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Interaction Between Walls and Roofs in Non Air Conditioned Rooms

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Abstract

In this work we present evidence of the interaction in the heat transfer through the buildings envelope components when not using air conditioning. A comparison between a test cell analysis and a single component analysis is carried out for two different constructive systems considering an air-conditioned room and a non air-conditioned one. For an air-conditioned room, the results the results of both analysis are almost identical. For a non air-conditioned room, the results from these analysis are different because the heat transfer through an envelope component is affected by the heat transfer to the indoor air by other components. This is not the case for the air-conditioned room where the indoor air temperature is kept constant.

1. Introduction

The heat transfer through the components of the building envelope plays an important role in the thermal performance of the whole building. When considering an air-conditioned room, a good thermal performance is achieved when selecting the constructive system that reduces the energy used to keep the inside air temperature at the desired value. For non air-conditioned rooms, a good thermal performance is achieved by those constructive systems who keep the inside air temperature closer to the comfort temperature.

The thermal performance evaluation can be carried out considering a single component of the envelope (Vijayalakshmi et al 2006, Ozel and Pihtili 2007, Al-Sanea et al 2012, Kontoleon et al 2013, citas) or using software developed to simulate the whole building (Crawley 2008). When simulating a single component, a roof for example, the physical representation would be that all others walls and floor are adiabatic. In the whole building simulation, all walls, roofs, floor, windows are included, even the internal heat gains and activity is considered in the heat balance.

In this work, we present evidence that the walls and roof interact in the heat transfer phenomenon depending on the condition assumed inside (air-conditioned or non air-conditioned). For this, we present the heat transfer analysis obtained using EnergyPlus for two full scale test cells in Torreón, Coahuila, Mexico for two different conditions: air-conditioned and non air-conditioned and the comparison with the heat transfer analysis for a single component of each wall and roof of the test cell. Section 2 describes the numerical simulations for the test cells and single component analysis. In Section 3 the parameters to identify the interaction are presented. The interaction inside the test cells and in the single component is reported in Section 4, and finally we present some conclusions in Section 5.

2. Simulations

The heat transfer analysis is carried out using EnergyPlus(cita) through the walls and roof via the conduction transfer function method. The EPW weather file is created using data obtained from Ener-Habitat (2014). This tool uses a periodic weather and its database contains about 60 cities of Mexico. The weather corresponds for the typical day of the hottest month (May) of Torreón, Coahuila, Mexico. For the air-conditioned room, the inside air temperature is kept at 25 º

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The two test cells are identical, each one has a square base of 2.7m and a height of 2.5m. Because we are interested in the identification of the interaction, there is no infiltration, no internal heat sources, no doors and windows and the floor is assumed adiabatic. Walls and roof of each test cell use the same constructive systems. One test cell is composed on all its walls and roof by a 10cm monolayer of EPS. The other test cell is composed by a two layered constructive system composed by 2cm of EPS in the exterior and 8cm of high density concrete (EPSext test cell). The thermal properties of the materials are listed in Table 1. Both test cells have a solar absortance and emissivity of 0.4. These constructive systems have been selected because the EPSext has been reported with a good thermal performance for non air-conditioned rooms, and the EPS for air-conditioned rooms (Barrios, 2012).

Tab. 1: Thermal properties for the materials employed in the constructive systems for the test cells, EPS and high density concrete (HDC).

Material	Thermal conductivity W/mK	Density kg/m3	Specific heat J/kgK
EPS	0.04	15	1400
HDC	2.00	2400	1000

In order to identify the interaction of the heat transfer between walls and roofs, each wall and roof for each test cell is simulated individually in what we call *single component*. For the simulation of the roof, for example, all walls are set adiabatic, with no thermal mass and with emissivity zero, then we simulate the east wall, assuming all other walls and roof adiabatic, with no thermal mass and with emissivity zero, and so on, until we have the individual simulation of all components.

3. Parameters

The thermal evaluation is carried out considering an air-conditioned or a non air-conditioned room; usually, for an air-conditioned room, the parameter is the total thermal load. For a non air-conditioned room the parameter can be the decrement factor or the energy transmitted through each component (Barrios 2012). In this paper, we use for both (air-conditioned or non air-conditioned room) the heat flux transmitted through each component of the test cell. This can be measured by the Newton's law of cooling for each wall and roof,

$$Q\_c = h\,(Ts - Ti)$$
(eq.1)

where *Q_c* is the heat flux for each component, *h* is the inside convective coefficient, *Ts* is the inside surface temperature and *Ti* is the inside air temperature. Also, we measure the heat flux in all the envelope given by

$$Q\_env = sum\ Q\_c$$
(eq.2)

where *sum* indicates the sumatory over all the components of each test cell. For the *single component*, the *Q_env* can also be defined in the same way, even when all the components do not form a test cell.

1. 4. Interaction

In this section we present a comparison in the heat flux for the test cell and the single component for an air-conditioned and a non air-conditioned room in order to demonstrate the interaction in the heat transfer.

In Fig. 1 we present the heat flux per component considering an air-conditioned room for the EPS test cell at the left, and EPS single component at the right. As can be seen, both heat fluxes are very similar so, for an air-conditioned room, it does not matter if the component is evaluated together with the building or individually. On the other side, from this figure it can be observed that the east wall is the one with the greater heat flux, being positive at sunset. This wall can be identified by the peak in the heat flux passing middle day. The roof can be identified because it has a peak starting at sunrise and ending at sunset. South and north walls exhibit a similar behavior. From the heat flux through the envelope it can be seen that this constructive system, for this climate and setpoint, requires heating energy during the night and cooling energy during the day.

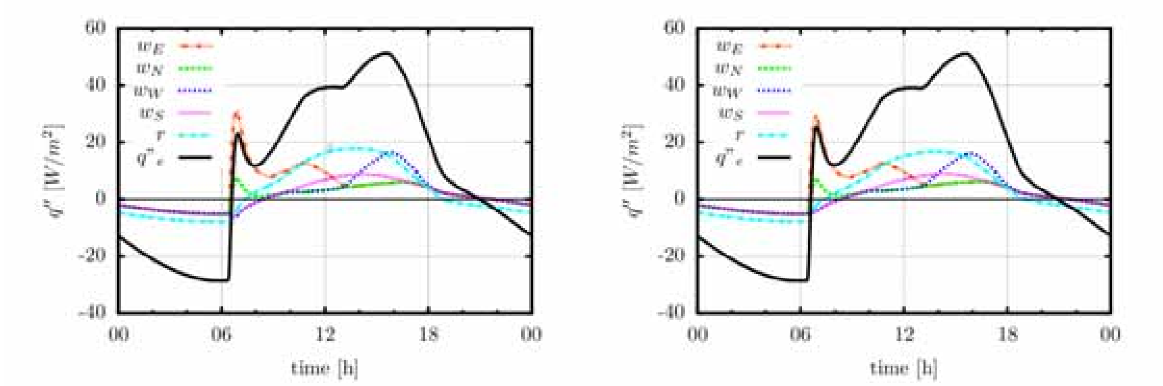

Fig. 1: Heat flux for the east wall W_E, south wall W_S, west wall W_W, north wall W_N, roof r, and all the envelope $q"_e$, for the EPS test cell (left) and EPS single component (right) considering an air-conditioned room.

In Fig. 2 we present the heat flux per component considering an air-conditioned room for the EPSext test cell at the left, and EPSext single component at the right. Again, the behavior of the heat fluxes for each component of the envelope are very similar when analyzing the test cell or the single component. From the heat flux through the envelope it can be seen that this constructive system, for this climate and setpoint, requires cooling energy during all day.

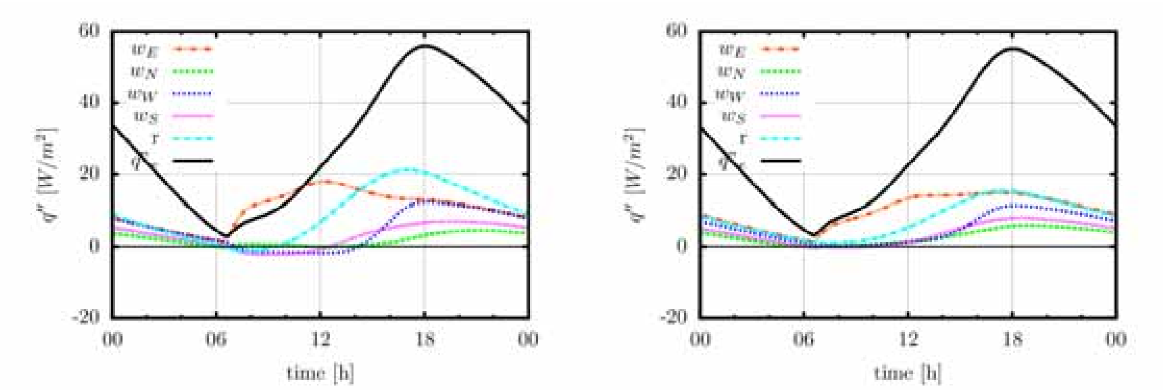

Fig. 2: Heat flux for the east wall W_E, south wall W_S, west wall W_W, north wall W_N, roof r, and all the envelope $q"_e$, for the EPSext test cell (left) and EPSext single component (right) considering an air-conditioned room.

In Fig.3 we present the heat flux per component considering a non air-conditioned room for the EPS test cell at the left, and EPS single component at the right. Under this operation condition (non air-conditioned), the heat fluxes are not the same. When observing the test cell, the heat flux is negative for all components during the sunrise and only becomes positive for the east wall and roof, while all other components keep loosing energy. For the single component analysis, it can be seen that each component follows the next pattern. During the night, the heat flux is negative, but when the sun rises almost all components present a positive heat flux, and after the sunset, the heat flux is negative again. The variations in the behaviour in the heat flux is clearly associated to the incident solar radiation on the surface, which depends on the orientation of the wall or roof. Under this condition, the heat flux through all the envelope is also different than that of the test cell.

In Fig.4 we present the heat flux per component considering a non air-conditioned room for the EPSext test cell at the left, and EPSext single component at the right. Under this operation condition (non air-conditioned room) the heat fluxes, as in the previous case, are not the same. For the single component analysis, it can be seen that each component follows the pattern shown in the previous case for the single component, during the night, the heat flux is negative, but when the sun rises almost all components present a positive heat flux, and after the sunset, the heat flux is negative again. For this climate and constructive system, the roof and the east wall for the test cell case, are the only components with positive heat flux. It can be appreciated that the integral of the envelope heat flux is different for each case, as well.

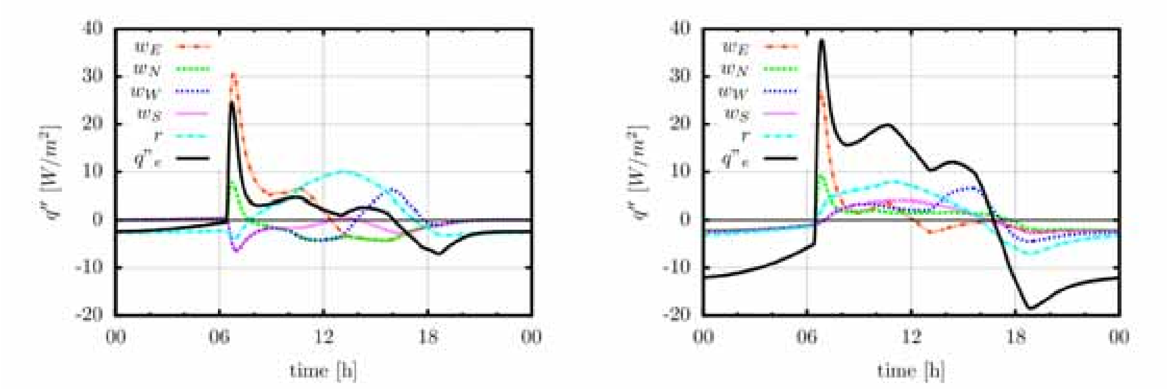

Fig. 3: Heat flux for the east wall WE, south wall WS, west wall WW, north wall WN, roof r, and all the envelope q"e, for the EPS test cell (left) and EPS single component (right) considering a non air-conditioned room.

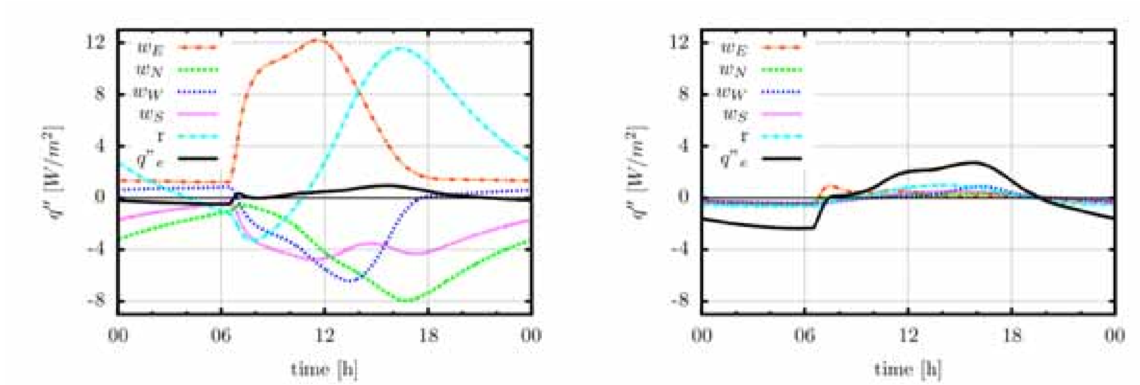

Fig. 4: Heat flux for the east wall WE, south wall WS, west wall WW, north wall WN, roof r, and all the envelope q"e, for the EPSext test cell (left) and EPSext single component (right) considering a non air-conditioned room.

2. 4. Conclusions

We have presented the comparison of two constructive systems, one with a good thermal performance for non air-conditioned rooms, EPSext, and another with a good thermal performance for air-conditioned rooms, EPS. The constructive system was compared with itself in a test cell and in a single component analysis. For the test cell analysis, only the floor was assumed adiabatic and the test cell had no internal heat gains. For the single component analysis, all other components but the one of interest, are considered adiabatic and with zero emissivity. Both analysis were carried out for the hottest month of Torreón, Coahuila in Mexico.

When comparing the test cell and the single component analysis for an air-conditioned room, both analysis are almost identical, using the EPS or the EPSext. This is because each component behaves the same even if it is evaluated in the test cell or in the single component. For non air-conditioned rooms, the test cell analysis is different from the single component. For the single component analysis, all components behave more or less the same; heat flux positive during the day, negative during the night. While for the test cell analysis, it depends of the temperature and thermal load of each component. Usually, the east wall and the roof are the components with the largest heat flux.

Future work includes the quantification of the interaction for the non air-conditioned room and recommendations, if possible, for the selection of the constructive system for each wall to achieve comfort for non air-conditioned rooms.

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