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Investigation on the thermal comfort of a vernacular dwelling in hot and arid climate.

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***Abstract*— The problem of excessive energy consumption in building sector has now become one of the major challenges of constructive strategies. Although hot and arid contexts are the most affected by temperature fluctuations in summer, so the search for other economic and ecological alternatives is a prerequisite. This article presents an analysis of the thermal comfort of a vernacular dwelling in warm context, with the aim to proving its thermal performance without recourse to air-conditioning modern systems. The method is based on in situ measurements on the hottest summer day of the year 2019 using an Anemometer measuring the three factors: ambient temperature, relative humidity and air velocity, on a sample of vernacular dwelling constructed of local materials (the sand and gypsum rose), accompanied with a numerical simulation with energy plus 9.1 software. The results obtained show that the dwelling is capable of guaranteeing an acceptable level of comfort within the living spaces with a difference of 8.9C°, between the inside and the outside, especially during the period of overheating. This work forms a reference to promote local ecological architecture through the investment of vernacular thermal potentialities and local materials.**

***Keywords*— Vernacular architecture, thermal comfort, climate, local materials, thermal resistance.**

I. INTRODUCTION

The development of towns in southern Algeria, was like the northern cities, thus marginalizing the very harsh climatic characteristics of these regions. From this habitat type derived from the integration issues involving climate consume considerable energy for the thermal comfort. Figure01. This problem is mainly related to the excessive use of electric heating and air-conditioning system, caused by neglect of climatic peculiarities in the architectural process. For this reason, the research for new ecological, comfortable and economical construction alternatives is a necessity. In the South of Algeria, as the population grows, the Saharan city spreads out and expands, it renews itself profoundly in its forms and constructive typologies, in fact traditional materials give way to cinderblocks, and local architecture is marginalized in favour of standardized constructions. This type of construction seems indifferent to the environment in which it is inserted and obviously gives the impression of a graft to a specific environment, as a consequence the city in the desert has lost its bioclimatic qualities and it only works through the use of thousands of air conditioners. Following this observation, the study of vernacular architectural experiences in order to understand the tools of climate adaptation, offers us the opportunity to draw a sum of information for the promotion of effective local architecture. [2]. The present work analyses the thermal comfort of a vernacular dwelling in the Souf region, which is part of the lower Algerian Sahara, in terms of its distinct architectural typology built in vaults and domes, as well as the original traditional materials: sand rose stone and gypsum. The investigation is done by an experimental approach presented by in situ measurements and dynamic simulation with energy plus software. All the results obtained prove the effectiveness of passive vernacular techniques in reducing temperature fluctuations inside spaces and guaranteeing acceptable comfort in the hot season without total or partial recourse to mechanized air conditioning system.

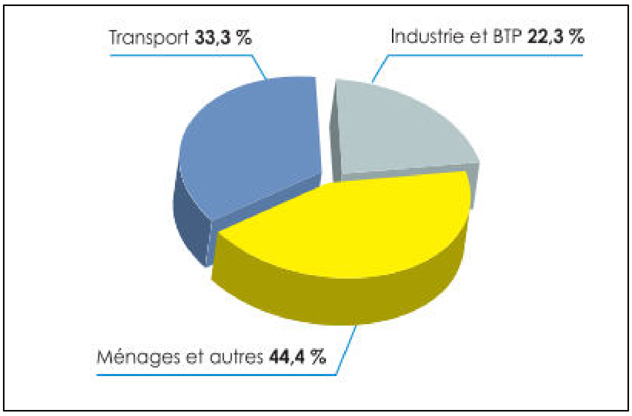

Fig. 01: Energy consumption rate by sector. [1].

- *Method and technique:*

The method followed is essentially based on an experimental approach, starting with a prior knowledge of the general climatic context of the region in order to locate the critical period of the warm season. This task is done using the climate consultant.06. [3]. experimentation is presented by a measurement campaign using an anemometer measuring the three factors: indoor temperature, relative humidity and air speed. [4], in the months of July and January of the year 2019 on an individual dwelling of vernacular typology. Followed by dynamic modeling and simulation with energy plus software.

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II. PRESENTATION OF THE REGION:

A. *Location and Geographical Coordinates*:

The study area is part of the lower Algerian Sahara, located in the South-East, on the northern borders of the Eastern Erg. Bordered to the North by the Melghir and Merouane chotts, to the South by the extension of the Grand Erg Oriental, to the West by the immense oasis of Oued Righ and to the East by the Tunisian borders. [7]. Figure.2.

Geographical coordinates:

Attitude of: 33.35° North, Longitude: 6.86° East. Altitude above sea level: 84m. [8].

B. *Architectural typology:*

The city with a thousand and one thousand domes was the name given by the writer: *Isabelle Eberhard* to the region of El Oued Souf during her tourist visit to the lower Algerian Sahara. [9]. This name reflects the specific architectural typology that characterizes the region to other Saharan cities, all the houses are covered by domes and hemispherical vaults.

Fig. 2. Geographic situation of the region.

C. *Climatic Context and Psychometric Diagram:*

The study region is characterized by a dry climate of the Saharan desert type, it is part of the zone pre-Saharan (E3) with: dry atmosphere, high temperature, lack of bad weather and violent sand winds. [10]. Summers are scorching, arid and clear and winters are chilly, dry and clear on the whole. Temperatures generally range from 5°C to 45°C throughout the year. Fig.3. Metrological data show that: The very hot season lasts 3 months, with a maximum average temperature of 45 °C and a minimum of 27 °C. While the cool season extends from November to March, with a minimum average temperature of 5 °C and a maximum of 16 °C. In fact the region is exposed to a movement of active winds almost all year round, the most violent is the very hot and dry Sirocco, and it blows from the south side and causes very important damages (drying out, dehydration). [11]. Figure.3. The psychometric diagram and the data for the maximum and minimum temperature as well as the comfort zone according to the ASHRAE Handbook standard are carried out using the energy plus tool: climate consultant [3].Fig.4.

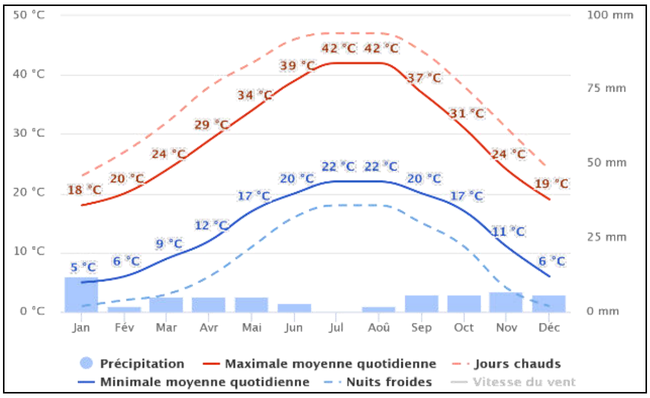

Fig. 3. Climatic data. [11].

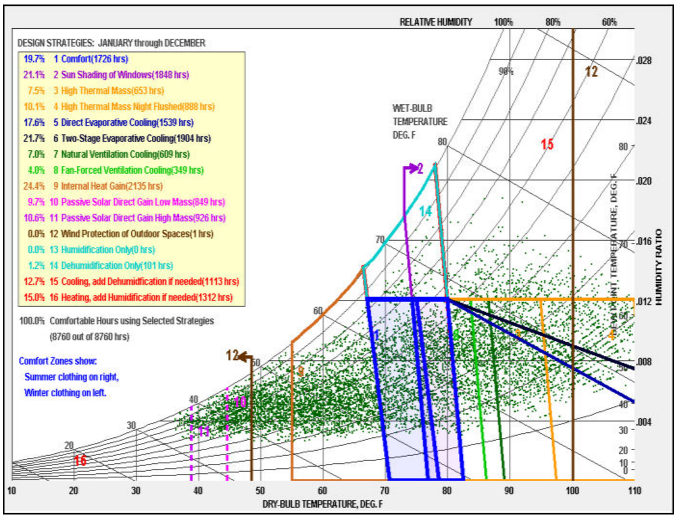

Fig. 4. Psychometric diagram of the region. [2].

III. EXPERIMENTAL INVESTIGATION:

A. *Measurements in situ:*

* Presentation of the sample:

The Vernacular Housing Sample was chosen from the ancient district (*Taghzout*). This dwelling is limited to a single level consisting of three bedrooms and the space called Sabbath, kitchen and bathroom, all organized around a large central courtyard covered with sand, the roof is in the form of elongated vaults pierced by air vents. The walls are built with sand rose stone and gypsum mortar with a thickness of about 50 cm, plastered with gypsum plaster. The measurements were taken in the living room, which faces south-west.

Fig. 04. View of the housing sample.

*The building materials: Given the nature of the soil and subsoil which excludes the use of wood, stone and clay, only the local materials are fully exploited: sand rose stone (*Louss*) and gypsum stone (*Tafza*). [13]. The first is a very hard gypsum concretion, which in free form gives sand roses, but in continuous sedimentation gives a resistant slab, this material constitutes the building stones of the walls and bases as well as the vaults and domes of the roofs. Figure.5. The second one is a lighter crust which, once baked, gives a good plaster, once dried it constitutes a very resistant binder. Found buried under the sand in the form of slabs in the northern part of the region, this stone is removed and then burned in incinerators and then beaten with a kind of pestle to them a powder, used as a binder between the stones. Fig.5.

Fig. 05. Local materials used in construction.

*Description of the instrument:
The instrument used is an anemometer of type Amprobe TMA5 with one capacitive humidity sensor and one precision thermistor sensor, and an external temperature sensor for measuring wall and floor temperatures. It also includes a fan to measure air velocity. Fig. 6.

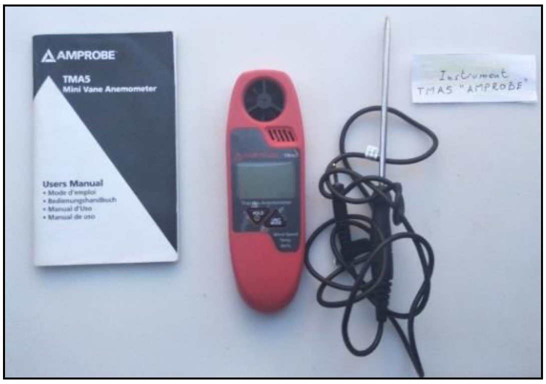

Fig. 04. View of the housing sample.

Specifications: [14]
Air Temperature Range: 0*°C to 50°C (32°F to 122°F)*
Humidity Range: 5*%RH to 95% RH*
Wind Speed Range: *0.5 - 44.7 MPH, 60 - 3937 FT/M, 0.4-38.8KNT, 1.1-20.0 M/S, 0.7-72.0KMH, 1-8 BF.*
*Procedure: the measurements were started from 6:00 h until 22:00 h with an interval of one hour between measurements, the instrument is placed at height of 1.40 m below the ceiling [15] in the center of the room and facing the door. Fig.04.

C. **Simulation with energy plus:**
The version used for the simulation is: energy plus 9.1.
The version used for the simulation is: Energy plus 9.1.
Insertion of data related to:
Geographic coordinate.
Climate data from metronome.
Data on the thermal properties of building materials. **Table.1.**
Vertex modeling of the dwelling.

	Material	*Thermal Conductivity W/ (m.K).*	*Thickness (cm)*	*Thermal Resistance (m².K)/W.*
Exterior wall	Sand pink	0.89	50	0.57
	Gypsum	0.4	5	0.25
Total Thermal Resistance: 0.82 (m².K)/W.				

Table.1. Thermal resistance of the exterior wall.

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IV. RESULTS AND DISCUSSION:

The data required for the investigation is processed by origin in the form of a graph: Figure.07. 08

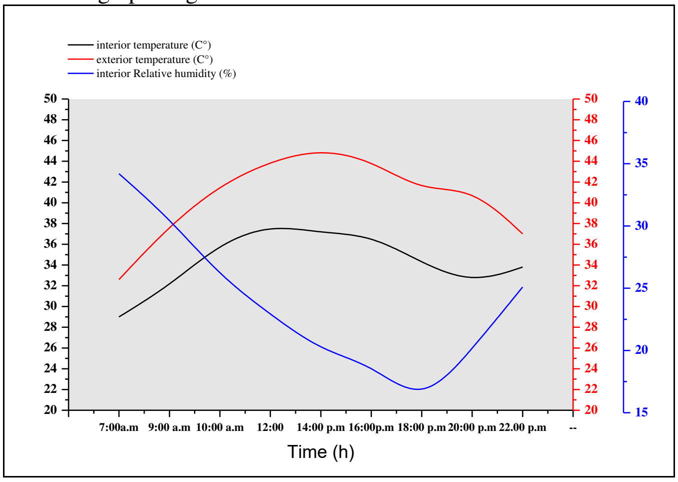

Fig. 08. Measurement of internal and external temperature and relative humidity. Room July 2019. (Vernacular housing).

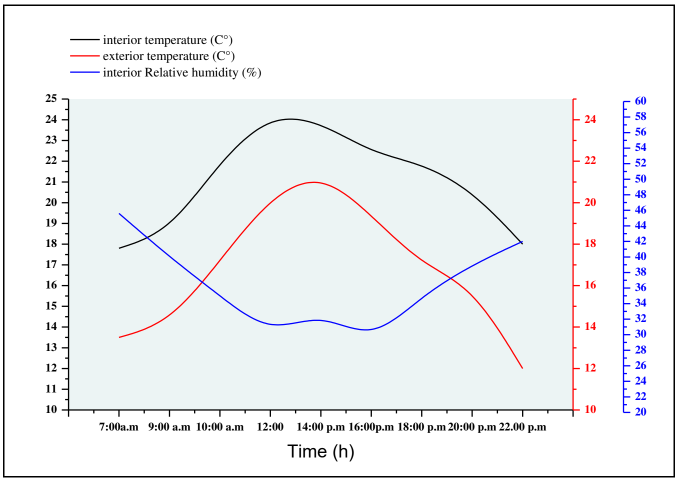

Fig. 09. Measurement of internal and external temperature and interior relative humidity. Room February 2019. (Vernacular housing).

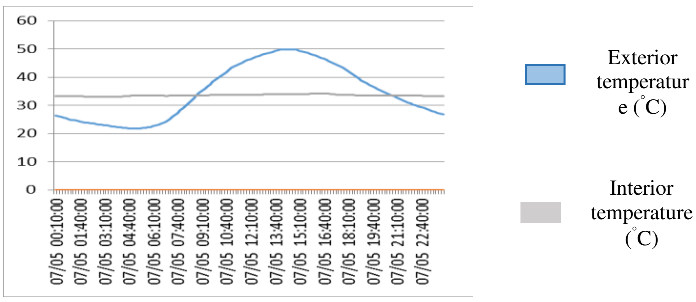

Fig . 10 . Simulation of the summer day (july 2019).

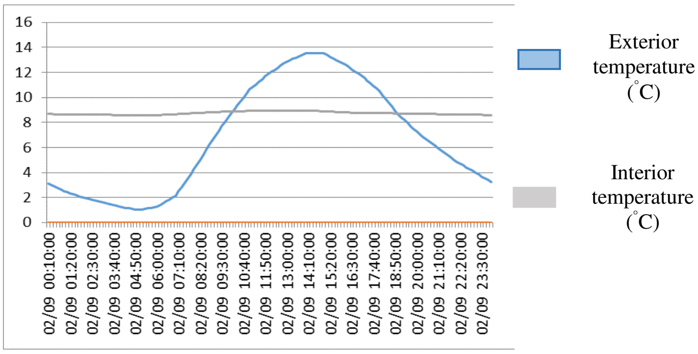

Fig. 11. Simulation of winter day. (February 2019).

Measurement in summer:

The diagram in the figure shows the evolution of the inside and outside temperature from 6:00h to 22:00h, it can be seen that the temperature inside the chamber rises but always remains between 5C° and 7C° away from the fluctuations of the outside temperatures. It should be noted that during the measurements no mechanical cooling system has been activated, the doors and windows are open.In relation to the humidity values and air speed inside the chamber, the maximum humidity level was recorded at night and in the early morning hours due to the accumulation of energy dissipated through the walls. This increase gradually decreases with a maximum air speed of 0.2 m/s.

Measurement in winter:

The measurements on the graph show that the room has a comfortable temperature of 20 to 24 C° maximum, without heating, with an air velocity of 0.3 m/s.

We can refer this positive behaviour of the chamber to two main factors: the first is related to the shape of the roof, in the figure, the roof is formed in 2 domes of 1.5 m diameter, in summer the dome serves to store the hot air that accumulates at the top of the room by pressure difference and evacuate it through small openings at the ends, which gives a coolness to the space. The warm air rises and is stored at the top and is then transported through the openings at the ends, which favours a regular renewal of air inside the chambers. [19].

The second factor is related to the thermal characteristics of the local materials that make up the exterior walls, although all the walls are composed of rose stone sand and gypsum mortar, with good thermal resistance table. 01. During the hot season the walls insulate the interior from outside and maintain a coolness inside fat to its significant thickness, in winters serving to store heat throughout the day and dissipate it at night.

This result is in line with opinion of Givoni , which has shown that in a massive construction, well insulated and protected from solar radiation, the variation of the inside temperature normally represents 10 to 20% of the amplitude of the outside temperature. [4].

Compared to the simulation with energy plus:

The diagrams on the figures show an agreement between the results of the investigation and the dynamic simulation by the software energy plus, the temperature inside the room remains within a comfort limit and only in summer is so in winter:

these results the performance of the vernacular unit, due to its design and insulation as well as the thermal characteristics of the materials, it is able to guarantee an acceptable comfort in hot or cold seasons without total recourse to mechanical heating or cooling systems

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V. CONCLUSION:

For a long time, populations exposed to extreme climatic conditions, particularly in hot and arid contexts, have tried to invent architectural devices adapted to the environment. This is manifested through intelligent vernacular architecture in terms of architectural design and ancestral building techniques. [20]. based on natural energies, which allow inhabitants to enjoy comfortable living conditions inside their homes, thanks to a good understanding of the environment and successful adaptation to its constraints.

Nevertheless, the construction that makes up the Saharan city today seems to be turning its back on the principles developed over the centuries. Marc Cote reminds us that "*there is a statistical break in the pace of urbanization and architecture in the Sahara: the 20th century has introduced something radically new*". [12].

The materials and the architectural design currently applied do not take account of the harsh climate of the region. Nevertheless, it seems to us that the time has come for the Saharan city to make a qualitative leap forward after having lived through the years spent between expectation and the right quantity.

Through this example, we can see that the vernacular dwelling is capable of guaranteeing an acceptable level of comfort, particularly during the critical period of overheating, without the use of air conditioning tools. These results form a reference to develop an economic and ecological conceptual model, based on the thermal efficiency of local materials.

This result forms a basis for developing a comfortable and energy-efficient housing model based on materials with high thermal inertia and a design that complies with the climatic constraints of the region.

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REFERENCE:

[1]. Bilan énergétique national par secteur. www.energy.gov.dz.

[2]. Willi Weber, Simos Yannas. 2014. Lessons from vernacular Architecture. Routledge. pp 09, 177. 2014.

[3].Climate consultant, ASHRAE Handbook of Fundamentals Comfort Model, 2005.

[4]. Givoni B, L'homme, l'architecture et le climat, Edition de Moniteur, pp.21

[5].Méthodes de mesure de la conductivité thermique. www.thermoconcept-sarl.com.

[6]. Chelghoum Z et Belhamri A. 2011. Analyse des propriétés thermiques des matériaux de constructions utilises dans la ville de Tamanrasset, Université Mentouri Constantine, Algérie. Sciences et Technologie D – N°33, (Juin), pp. 47-56.

[7]. Bataillon Claude. Le Souf étude de géographie humaine. Mémoire n° 2, Alger : institut de recherche saharienne, 140p. 1955.

[8]. Organisme Technique de Mise en valeur des Richesse du sous-sol Saharienne. Présentation du Souf. Le Porodon-Hydra. Alger. pp.02.

[9]. André voisin, le Souf monographie d'une région saharienne, El Walid, pp113-117. 1985.

[10]. Règlement thermique des bâtiments thermique, DTR c3-2, règles de calcul des déperditions thermiques, fascicule1, Annex 03.

[11]. Office national de métrologie

[12]. Cote Marc. La ville et le désert : le bas Sahara algérien, Karthala et Ireman, Paris. pp.141-143. 2005.

[13]. Jean Brunhes. Les Oasis du Souf et du M'zab comme types d'établissements humain. In : Bulletin de la société des géographes, tome V, one Semestre, Masson ET Cie éditeurs. Paris. pp.7-14. 1902.

[14]. User manuel,

[15]. Amar Bennadji. Adaptation climatique ou culturelle en zones arides : cas du Sud-Est Algérien. Université de Provence - Aix-Marseille I. p 113-121-131. 1999.

[16].Gina Penu. La thermique du bâtiment, en 36 fiches outils. Dunot, Paris, 2013.

[17]. (Hyde R. Bioclimatic housing: innovative designs for warm climates. London: Earthscan. 2008 .

[18]. Cote Marc. Si le Souf m'était conté, commet se fait et se défait un paysage, Media plus. Constantine, pp07, 10, 31. 2006.

[19]. Hassn Fathi . Natural energy and vernacular architecture. Principals and examples with references to hot and climates. The univercity of chicago press. Ed chicago. P15-19. 1986.

[20] Liébrard A. De herde A. Traité d'architecture et d'urbanisme bioclimatique. Concevoir, édifier et aménager avec le développement durable. Le moniteur. pp181. 2005.

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