Effect of the passive strategies on thermal comfort in economic dwellings in warm-dry climates

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ABSTRACT

Some regions of Mexico have recently increased their population significantly, due to locally economical growths. Because of this situation, an accelerated growth in the construction of certain type of “economic” dwellings takes place. These houses vary from 36 to 45 m^2 of construction area. The behavior of these types of dwellings in warm-dry climates has been analyzed. In these climates, an adequate architectonic design, considering thermal aspects, is indispensable, in order to obtain the required comfort conditions. Simulation results of these dwellings located in northwest Mexico are shown, using PowerDoe and Ecotect programs. The building has been analyzed under its current conditions, and changing its orientation, applying shadow devices on windows and optimizing the construction materials, with the purpose of improving the thermal comfort indoors. The heat gains through the different constructive elements have been obtained, to analyze the impact of them on global thermal comfort. Also, the viability of using the exergy methodology in the analysis of building elements is demonstrated.

1. INTRODUCTION

In dry warm climates, such as in north-west Mexico, where sensible heat loads are high, spaces without air conditioning are uncomfortable and unhealthy. In these climates, temperature control is a determinant factor in comfort and significant air conditioning processes.

However, in climates with high solar radiation, like Hermosillo, Sonora, Mexico, are able to take benefit of favorable natural lighting conditions for energy savings and visual comfort in dwellings. Nevertheless, a bad design of windows and envelope can increase the thermal loads producing an extra load to air conditioning systems. Adequate design strategies and thermodynamic concepts have to be applied to make comfortable dwellings. Thermal comfort can be defined as a mental condition or sensation in which one expresses satisfaction with the thermal conditions of the environment. The comfort zone is the range of ambient conditions with which most people express satisfaction, (ASHRAE, 2001).

Recently, there has been an increasing interest in incorporating daylight in the architectural and building designs (Li et al., 2005). And other authors have related exergy analysis with thermal comfort to reduce energy in buildings (Saito and Shukuya, 2001). The exergy analysis is a methodology that allows determining if a system has energy losses due to irreversibilities. Exergy analysis is not a substitute for first law analysis, rather a supplement. It can thus indicate possibilities for improvement of a process but cannot indicate the practicality of any possibility (Bejan, 1997). In this paper the main objective is to contribute to the improvement of dwellings design for warm dry climates by using exergy analysis of humid air and its influence inside the dwelling based on the methodology used by Alpuche et al, 2004. In addition, we want to find out the influence of daylight on comfort range.

Table 1: Brief description of base-case dwelling (current conditions).

Location	Hermosillo, Sonora, Mexico (Latitude 29º 06' N, longitude 110º 58' W)
Building type	Economic dwellings
Floor areas	Total floor area= 45 m^2
	Air-conditioned area = 45 m^2
Construction of building envelope	
Walls (sand/cement mixture plastering, concrete blocks) U-value = 3.74 W/K-m^2	
Roof (Reinforced concrete with polyurethane block, sand/cement mixture plastering)	
U-value = 1.32 W/K-m^2	
Windows (3mm commun single glazing) U-value = 6.31 W/K-m^2	

2. DESCRIPTION OF THE DWELLINGS

Recently, an accelerated growth in the construction of certain type of “economic” dwellings has taken place in Mexico. These houses have 36 to 45 m^2 of constructed area on 118 m^2 total land area. Two “economic dwellings” in the region have been selected as case study for daylight and exergy analysis. Both have two bedrooms, a dinning room, a kitchen, a bathroom and a living room. The dwellings are shown schematically in Figure 1. The construction materials are locally manufactured blocks for the walls, reinforced concrete roofs and concrete floors with a ceramic floor tiles and sand/cement mixture plastering on the other interior surfaces. They are originally constructed without insulation materials. Case study 1 represents the actual situation.

Also, the dwellings have been designed without daylight considerations. Nevertheless, for this study, insulation in walls and ceiling are proposed for the second case. The Table 1 shows a brief description of base case dwelling (current conditions).

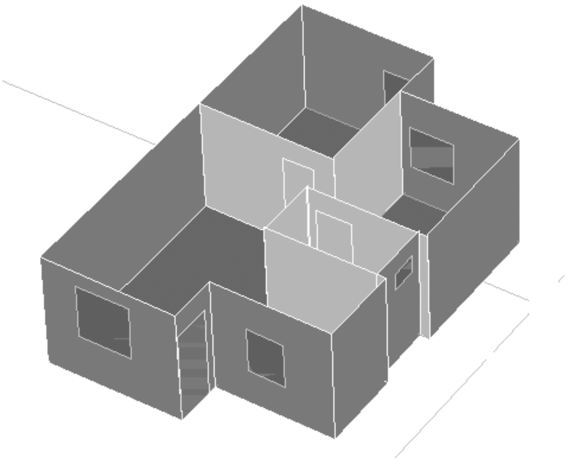

Figure 1: Schematic representation of the dwellings.

Commercial air conditioning packaged units are used for inside conditioning, resulting in significant electricity consumption. A packaged single zone system was analyzed for both dwellings.

2.1 Building simulation and Daylight analysis

PowerDoe® software was used to calculate the heat gains, temperature and relative humidity through the dwellings envelope and daylight levels have been simulated with Ecotect® software. Meteorological data has been obtained from Meteonorm® software, using one year with hourly time step.

2.2 Exergy balance

The exergy analysis of the building was carried out in the simplified open system, where humid air enters at the input condition and crosses the wall arriving at the output condition (Alpuche et al, 2004). The exergy at the inlet condition is zero since it is identical to the reference condition. To evaluate an air conditioning system used in the case studies, the equation of the second law efficiency is applied, defined as:

$$\eta_{\Pi} = \frac{ex_{out}}{ex_{in}} = \frac{exm_{out} + exQ_{Lat+Sen}}{exW} \tag{1}$$

where

ex_{out} is exergy at oulet,
ex_{in} is exergy at inlet,
exm_{out} is the mass exergy,
exQ_{Lat} is latent heat exergy,
exQ_{Sen} is sensible heat exergy and
exW is work exergy.

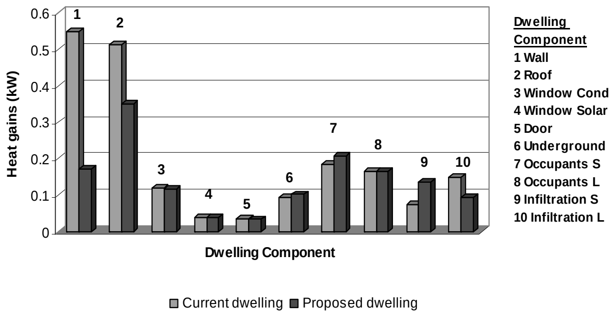

Figure 2: Heat gains for each dwelling component.

3. RESULTS

3.1 Thermal and daylight simulation

The results of the thermal and daylight simulation have been limited to the living-dining room, which is the largest space (Fig. 1).

As first results, a comparison of heat gains for each dwelling component is carried out between the first dwelling in its current conditions and the proposed dwelling (Fig. 2). For a better visualization of values, only the highest heat gain hour is shown, which was August, 9th, 6 p.m.

Comparing the heat gains of both buildings, the proposed dwelling reports decrease to 26% lower heat gains, than the current dwelling, at same hour. The dwelling component with higher heat gain is the wall without insulation which is the actual situation in current dwelling.

Figure 3, shows total cooling loads of both dwellings during 24 h. The values show that the current dwelling has higher cooling loads to remove from the living space, than the proposed dwelling. The effect of the use of insulation materials in the dwelling envelope, is shown more clearly in the reduction of cooling loads,

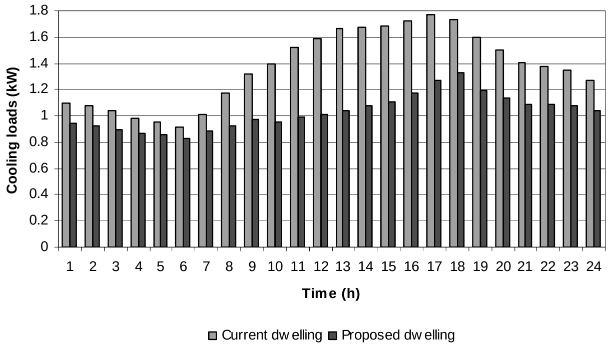

Figure 3: Cooling loads for both dwellings.

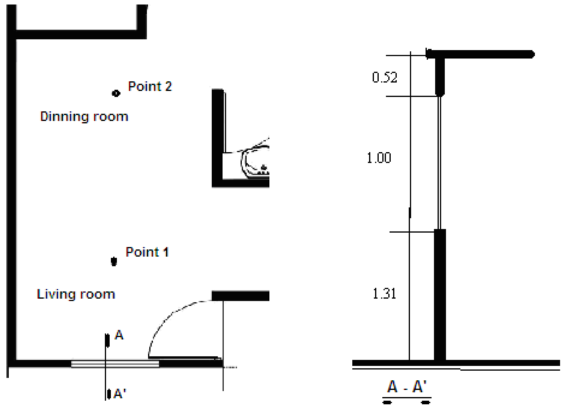

Figure 4: Sketch of space plan and analyzed window.

The next step of the present research is to analyze the daylight levels inside the dwelling and the effect on cooling loads. Daylight levels have been calculated in two reference indoor points: point 1 at 1.50 m from the window and point 2 at 4.20 m. Daylight levels have been calculated at each point according to the window size showed in Figure 4. The window transparent material is regular glass 5 mm thick, visible transmittance of 0.898, solar transmittance of 0.840 and reflectance of 0.080.

As expected, daylight levels change according to the distance between the reference points. The Figure 5, shows that at the most distant point (2), the daylight level is higher than 400 lx during 7 hours (the minimal recommended is 300 lx), while at the nearest point (1) there are more than 1400 lx daylight level during 6 hours.

The values show that the relationship between the dwelling orientation and the window area in this particular case indicates an appropriate daylighting design to obtain an adequate visual comfort. Also, the heat gains won over the window have not an important influence on the total cooling loads, as can be seen in Figure 2.

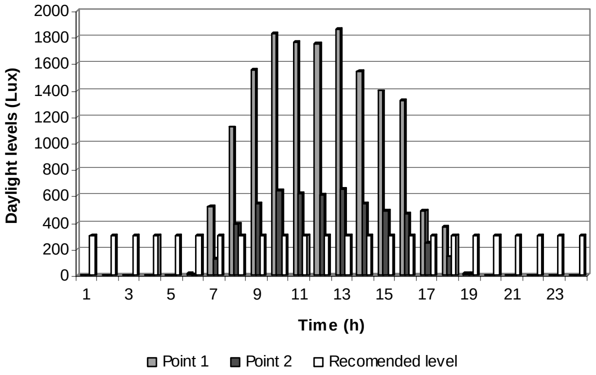

Figure 5: Daylight levels at the current and proposed dwellings.

Table 2: Hours inside the comfort zone in the interior of the current dwelling with PSZ-1.

	Relative Humidity (%)									
Temp.(°C)	x<10	10<=x<20	20<=x<30	30<=x<40	40<=x<50	50<=x<60	60<=x<70	70<=x<80	80<=x<90	90<=x
10<=x<12	0	0	0	0	0	0	0	0	0	0
12<=x<14	0	0	0	0	0	0	0	0	0	0
14<=x<16	0	0	0	0	0	0	0	16	1	0
16<=x<18	0	0	0	0	0	0	11	97	0	0
18<=x<20	0	0	0	0	0	0	46	302	0	0
20<=x<22	0	0	0	0	0	1	150	621	0	0
22<=x<24	0	14	15	2	1	2	255	897	0	0
24<=x<26	3	244	284	277	2982	1297	491	751	0	0
26<=x<28	0	0	0	0	0	0	0	0	0	0
28<=x<30	0	0	0	0	0	0	0	0	0	0
30<=x<32	0	0	0	0	0	0	0	0	0	0
32<=x<34	0	0	0	0	0	0	0	0	0	0
x>=34	0	0	0	0	0	0	0	0		0
				5307	Total Comfort Hours					

Table 3: Hours inside the comfort zone in the interior of the proposed dwelling with PSZ-2.

	Relative Humidity (%)									
Temp.(°C)	x<10	10<=x<20	20<=x<30	30<=x<40	40<=x<50	50<=x<60	60<=x<70	70<=x<80	80<=x<90	90<=x
10<=x<12	0	0	0	0	0	0	0	0	0	0
12<=x<14	0	0	0	0	0	0	0	0	0	0
14<=x<16	0	0	0	0	0	0	0	0	0	0
16<=x<18	0	0	0	0	0	0	0	0	0	0
18<=x<20	0	0	0	0	0	10	51	0	0	0
20<=x<22	0	0	0	0	2	26	341	12	0	0
22<=x<24	0	0	0	0	3	34	963	185	0	0
24<=x<26	1	215	246	207	2946	1853	1386	279	0	0
26<=x<28	0	0	0	0	0	0	0	0	0	0
28<=x<30	0	0	0	0	0	0	0	0	0	0
30<=x<32	0	0	0	0	0	0	0	0	0	0
32<=x<34	0	0	0	0	0	0	0	0	0	0
x>=34	0	0	0	0	0	0	0	0		0
	1	215	246	207	2951	1923	2741	476	0	0
				7392	Total Comfort Hours					

3.2 Exergy analysis

After the thermal simulation above presented, a packaged air conditioning unit, Package Single Zone (PSZ), was analyzed, this is usually used for inside conditioning in dwellings. The same system was analyzed for the current and proposed dwellings. The performance of the systems in achieving comfort conditions was first determined and then their exergy efficiencies were compared.

Tables 2 and 3, show the number of hours for a complete year, that indoor conditions in dwellings are inside the comfort zone. With the PSZ-1, Table 2, 5307 hours inside the comfort zone can be achieved, and while with PSZ-2, Table 3, 7392 hours.

The total annual energy consumption of the same air conditioning systems located in different dwellings is compared in Figure 6.

The energy consumption for both systems has a high influence over the small exergy efficiency obtained like was observed in Figure 7.

The Figures 6 and 7, show that, as expected, the air conditioning systems in the proposed dwelling has low electricity consumption and better exergy efficiency during a complete year than the air conditioning system in the current dwelling.

The data obtained, reflects that the annual energy consumption for air conditioning systems has been excessively to get the thermal comfort conditions.

The results of exergy efficiency show that the type of air conditioning system analyzed is not the bet to obtain the comfort level inside the dwellings in warm dry climates.

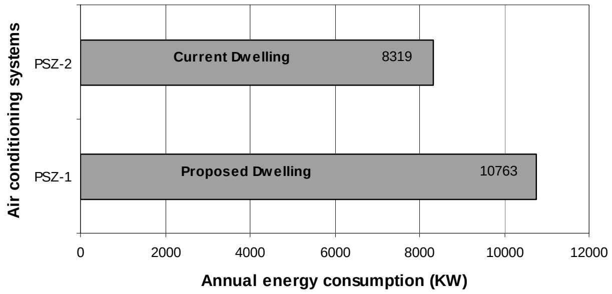

Figure 6: Annual energy consumption by air conditioning systems.

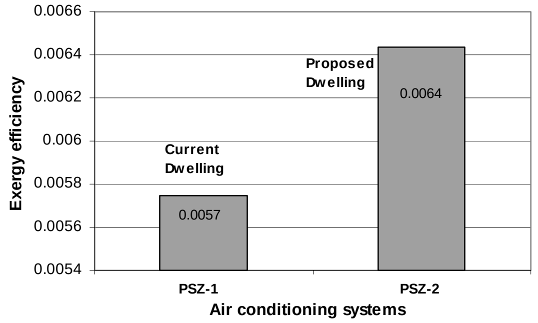

Figure 7: Annual exergy efficiency achieved by air conditioning systems.

4. CONCLUSIONS

Results obtained show that adequate insulation in economical dwellings envelope can decrease substantially the heat gains inside and that a medium size well located window can be enough to reach users lighting needs, without gaining a relevant heat.

The exergy analysis method has been applied, to study the same air conditioning system in different dwellings, and the method provide an important benchmark for the study of this system. It is necessary to locate a better air conditioning system that can provide thermal comfort conditions at inside of dwellings and have low consumption energy for using in the warm dry climates.

The type of analysis here presented, that relates to daylight, thermal comfort and exergy is not usual, and is able to provide a benchmark for improvement of the dwellings design.

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