Energetic expenses of walls and roofs used in the metropolitan zone of Tampico, Madero and Altamira

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ABSTRACT
This is a presentation showing the procedures and results obtained from the analysis of the energy transmitted in walls and roofs of the selected homes in the south zone of the state of Tamaulipas, one of the five zones established in the "Development and validating of a methodology to estimate the impacts in the saving of energy for the use of passive-constructive systems in the edification for different climates in México" project, which third stage of execution's objective consisted in making use of the Ener- Habitat software, developed during the project's second phase. This research was sponsored by the Energy Sector Sustainability Fund SENER - CONACYT S0019 - 2009-01 call log under the project No. 118665. With this software the comparative energy expenses of four constructive systems for walls and three constructive systems for roofs were determined. With the acquired information and through the use of the methodology developed to estimate the impacts on energy saving, the energetic price of each of the constructive systems was evaluated. With the acquired results it was determined which were the walls and roofs of less energy expense for the study zone.

INTRODUCTION

It is essential in locations which have high solar insolation and large temperature variations through the day to evaluate the thermal performance of building systems. This emphasizes G. Barrios, P. Elias, G. Huelsz and J. Rojas (2010) who state that "in climates where solar radiation is significant and the daily temperature swing is important, as in most of Mexico, the heat transferred through walls and roofs must be analyzed as a function of time. For these climates, the steady state heat transfer model from a period of time can lead to the improper selection of materials".

The objective of this project is to provide guidance for the selection of suitable constructive systems for the warm-humid climate of the southern part of the state of Tamaulipas to help improve the thermal comfort inside the home without using air-conditioning systems.

The study was divided into three parts:

A. Apply the methodology established in the project protocol .

B. Analyze the results derived from the Ener - Habitat program[1] construction systems of the

[1] For further information consult: http://www.enerhabitat.unam.mx/Cie2/

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selected walls and roofs, comparing energy costs.

C. Get the conclusions of the investigation in the study area.

This also implied a review of climatic factors existing in the study area formed by the municipalities of Tampico, Madero and Altamira, prevailing therein a warm-humid climate with average summer temperatures of 29°C in summer and 21°C in winter. The variations of weather through the year fluctuate in summer ± 10°C and in winter ± 8°C.

METHODOLOGY

As part of the established objective, the following steps to define the selection of constructive systems for the warm-humid climate of the study zone were generated.

A. Twenty five housing buildings were selected in the south zone of Tamaulipas for investigation.

B. A data sheet designed to provide the information of each of these homes on their behavior with regard to the thermal comfort inside, provided the m2 of property, the square meters of construction, typology, orientation, vegetation and exterior colors.

C. Determine which passive systems impact on each housing building.

D. Analyze the constructive systems of walls and roofs using the software. Ener-Habitat solves the time dependent one dimensional heat transfer equation using the sol-air temperature at the exterior. At the inside, the indoor air temperature can be assumed constant (air-conditioned) or as a function of the heat transferred through the constructive system (free running).

E. Compare, using the Ener- Habitat software, the two most widely used construction systems in the area which transmit less energy for walls and roofs.

F. Suggest other systems of walls and roofs in different layers, so as to establish the best benefit cost.

G. Different layers of walls and roofs were proposed which were analysed for their energy-cost with the information provided by the Ener-Habitat software.

H. Determine which were the final layers of walls and roofs of lower expense and energy-cost of the climatic zone of study.

RESULTS

With the information gathered in the data sheets of the 25 homes tested, it was determined how passive systems impacted in each of these homes .

It was shown on a study which were the constructive materials for walls and roofs more widely used. This information was used to feed the Ener-Habitat software which steps are:

I. Select the construction system (wall or roof). Determine whether the layers are homogeneous or not and understanding that homogeneous are those with a single material and no air gaps.

II. The following information is selected from the database:

a) The city where the calculation will be made: in this case Tampico.
b) The time period analyzed: annual or a specific month.

c) Use of air-conditioning: yes or no.

d) Select the tipe of construction element: roof or wall.

e) Number of building elements to compare: 1 to 5.

III. Determine the amount of building elements to be analyzed, for all the following (Image 3):

a) Orientation: north, south, east, west, other.

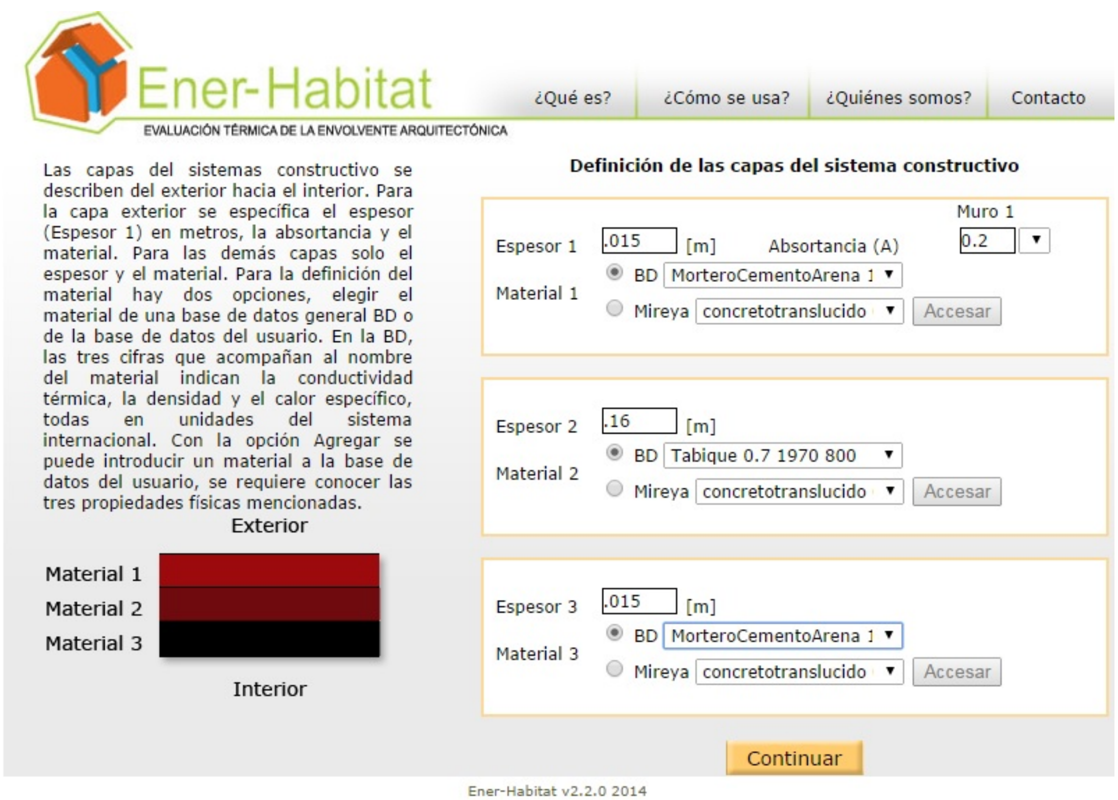
b) Tilt angle: 0º to 90º.

IV. The layers of the construction system from 1 to 7 are introduced to be analyzed

V. Determine the absorptance, the thickness and the material of the outer layer of this system. And subsequently, determine the thickness and the material of the following layers. Because the time dependent heat transfer equations are solved, being the thermal properties needed for the evaluation the thermal conductivity, the density and heat capacity, as well as the width of each layer.

VI. Finally, after entering all the data, the software shows the results from the Ener-Habitat through tables and graphics .

Image 1. Selection of layer material.



The calculation of the energy transferred to the two different wall construction systems to compare the walls and roofs of the building envelope used in the area of Tampico was made considering that all the walls are west facing. This was done in order to compare them regardless of orientation.

In Table 1, the two types of walls most used in the zone are shown. Percentages of the construction systems used in homes as well as the transmitted energy values are included. Each system has two extreme values of transmitted power; the minimum value corresponds to the wall that transfers the least amount of energy and the maximum value corresponds to the wall that transfers more energy, classified within the same type.

Furthermore, the values of energy transmitted in the same type of construction system presented in Table 1 are associated with walls with clear exterior colors, which have low solar absorptance (A). Without air conditioning, it is observed that the energy transmitted by the walls with no homogeneous layer (wall of hollow concrete block) is 2.56Wh/m^2 day. This allows us to affirm that the walls with no homogeneous layers and more space between their inner sides are more suitable for homes without air-conditioning operating in southern Tamaulipas.

The calculation of energy transmitted in the walls north, south, east and west to find the best orientation and also using white colors with absorptance 0.1 was found to be the most used in the building systems in the area.

The most energy transmitted is from the wall facing west with an average of 4.80Wh/m2 per day and the wall with less energy is facing east with an average of 3.62Wh/m2 per day and therefore being the best orientation for the zone.

Table 1. Result rates of transmitted energy in the wall construction systems.
Source: Created by researches with Ener-Habitat (2012).

Wall construction system	Label	% Construction systems	Without air conditioning Energy transmitted warmest month (Wh/m2 day)
Hollow concrete block 10cm	BH_acay_10	36.0	19.12
Hollow concrete block 15cm	BH_acay_15	64.0	2.56
Total non homogeneous construction systems		100	
Total housing represented		1325	

The best wall construction systems without air conditioning is using hollow blocks of 15cm with 2.56Wh/m^2 per day, in second place, with a bigger difference, is using hollow blocks of 10cm with 19.12Wh/m^2 per day.

The wall construction system non homogeneous to analyze the effect of color is shown in Table 2.

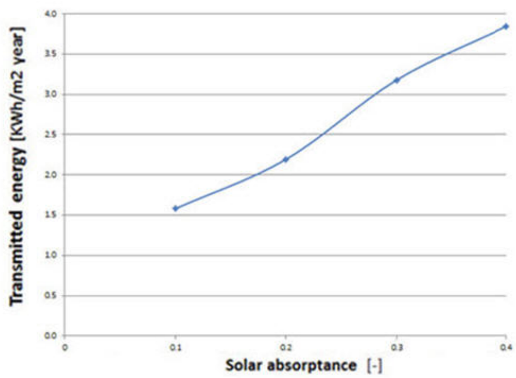
Table 2. Specification wall construction system used to study the effect of color.

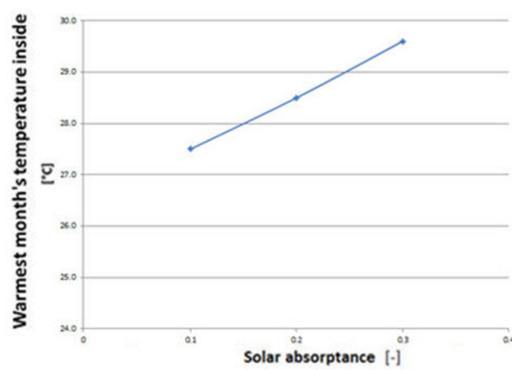
Construction system components (outer layer → inner layer)	**Thickness (cm)**
Sand-cement mortar	1.50
Hollow concrete block	15.00
Plaster	1.50

With the Ener-Habitat software solar absorptance varied from 0.1 to 0.7 without air conditioning during the critical summer month of August. The transmitted energy increases linearly with solar absorptance 0.4kWh/m2 per year for each 0.1 of solar absorptance, is shows in graghic 2.

The average interior temperature in the warmest month also increases linearly with the increase of solar absorptance as shown in figure 3. For A = 0.1 the average temperature is 27.5ºC, while for A = 0.3 is 29.6ºC. In this case, the increase is 1ºC for every 0.1 increase in solar absorptance. For this reason light colors are recommended in the outside of the walls, especially the west and eastern walls, which receive more solar radiation is shows in graghic 3.

The evaluation of energy cost, using the Ener- Habitat software, was conducted using horizontal roofs. Two types of homogeneous roofs were used, concrete ribs and polystyrene blocks of 10cm and 15 cm. The systems were evaluated without air conditioning.





Graph 2. Transmitted energy as a function of solar absorptance on the wall. Graph 3. Indoor-air-average temperature as a function of solar absorptance on the wall.

Table 3 shows the percentages of each type of construction systems used in homes as well as the transmitted energy values. The best rated roof construction system shows that the transmitted energy is of 8.55 Wh/m^2 per day. ||

Roff construction systems	Label	% Construction system	Without air condition Energy transmitted warmest month (Wh/m2 day)
Concrete rib slab and polystyrene block 10cm	NeCa_cfy_10	16.0	9.31
Concrete rib slab and polystyrene block 15cm	NeCa_cfy_15	84.0	8.55
Total non homogeneous roof construction systems		100	
Total housing represented		1325	

Table 3. Result Rates of transmitted energy in roof constructive system.
Source: Created by researchers with Ener- Habitat software (2012).

To calculate the cost-benefit of wall construction systems, three systems were used: the first system is a brick wall with an exterior and interior finish of sand-cement mortar of 1.5cm, the outer surface being white with a solar absorptance of 0.1; the second being a wall of compressed earth block 14cm thick, with an interior and exterior finish of sand-lime mortar 1.5cm with solar absorptance of 0.10; which mechanical behavior is shown in table 4. The third is a set of five layers, two layers of compressed earth block joined by a sand-lime mortar being the same used for the interior and exterior layers.

Dry condition		Humid condition	
% Dry cement	Resistance Kg/cm	% Humid cement	Resistance Kg/cm
6%	41.40	6%	41.40
8%	77.72	8%	44.63
10%	120.74	10%	44.63

Tabla 4. Mechanical behavior, compressed earth block.
Fuente: Roux (2010).

The analysis for the proposed wall construction system is to compare the cost-benefit factor that obtained from the product of the energy (E) for the cost (C) of the 3 proposed systems, taking care that the standard cost (Cu) is not too high.

Table 5 shows that "Wall One" transmits more energy (E=1.20) than the "Basic Wall", its cost is equal to the "Basis Wall" (C01.0), so that a cost- benefit factor is E*C=1.20. "Wall Two" transmits a fraction of energy E= 0.70, and has less cost than the "Basic Wall" (C=0.70) and the cost- benefit factor is E*C=0.49. "Wall Three" transmits less energy than the "Basic Wall" (E=0.10), the standard cost is C=1.10 and its cost- benefit factor is E*C=0.11.

"Wall 3" is the one with the lowest cost-benefit factor E*C = 0.11 and this cost is even higher than the basic system. Note that this type of construction system with double compressed earth block 32cm thick is not currently on the market in the area.

For the proposed roof construction system, the same methodology for walls is used.

"Roof One" is a conventional slab of reinforced concrete; while "Roof Two" has in addition a layer of polyurethane foam of 2.5cm of thickness. The two systems have an exterior finish of white acrylic waterproofing (absorptance of 0.20) and an internal plaster finish.

Wall construction systems	**α [-]**	**Layers**	**e [m]**	**Eu [Wh/m² day]**	**Cu [$/m²]**	**E* [-]**	**C* [-]**	**E*C* [-]**
Basic Wall	0.1	sand-cement mortar	0.015		85.8			
		hollow concrete block	0.150		151.6			
		sand-cement mortar	0.015		85.8			
Total basic wall			0.150	2.056	484.0	1.00	1.00	1.00
Wall One	0.1	sand-cement mortar	0.015		85.8			
		brick	0.160		143.0			
		sand-cement mortar	0.015		85.8			
Total Wall One			0.170	3.035	314.5	1.20	1.00	1.154
Wall Two	0.1	sand-lime mortar	0.015		40.0			
		compressed-earth block	0.140		140.0			
		sand-lime mortar	0.015		40.0			
Total Wall Two			0.170	1.90	220.0	0.70	0.70	0.50
Wall Three	0.1	sand-lime mortar	0.015		40.0			
		compressed-earth block	0.140		125.0			
		sand-lime mortar	0.010		40.0			
		compressed-earth block	0.140		125.0			

		sand-lime mortar	0.015		40.0			
Total Wall Three			0.320	0.375	370.0	0.10	1.10	0.168

Table 5. Comparison of wall construction systems in Tampico.
Source: Created by researchers (2013).

Table 6 shows that "Roof One" transmits more than twice the energy value of the "Basic Roof", with E = 2.4 which has a standard cost of C = 0.9 and a cost-benefit factor E * C = 2.16. "Roof Two" transmits a normalized energy E = 0.1, and has a cost of C = 1.0 as the "Basic Roof" with a cost-benefit factor E * C = 0.10.

Roof construction system	α [-]	Layers	e [m]	Eu [Wh/m^2 day]	Cu [$/m^2]	E* [-]	C* [-]	E*C* [-]
Basic Roof	0.10	acrylic waterproofing	0.001		70.0			
		compression layer	0.035		650.0			
		polystyrene block	0.150					
		plaster	0.015		180.0			
Total Basic Roof			0.201	5.52	900.0	1.00	1.00	1.00
Roof One	0.10	acrylic waterproofing	0.001		70.0			
		reinforced concrete	0.120		540.1			
		plaster	0.015		180.0			
Total Roof One			0.136	13.06	790.1	2.4	0.9	2.07
Roof Two	0.20	acrylic waterproofing	0.001		170			
		polyurethane foam	0.025					
		reinforced concrete	0.120		540.1			
		plaster	0.010		180.0			
Total Roof Two			0.156	0.791	890.0	0.1	1.0	0.142

Table 6. Comparison of roof construction systems in Tampico.
Source: Created by researchers (2013).

CONCLUSIONS

The thermal performance of a house depends on many variables; most of them derive from the architectural design, especially, the morphology rather than the materials and construction systems; however the knowledge and use of thermophysical properties of materials is an aspect that can more easily be subjected to regulation. Some decisions regarding the selection of materials can contribute to the better performance of the building, particularly if the materials are appropriate to the environmental conditions of a region.

The study in the area has shown in its initial stages that the construction processes used for architectural housing envelop are not the most appropriate. So to continue analyzing and comparing these processes, it has been established that in the case of the walls, the compressed-earth block has a better thermal performance than the traditional hollow-concrete block used for building walls. For roofs, the results of the analysis showed that the lightened layers (polystyrene foam and reinforced concrete) are less efficient than the reinforced concrete with polystyrene foam.

For the south zone of Tamaulipas, where a warm humid climate prevails, the construction systems recommended without air conditioning are:

For walls, a double compressed earth block with a thickness of 29 cm and an outside and inside finish of sand-lime mortar 1.5cm thick using white exterior colors and a solar absorptance of 0.1 are proposed. The energy transferred from this construction system is 0.10 used and its cost is 76 % of the value of the most used in the zone, with a value of the cost -benefit factor of E*C=0.11

For roofs, a reinforced concrete slab of 12 cm with a layer of polyurethane foam 2.5cm on the top and a finish of acrylic waterproofing 1cm thick using white colors with a solar absorptance of 0.10 and in the interior a plaster of 1cm thick is proposed. The energy transferred from this construction system is 0.1% of the value of the most widely used in the area with a cost-benefit factor of E*C=0.10.

For the south zone of Tamaulipas, where a warm-humid climate prevails, the dwellers usually have mechanical ventilation, like air-conditioning, to improve the thermal confort.

The study showed that the construction systems proposed and mentioned above were efficient for thermal confort even without using air conditioning.

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