

# *The Impact of Envelope Building Materials On The Thermal Comfort .Case of hot and dry climate*

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**Abstract—** Envelope Building materials play an important role in the architecture by providing the protection requirements, comfort, and technical performance while promoting an architectural language and an image. The impact of the building materials varies according to their physical, chemical, mechanical and thermal properties; Also, their interaction with the environmental factors: heat, humidity ... etc. Therefore choosing the right building materials is a key factor in achieving a certain level of comfort inside the building witch effect directly the energy use and consumption. In this study, we investigate the impact and the thermal behavior of different envelope materials, the most used materials; traditional and modern under the climatic conditions of Biskra a hot and arid climate. Also, we analyzed the results of a different simulation using “ecotect5.0” to performed thermal analysis and we used “opaque3.0” and “u-wert” to figure some envelope materials proprieties in order to choose the best material that ensures thermal comfort inside the building. The results show that choosing local massive materials and thermal insulation can achieve that to a certain degree.

**Keywords—** *Envelope, Building Materials, Thermal comfort, energy consumption, passive strategy, Hot and Dry Climate.*

## I. INTRODUCTION

Making a shelter was one of the first human's activities to provide the protection from danger and aggressive environmental situations after that, he started to look for making it more comfortable so he started to develop out building according to the environment weather conditions and local existing materials. according to Hassan Fathy [1] « *in every environment there is what resists its problems of materials and the intelligence of the architect is in dealing with the materials that are under his feet because they are the materials that resist the harsh environment of the place* », therefore accomplishing comfort specially thermal comfort basing on materials choices it was naturally practiced since the beginning as a passive strategy. However Throughout the years and with the industrials revolution new materials has been discovered and used then the focus has shifted to the image and aesthetic of the building, with that comes the problem of achieving thermal comfort passively, however with

the technological development it become possible to achieve it with the technology and active systems HVAC (heating, ventilation and air conditioning). the consequences of this massive depend appeared after the first oil crisis of 1973, which showed the fragility of the systems that depend totally on fossil fuels, as a result, it appeared a global necessity to the management of natural sources, fossils energies [2]. Thus make a global energy problem of over consuming energies. Building sector has a substantial share of the primary energy supply being a major contributor to conventional fuels consumption, thus creating a significant environmental burden through materials production and global warming gas releases. Buildings account for about 40 % of the global energy use [3]; this large consumption comes from the needs to achieve thermal comfort inside the building using HVAC systems. Nowadays there is a great deal of interest in passive climate control systems, because of high energy costs and the impracticality of HVAC systems. These passive methods provide a good microclimate and are designed to regulate heat gain and loss and to improve air circulation. Construction materials and their coverings, affect both the indoor thermal environment and the potential to save energy [4]. Therefore the question of this research is how to achieve thermal comfort in a hot climate by making the wright choose of envelope materials that resist and work well with this type of climate conditions.

## II. THE THEORETICAL CONTEXT OF THE STUDY

### A. Thermal comfort in the building:

Thermal comfort is an essential requirement for the quality of the built spaces. It is an interaction between the occupant, the building and the outside environment. Thermal comfort is a fundamental target for the quality of the ambiances and the well-being of users. It is commonly defined as a state of satisfaction by the thermal environment. Givoni defines it as the absence of discomfort due to heat or cold or as a state of thermal well-being [5]. Thermal comfort is a complex concept and Intervene in several physicals, physiological and even psychological factors. In his physical sense, it corresponds to a balance between the gains made by the human body and its

heat loss [6]. It depends on six aspects: activity and metabolism, clothing, air temperature, relative humidity, surface temperature, and air velocity.

### B. Building materials and thermal comfort

Choosing building materials is essential solutions and can guarantee to maintain the comfortable conditions inside the building in all seasons [7]. In another word choosing building envelope materials is a passive strategy. In [5] Givoni points out that the envelope of a building is not only a separator from the external environment but also is a prevention for climatic elements to affect the building directly. Three types of building materials can be used to build this envelope which is: opaque, transparent and translucent. He further points out that heat may enter the buildings firstly, through transparent and translucent materials and open windows secondly, through the modifying influence of the rest of the building materials. The internal thermal comfort conditions that may be affected both directly and dependent on the properties of the materials by the external temperature and humidity. [8].

#### B.1. Thermal characteristics of building materials

To ensure a good thermal quality of an indoor environment without the use of the technologies, we can intervene on the thermal performance of envelope materials to ensure; the thermal inertia of the building and the insulation of the envelope materials which receive differently the radiation according to their degree of transparency or opacity, their color or surface texture. These thermal characteristics will be taken into the design of the walls of a bioclimatic building, whose mission will be first depending on the case to capture, store, transmit and/or conserve calories. These thermal characteristics of the materials are of two kinds: Static characteristics: conductivity and thermal capacity; and Dynamic characteristics: diffusivity and effusivity. [9].

#### B.2. Heat transfer modes:

In a building, there are many different types of energy transport. Often, heat is transported by different modes to or from the same place. The energy that reaches a point via different paths and modes may be added up for the heat balance. For instance, the heat loss of a human body is the sum of convection, radiation, and latent heat released by sweating and so forth. Primary heat transport modes are: conduction, convection and radiation [9].

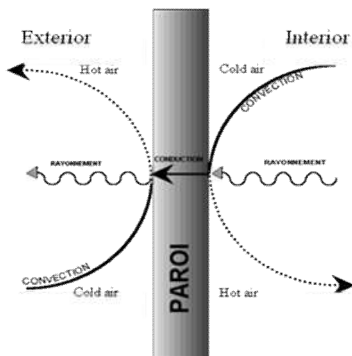


Fig. 1. Heat transfer modes

#### B.3. Thermal inertia:

According to Liebard, “thermal inertia is the accumulation of heat and its restitution, with a phase shift depending on the physical, dimensional and environmental characteristics of the wall of storage”. The speed of storage or removal of heat is determined by two other quantities which are diffusivity and effusivity. [9]. The thermal inertia of buildings can help to reduce energy consumption, improve comfort, and even replace HVAC systems. This thermal inertia is usually associated with heavy wall construction, but the truth is there are other parameters that can have a significant effect on this property. [4].

#### B.4. Thermal isolation:

Thermal insulation is the property of a building material to reduce heat transfer between two ambiances. It allows to reduce consumption of heating or cooling energy (limits losses in winter and heat supply in summer) and to increase comfort (maintaining temperatures and hygrometry at summer comfort levels like winter and solves the problem of cold walls in winter or hot in summer). [9].

### III. THE CLIMATIC CONTEXT OF THE STUDY: THE CITY OF BISKRA

The city of Biskra is a Saharan city which has a high rate of solar radiation, it is located in the south-east of Algeria; It is characterized by a cold winter and a hot dry summer. The geographical features of the city: The latitude = 34.48 North, the longitude = 5.44 North, the altitude which is equal to 83 meter above sea level.

The city of Biskra is characterized by a maximum temperature in summer which reaches in the month of July 45 and a minimum temperature in winter that reaches 5 ° C during the month of January. With a rare level of precipitation (less than 30 days per year) The average relative humidity is low around 47%, with a maximum value of 65% in the month of December, and a minimum of 28.29% in July and August.



Fig. 2. Location Map the city of Biskra

#### IV. METHODOLOGY :THE EMPIRICAL STUDY

TABLE I. ANNUAL TEMPERATURES LEVEL IN BISKRA

Month	J	F	M	A	M	J	J	A	S	O	N	D
Average T (c°)	12	13	18	22	27	32	37	35	29	25	18	13
Average Max T (c°)	20	24	24	32	36	41	45	46	43	36	28	20
Average Min T (c°)	8.4	5.2	9.1	10	12	25	30	28	20	14	8	5

TABLE II. ANNUAL AVERAGE RELATIVE HUMIDITY

Month	J	F	M	A	M	J	J	A	S	O	N	D
RH %	60	62	44	36	34	29	28	29	41	41	59	65

TABLE III. AVERAGE MONTHLY RAINFALL OF BISKRA

Month	J	F	M	A	M	J	J	A	S	O	N	D
P(mm)	53	29	1	13	11	0.2	0	0.7	16	9	28	10

TABLE IV. MONTHLY MEAN WIND SPEEDS OF BISKRA.MONTHLY RAINFALL OF BISKRA

Month	J	F	M	A	M	J	J	A	S	O	N	D
W(m/s)	4.2	4.2	5.6	5	4.3	5.3	4	4.2	4.2	3.4	3.2	4

According to Givoni, in order to ensure thermal comfort in a hot arid climate, buildings must be adapted to summer conditions and this assuming that winter requirements will be met accordingly [5].therefore the main challenge is to limit the discomfort due to the large variations in temperatures in buildings in summer, without the need of air conditioning In winter, it consists of reducing heating consumption by the storage of free solar gains transmitted by walls and windows. [8]. the comfort zone was defined using the psychometric chart and based on the environmental parameter of thermal comfort (interior air temperature and relative humidity) in the hot and dry climate of Biskra comfort zone in the summer and winter periods.

According to ASHRAE 55, the acceptable thermal comfort range for a PMV is between -1 and +1 and -3, -2, +2 or +3 are unsatisfied and the PPD is less than 20%.

TABLE V. THERMAL COMFORT ZONE ACCORDING TO GIVONI'S CHART

Parameter	Summer Period	Winter Period
Interior air Temperature °C	23-26	20-24
Relative Humidity %	40-60	40-60

The evaluation of thermal comfort in this study was conducted by numerical simulation using the software of "Ecotect 5.0" and "U-Wert".

Thermal Simulation makes it possible to analyze the phenomena that develop simultaneously through the envelope, influencing the interior environment, In this research, we analyzed the thermal behavior of different wall compositions to investigate the thermal impact of building materials; also the research was limited to the opaque parts of the envelope (walls/roofs/insulation).

##### A. Case of study

We compared between different thermal characteristics of traditional materials and modern materials after that we studied different walls compositions (the most common) so we set as variables: the composition of the wall, the thickness, and the insulation level.

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##### A.1.Local traditional materials

We compare different Characteristics of the most used traditional building materials in Biskra.

TABLE VI. CHARACTERISTICS OF ENVELOPE LOCAL TRADITIONAL MATERIALS AND WALL.

Materials	Dancité D (Kg/m3)	specific heat (j /KG.K)	conductivity $\lambda$ (W/m.k)	Thickness T (cm)
<i>Envelope walls</i>				
Soft limestone	1650-1840	828	1.05	/
Toub (clay)	1700-2000	936	1.15	40-50
<i>Insulation</i>				
Branch Palm /straw	120	612	0.05	/
Earth	1700-2000	936	1.15	/

Wall composition: Bearing wall en clay / earth **Thickness 50 cm (case 1)**

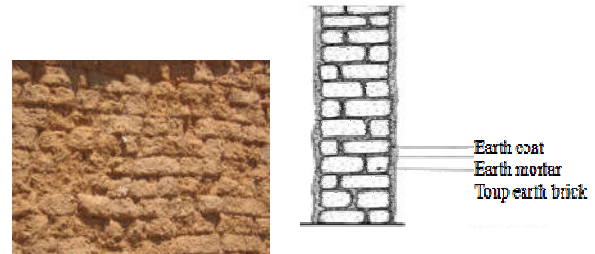
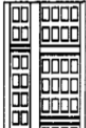
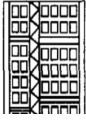
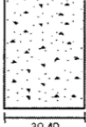


Fig. 3. Traditional wall composition

## A.2. Modern current used materials

We compared different Characteristics of the most used traditional building materials in Biskra.

TABLE VII. CHARACTERISTICS OF ENVELOPE MODERN CURRENT MATERIALS AND WALLS.

Materials	Dancité D (Kg/m3)	specific heat (j/KG.K)	conductivity $\lambda$ (W/m.k)	Thicknes s T (cm)
<i>Envelope</i>				
<b>Cement brick</b>	1200-1400	800	0.56	10
<b>Cement mortar</b>	1900	1000	0.80	0.2
<b>Plaster mortar</b>	1150	1008	0.57	0.2
<b>Cinderblock (parping)</b>	975	1080	0.95	20
<b>Reinforced concrete</b>	2500	1080	1.75	10
<b>Hollow brick</b>	1200	260	0.39	10-15
<i>Insulation</i>				
<b>Air</b>	1	1000	0.047	05
<b>polystyrene</b>	16-20	1450	0.038	05
<i>Wall composition</i>				
<u>Walls of hollow brick :</u>				
<b>Case 2:</b> (brick 15cm+air 5cm + 10cm brick)				
<b>Case 3:</b> (brick 15cm+ polystyrene 5cm + 10cm brick)				
<b>Case 4 :</b> concrete bearing wall 40cm				

### B. The simulations:

In this research, we have used the « Ecotect 5.0 » for thermal analysis to measure the internal and the external temperature in different wall compositions (the data was added through a climatic data file of the city of Biskra) Also “u-wert” and “opaque5.0” were used to determine some materials properties and wall compositions.

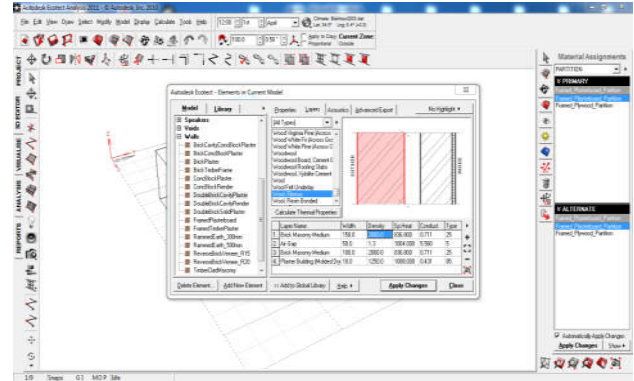


Fig. 4. The used software interface “Ecotect 5.0”.

## V. RESULTS AND DISCUSSION

We have conducted a thermal simulation of 4 wall composition to determine the best choice of materials and witch composition performed thermally better in the condition of hot and dry climate of Biskra so we measured the interior and the exterior ambience temperature in two different months the month with highest average Temperature T° (July) and the one with the lowest (December) in different time in the day using thermal simulation software.

R: Resistance ( $m^2.K. / W$ )

U: thermal transmittance ( $w / m^2.K.$ )

**Case 1:** Bearing wall en clay 50 cm, R=1.07 ( $m^2.K. / W$ ) , U= 0.93 ( $w / m^2.K.$ )

**Case 2:** Hollow brick 15cm+air 5cm + 10cm hollow brick, R=0.91 ( $m^2.K. / W$ ) , U= 1.09 ( $w / m^2.K.$ )

**Case 3:** Hollow brick 15cm+ polystyrene 5cm + 10cm hollow brick, R=1.52 ( $m^2.K. / W$ ) , U= 0.66 ( $w / m^2.K.$ )

**Case 4:** Bearing wall en concrete 30cm, R=0.38 ( $m^2.K. / W$ ) U= 2.60 ( $w / m^2.K.$ )

A. The thermal impact of traditional and modern materials on interior Temperature T° ‘comparaison between case 1 with case 4’:

-Temperature evaluation of case 1&4 in December

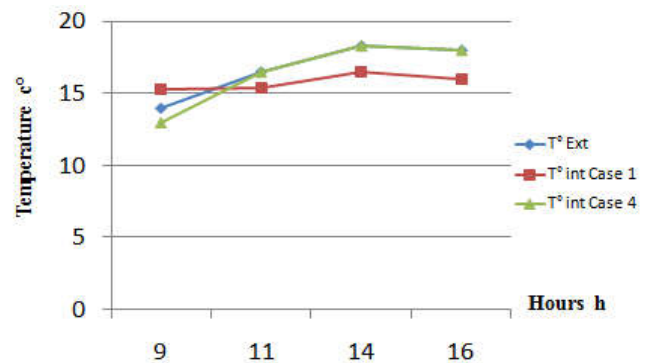


Fig. 5. .Exterior T° and Interior T° of 2 walls (1&4) in December.

For the December simulation (Fig.5) we notice a stability in the interior  $T^\circ$  in the wall of “earth” about  $15\text{ C}^\circ$  and for the concrete wall it is almost the same as the exterior  $T^\circ$  that’s because the earth wall is thicker so he accumulate the heat (the effect of thermal inertia) and the levels of temperature inside stays stable and a certain level of thermal comfort achieved in the evening.

-Temperature evaluation of case 1&4 in July

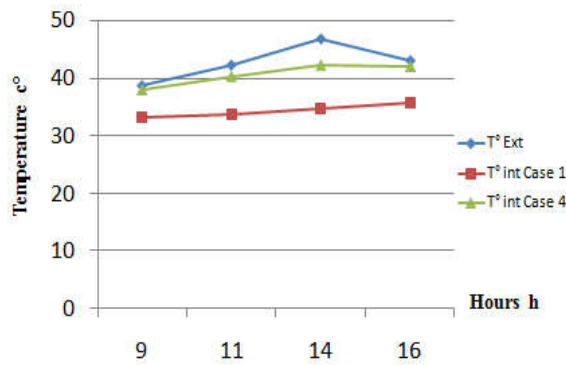


Fig. 6. Exterior  $T^\circ$  and Interior  $T^\circ$  of 2 walls (1&4) in July.

For the July simulation (Fig.6) we notice that the interior temperature in the modern bearing concrete wall it reach  $43\text{ C}^\circ$  inside, however it doesn't exceed more than  $35\text{ C}^\circ$  in the case of the bearing wall of earth that’s because earth brick walls has less thermal amplitude and they are more resistant and less conductive however both of them didn't succeed to insure a level of thermal comfort.

So thick traditional wall can achieve some level of thermal comfort due to their inertia and resistance.

**B. The thermal impact of traditional and modern materials on interior Temperature 'comparaison between case 2 with case 3':**

-Temperature evaluation of case 2&3 in December

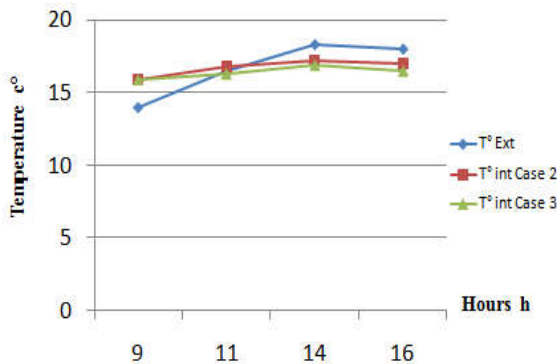


Fig. 7. Exterior  $T^\circ$  and Interior  $T^\circ$  of 2 walls(2&3) in December.

For the December simulation (Fig.7) and for the both cases with and without insulations the interior  $T^\circ$  levels are very close because Double-wall insulation is almost inefficient and does not bring significant heat gain.

-Temperature evaluation of case 2&3 in July

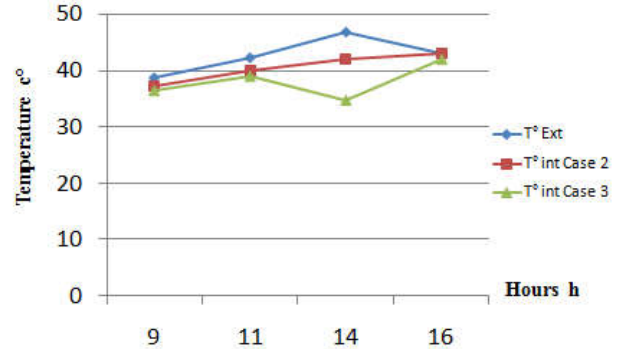


Fig. 8. Exterior  $T^\circ$  and Interior  $T^\circ$  of 2 walls (2&3) in July.

For the July simulation (Fig.8) we notice in the case of double wall with insulations interior  $T^\circ$  levels are the lowest can reach  $35\text{C}^\circ$  in the hottest time of the day so it was very efficient So we conclude that double wall insulation is very efficient in the summer time due to her résistance rather than winter when the heat gain is favorable.

**VI. CONCLUSION**

Thermal comfort can be achieved by combination of parameters that must be integrated into the design of the building. Choosing suitable envelope building materials guarantee a certain level of thermal comfort with the use of good thermal insulation material like red brick, massive earth walls massive materials to increase thermal inertia, resistant materials and the use of insulation, those solution may not guarantee a winter comfort (heat gain) however in a context of hot and dry climate summer’s thermal comfort is more prioritize than the winter’s.

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