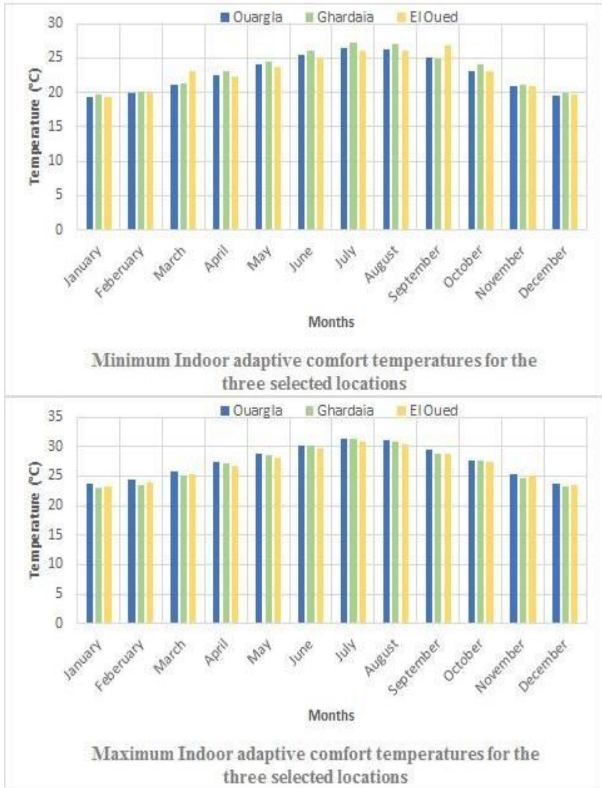

Figure 4. Adaptive indoor comfort temperatures for all three provinces

The adaptive comfort temperature ranges between the minimum and the maximum for each month are calculated for the three zones studied using of course the adaptive ASHRAE model and equation (1). The climate data applied in this study are the means of 15 years (2004–2018) for each area. Figure 4 indicates that all areas have an upper and lower limit for each month.

III.1. Olgyay Bioclimatic Chart for the three selected locations

Figure 5 highlights Olgyay Bioclimatic Charts for Ouargla, Ghardaia, and El Oued. During most of the year, the value of the minimum and the value of the maximum temperature are outside the comfort zone. This indicates the hard climatic conditions such as the high temperature level that due to their geographical position, which passes through the big Sahara of Algeria.

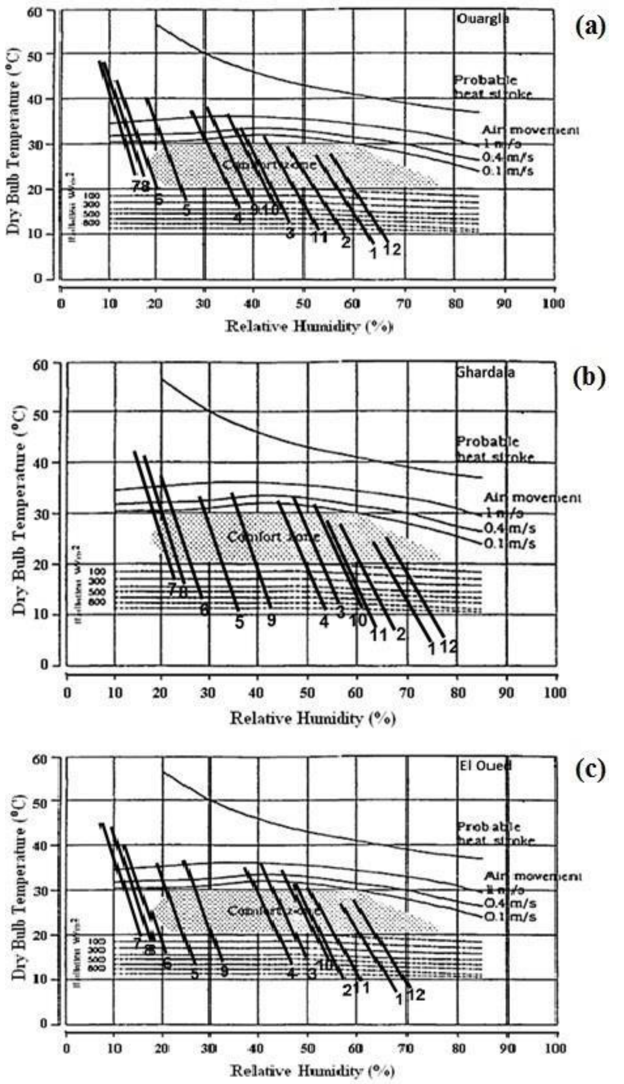

Figure 5. Olgyay Bioclimatic chart of (a) Ouargla, (b) Ghardaia, and (c) El Oued

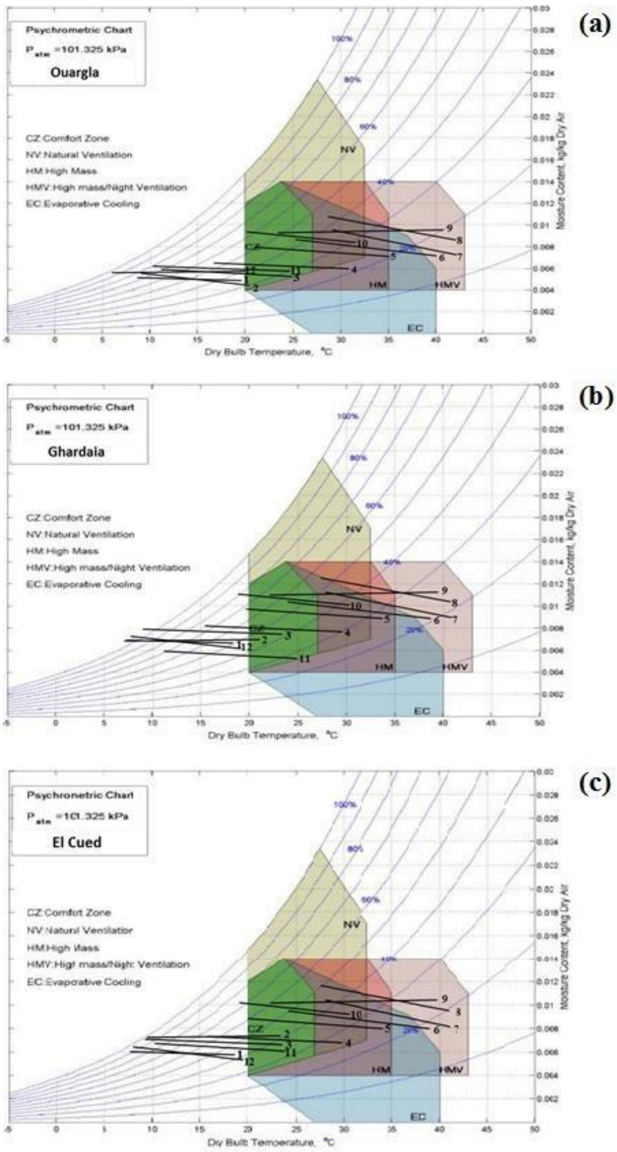

Figure 6. Givoni Bioclimatic chart of (a) Ouargla, (b) Ghardaia, and (c) El Oued

III.2. Givoni Bioclimatic Chart for the three selected locations

From Givoni bioclimatic charts (see Figure 6), the collection of the average monthly points suggest an arid and hot climate type. They show December, January, and February were projected on the comfort zone where solar radiation is sufficient for keeping the thermal comfort.

On the other hand, From June to August are the hottest months in the year are lying outside the comfort zone. In this case, cooling is necessary for maintaining thermal comfort. Similar results are observed for the three select locations Ouragla, Ghardaia, and El Oued.

IV. Conclusion

In this paper, two types of bioclimatic charts have been developed: Olgyay Bioclimatic chart and Givoni Bioclimatic chart using the ASHRAE-55 adaptive model.

The following findings are extracted based on the results obtained from the bioclimatic analysis. In general and according to the Olgyay's Bioclimatic charts, the climate in Ouargla, Ghardaia, and El Oued is particularly arid and warm throughout the year except for December and January. Moreover, making a shading device is also recommended to reduce solar radiation entering the buildings. The Givoni Bioclimatic charts indicate almost the same findings as the Olgyay charts. A requirement for natural ventilation is also suggested because of the intense heat, and making a shading device is required due to the high solar radiation intensity especially in the summer season where the day length becomes longer. The findings show that the maximum average temperature from June to August at around 43.1°C. After applying passive cooling strategies, the temperature inside can be decreased from about 26.1 to 31.4°C, representing the comfort zone for the three studied locations.

Finally, it will be better to take into consideration the comfort zones in the architectural conception of buildings and designing of cooling and heating installation systems in arid and hot climates of Algeria in order to minimize additional charges of energy supply.

References

[1] Energy and mine ministry, APRUE National Agency for Promotion and Rationalization of the use of energy, edition 2009.

[2] B. Hebbal, Y. Marif, M.M. Belhadj, “Bioclimatic architecture in the ancient villages of southern Algeria”, ICREE2019, Springer Proceedings in Energy. Springer Nature Singapore Pte Ltd. 2020.

[3] V. Olgyay, “Design with Climate, Bioclimatic Approach, and Architectural Regionalism”, New Jersey: Princeton University Press, 1963.

[4] B. Givoni, “Comfort, climate analysis and building design guidelines”, Energy and Buildings Vol. 18, 1992, pp. 11-23.

[5] N. Al-Azri, YH. Zurigat, N. Al-Rawahi, “Selection and Assessment of Passive Cooling Techniques for Residential Buildings in Oman Using a Bioclimatic Approach”, Journal of Engineering Research [TJER], Vol. 10, 2013, pp. 52-68.

[6] S. Santy, H. Matsumoto, K. Tsuzuki, L. Susanti, “Bioclimatic Analysis in Pre-Design Stage of Passive House in Indonesia”, Buildings Vol. 7, 2017, pp. 24.

[7] N.K. Khambadkone, R. Jain, “A bioclimatic approach to develop spatial zoning maps for comfort, passive heating and cooling strategies within a composite zone of India”, Building and Environment, Vol. 128, 2018, pp. 190–215.

[8] Bouchahm, F. Bourbia, A. Belhamri, “Performance analysis and improvement of the use of wind tower in hot dry climate”, Renewable Energy, Vol. 36, 2011, pp. 898-906.

[9] M. Benhammou, B. Draoui, M. Zerrouki, Y. Marif, “Performance analysis of an earth-to-air heat exchanger assisted by a wind tower for passive cooling of buildings in arid and hot climate”, Energy Conversion and Management, Vol. 91, 2015, pp. 1–11.

[10] M. Benhammou, B. Draoui, M. Hamouda, “Improvement of the summer cooling induced by an earth-to-air heat exchanger integrated in a residential building under hot and arid climate”, Applied Energy, Vol. 208, 2017, pp. 428–445.

[11] Repository of free climate data for building performance simulation, 2020. http://climate.onebuilding.org

[12] H.A. Mahmoud, “An analysis of bioclimatic zones and implications for design of outdoor built environments in Egypt”, Building and Environment Vol. 46, 2011, pp. 605-620.

[13] S. Bodach, “Developing Bioclimatic Zones and Passive Solar Design Strategies for Nepal”, The 30th PLEA Conference - Sustainable habitat for developing societies, 2014.

[14] N.K. Khambadkone, R. Jain. R, “A bioclimatic analysis tool for investigation of the potential of passive cooling and heating strategies in a composite Indian climate”, Building and Environment, Vol. 123, 2017, pp. 469- 493

[15] Gh.R. Roshan, M. Farrokhzad, S. Attia, “Defining thermal comfort boundaries for heating and cooling demand estimation in Iran's urban settlements”, Building and Environment, Vol. 121, 2017, pp. 168-189.

[16] F. Tartarini, S. Schiavon, T. Cheung, T. Hoyt, “CBE Thermal Comfort Tool: Online tool for thermal comfort calculations and visualizations”, Software X, Vol. 12, 2020, pp. 100563.