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The impact of building materials on the thermal comfort (Case of hot and dry climate city of Biskra)

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Abstract

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 properties: physical, chemical, mechanical and thermal. Also, each material has certain behavior to the environmental factors heat, humidity ... etc. so materials interact with these factors through conductivity, resistance. Therefore choosing the right building materials is a key factor in achieving a certain level of comfort inside the building. In this study, we investigate the impact and the thermal behavior of different materials and the most used building materials traditional and modern under the climatic conditions of Biskra a hot and arid climate. Also, we analyze 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 proprieties in order to choose the best building 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: Building Materials, Thermal comfort, envelope, passive strategy,Hot and Dry Climate

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1. Introduction

Making a shelter it was one of the first human activities in order to provide a protection from danger and aggressive environmental situations so after that, we start to look for making it more comfortable so we start to develop out building according to the environment, weather conditions and local existing materials. *according to* (Hassan Fathy, 1989) 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, so accomplishing comfort specially thermal comfort basing on materials choices it was naturally practiced since the beginning. However Throughout the years and with the industrials revolution new materials has been discovered and used in another word the focus has shifted to more in the image and aesthetic of the building and with that comes the problem of achieving thermal comfort passively however with the technological development it was possible to achieve it with the technology and active systems (HVAC). 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 (Mokhtari et al. 2008).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 (Kolokotsa et al. 2009); 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 (Orosa et al. 2012). 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.

2. The Theoretical context of the study:

2.1. 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 (Givoni B., 1978). Thermal comfort is a concept so complex 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 (Saddok A, 2016). It depends on six aspects: activity and metabolism, clothing, air temperature, relative humidity, surface temperature, and air velocity.

2.2. Building materials and thermal comfort:

Choosing building materials is essential solutions and can guarantee to maintain comfortable conditions inside the building in all seasons (Dudzińska et al. 2015), in another word choosing building envelope materials is a passive strategy.Givoni (1976) 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. (Gezer, 2013)

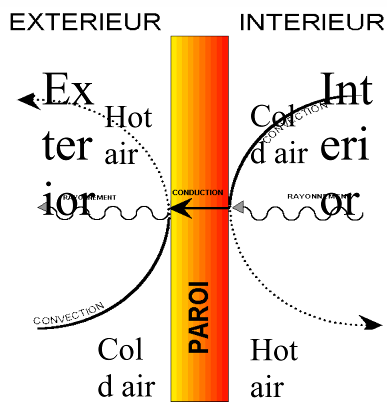
2.2.1. Thermal characteristics of building materials:

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 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. (Mazari, 2012)

2.2.2. 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: (Moser, 2011)

Figure 1: heat transfer modes



source: moser

1-Conduction 2-**Convection** 3-**Radiation** (fig 1)

2.2.3. Thermal inertia:

According to Liebard, A "thermal inertia is a notion that covers both 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. (Mazari, 2012). The thermal inertia of buildings can help to reduce such 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. (Orosa ET al.2012).

2.2.3. Thermal isolation:

Thermal insulation is the property that owns 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).(Mazari, 2012).

3. The climatic context of the study: the city of Biskra

3.1. 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 are: - The latitude = 34.48 N/- The longitude = 5.44 N.
The altitude which is equal to 83 m above sea level.
-The city of Biskra is characterized by a maximum temperature in summer which reaches in the month of July 45 ° C and a minimum temperature in winter that reaches 5 ° C during the month of January (table1)
-with a rare level of precipitation(less than 30 days per year) (table 2)
- The average relative humidity is low around 47%, with a maximum value of 65% in the month December, and a minimum of 28.29% in July and August (table 3)

Table3: Monthly Mean Relative HumiditySource: Biskra monograph

Mnth	J	F	M	A	M	J	J	A	S	O	N	D
T av (c)	12.4	12.9	18.8	21.8	27.6	32.4	37	35.2	29	25.2	18.1	13
Tmax(c)	20.9	24.7	24.6	32.2	36.1	41.1	46.7	45.7	43.1	36.1	28.3	20.4
T min (c)	8.4	5.2	9.1	10.1	12.5	25.1	29.8	28	20.1	14.2	8.4	5

Mnth	J	F	M	A	M	j	J	A	S	O	N	D
HR %	60	62	44	36	34	29	28	29	41	41	59	65

Table2: Average monthly rainfallof Biskra 2006. Source: Biskra monograph

Mnth	J	F	M	A	M	j	J	A	S	O	N	D
P(mm)	53.7	29	1	13.5	11.5	0.2	0	0.7	16.2	9	28.4	9.8

According to Givoni, in order to ensure hydrothermal comfort in a hot arid climate, buildings must be adapted to summer conditions and this assuming that winter requirements will be met accordingly. (Givoni,1998).thereforethe 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. (Gezer, 2013)

4 .The empirical study:

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 and interpret the phenomena that develop simultaneously through the envelope, influencing the mood interior, and during which thermal events with rapid variable). It allows gathering the potential evaluation criteria that can improve the comfort

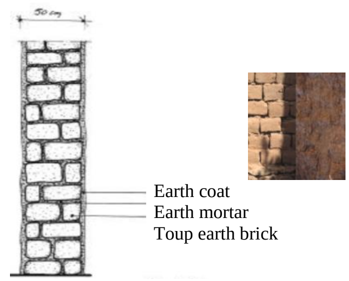
thermal. In this research, we analyzed the thermal behavior of different wall compositions to investigate the thermal impact of building materials,the opaque parts of the envelope (walls/roofs/insulation).

4.1. Case of study

We compared between different thermalcharacteristics 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

Table4: characteristics of envelope local traditional materials and wall compositions

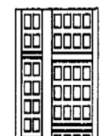
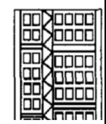
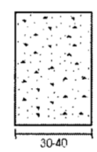
A-Local traditional materials:

Materials	**Dancité D (Kg/m3)**	**specific heat (j /KG.K)**	**conductivity λ (W/m.k)**	**Thickness T (cm)**	Wall composition
		Envelope			Bearing wall en clay / earth **Thickness** 50 cm **(case 1)** 
Soft limestone	1650-1840	828	1.05	/	
Toub (clay)	1700-2000	936	1.15	40-50	
		Insulation			
Branch Palm foliage /straw	120	612	0.05	/	
Earth	1700-2000	936	1.15	/	

Source: the author

B-Local traditional materials:

Table 5: characteristics of envelope current most used materials and wall compositions

Materials	**Dancité D (Kg/m3)**	**specific heat (j/KG.K)**	**conductivity λ (W/m.k)**	**Thickness T (cm)**	Wall composition
Envelope					
Cement brick	1200-1400	800	0.56	10	Walls of hollow brick **Case 2: (**brick 15cm+air 5cm +10cm brick) 
Cement mortar	1900	1000	0.80	0.2	
Plaster mortar	1150	1008	0.57	0.2	**Case 3: (**brick 15cm+ polystyrene 5cm +10cm brick) 
Cinderblock (parping)	975	1080	0.95	20	
Reinforced concrete	2500	1080	1.75	10	
Hollow brick	1200	260	0.39	10-15	
Insulation					
Air	1	1000	0.047	05	**case 4 :** concrete bearing wall 30cm
polystyrene	16-20	1450	0.038	05	

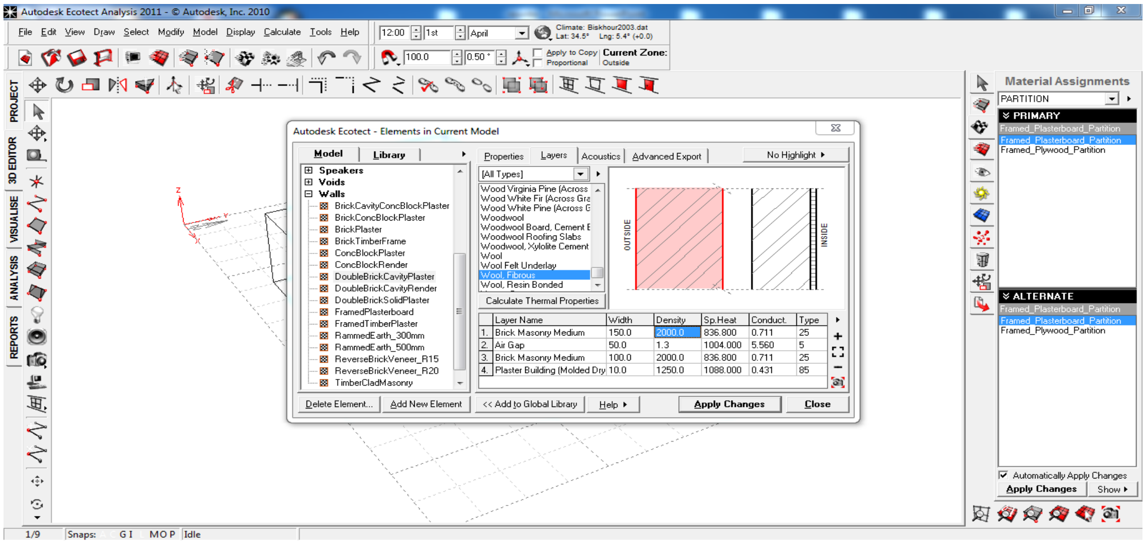
Source: the author

4.2. 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

Figure 2: the used software interface "Ecotect 5.0"Source: the author



5- Results and discussion:

We have conducted a thermal simulation of 4 wall composition simulation to determine the best choise 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 ambiance temperature in two different months the month with highest average T (July) and the one with the lowest (December) in different time in the day.

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

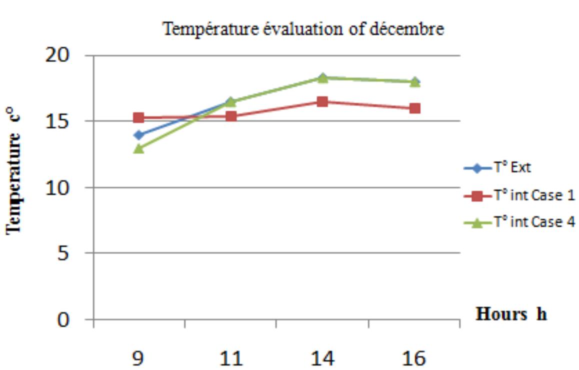
Case 2: Hollow brick 15cm+air 5cm + 10cm hollow brick, R=0.91 (m^2.K. / W) , U= 1.09 (w / m^2.K.)

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.)

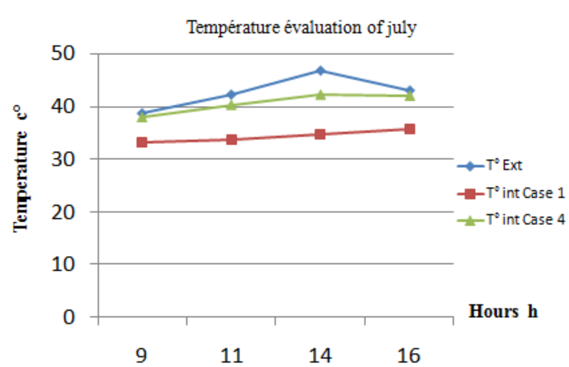
5.1. The thermal impact traditional and modern materials on interior T°:

Figure 3: exterior T° and interior T° of 2 walls in December



Source: the author

Figure 4: exterior T° and interior T° of 2 walls in July



For the December simulation (fig 3) we notice a stability in the interior T° in the wall of earth about 15C° and for the concrete wall it is almost the same as the exterior T° that 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.
For the July simulation (fig 4) we notice that the interior temperature in the modern bearing concrete wall it reach 43 c° inside however it doesn't exceed more than 35 c° 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

5.1. The thermal impact traditional and modern materials on interior T°:

Figure 5: exterior T° and interior T° of 2 walls in December

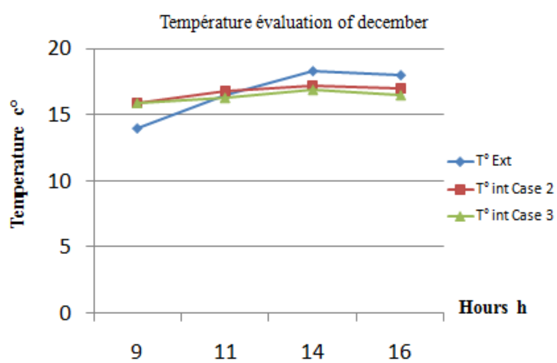
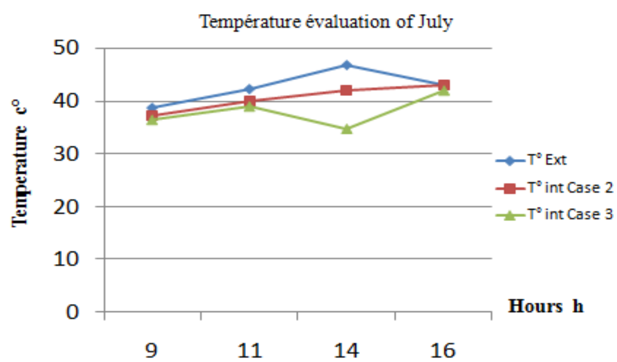


Figure 6: exterior T° and interior T° of 2 walls in July



Source: the author

For the December simulation (fig5) and for the both cases with and without insulations the interior T° levels are very close because Double-wall insulation is almost inefficient and does not bring significant heat gain.
For the July simulation (fig6) we notice in the case of double wall with insulations interior T° levels are the lowest can reach 35C° 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

6. Conclusion:

Thermal comfort can be achieved by combination of parameters that must be integrated into the design of the building. Basing on choosing 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, materials more resistance and the use of insulation, those solution may not guarantee a winter comfort (heat gain) however in a context of hot and dry climate thermal summer is more prioritize than the winter's.

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