Improving ventilation and envelope characteristics in order to decrease the energy consumption in existing buildings

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ABSTRACT

The building sector represents a great percentage of the total consumption of energy of a country, and of this, most is due to the existing buildings. The great number of existing buildings in comparison with the new buildings, and the worst constructive quality in the first ones, they explain the previous asseveration. It is, therefore, of a primordial importance, to promote measures guided to limit the energy consumption in these buildings, what can be obtained through the rehabilitation of the same ones.

The aim of the paper is to study the improvement of applying global strategies that promote the efficient energy consumption of refurbished buildings.

The first task to solve is the evaluation of the different contributions to the overall energy consumption in a building. Thus, from this study, it can be deduced what kind of rehabilitation proposals have a greater potential of energy saving.

The rehabilitation proposals will consider the use of passive and active systems; these techniques will deal with advanced glazing systems, natural ventilation, active solar systems and PVs, passive cooling techniques, advanced and integrated solar control devices and best integration of the components to the building envelope. These strategies and techniques have already reached a certain level of architectural and industrial acceptance however they have been used independently and for new buildings.

The novel in this paper consists of the study of the different measures individually and then joint in order to obtain the best solution in the rehabilitation of existing buildings.

1. INTRODUCTION

In this paper we will analyse the contribution of each one of the next measures individually. This analysis will give us the potential of each technique as well as the influence of the design parameters.

Knowing this, we will propose global strategies joining together the most interesting techniques with their best design. In order to do this we will describe a real case study based on the refurbishment of an existing settlement. Finally, these global strategies will be evaluated.

2. PASSIVE HEATING AND COOLING ELEMENTS

In this section we will show the improvements on the building energy demand caused by Trombe walls, ventilated envelope elements, and transparent insulation.

In order to compare and determine the benefit after implementing each one of them, we have made an analysis to clarify the behaviour of the alternatives considered, as a function of the principal variables affecting its operation. This analysis has been done following the prEN ISO 13790:2004 on Thermal Performance of Buildings.

2.1 Trombe walls and ventilated envelope elements

2.1.1 Influence of air velocity

For Trombe walls, the air velocity in the layer should be in the range of 0.2 m/s, lower values make decrease the improvement and higher values increases it, but this increment is not important as can be seen in Figure 1.

2.1.2 Influence of the air fraction supplied by the ventilated envelope element

The fraction of air supplied by the element refers to the ratio of air preheated by the element in relation to the total amount of air supplied to the space. Thus, this figure is equal to one if all the air entering the zone has been preheated by ventilated envelope element.

This element, must work to supply exactly the air requirements of the zone, but if the flow rate is superior to this requirement, the improvement decreases faster than if the flow rate is under this point. It means that the optimal operation is when all the air required is preheated by this element, but the space must not have infiltrations neither excesses of provided air by the element.

This behavior is due to the preheated air decreases its temperature with the air flow increment, and because, in general, this air is supplied to the building at lower temperature than the setting point -20ºC in this case-, so if there are more flow, there is more air to be heated by the heating equipment. However, on the other side, it is better to supply the air preheated than at outdoor temperature. Figure 2 shows the losses reduction in this element and their components.

2.1.3 Influence of the U-value of the external layer

Trombe walls and Ventilated envelope elements with internal absorber, works well, if the external element is low U-value, it means that it is better to have double-glazing as transparent external element than simple glazing (Fig. 3). The

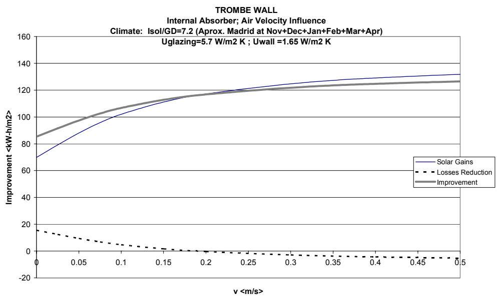

Figure 1: Influence of air velocity in Trombe walls.

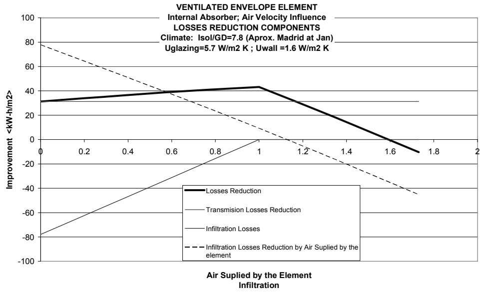

Figure 2: Influence of air velocity in Trombe walls.

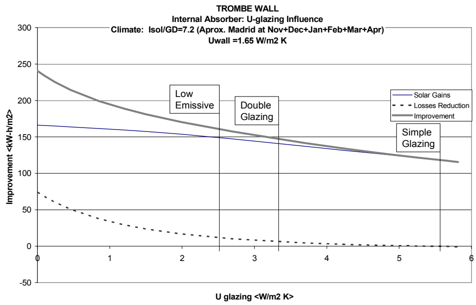

Figure 3: Influence of U-value of glazing in Trombe walls. For ventilated envelope elements the behaviour is very similar.

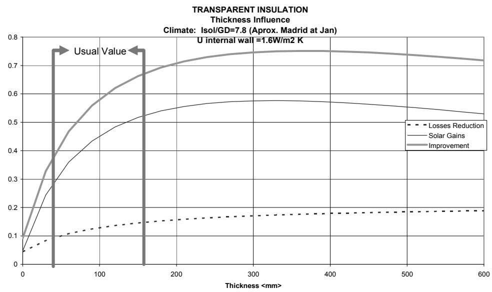

Figure 4: Influence of the thickness of TI layer.

U-value of the internal wall can be maintained without changes.

When Trombe Wall or Ventilated envelope element works with external absorber, there is not an easy rule to determinate the correct U value of this external absorber. In some cases, it is better to have a high U-value, while in other cases, low U-values are better. Thus, it is necessary to verify in each case the best value of the external absorber. As a general rule, we could say that, when the internal element is well insulated, the improvement increases if the U-value of external absorber is high. This behaviour is due to opposite tendencies, by one side, transmission losses decreases if the elements are well insulated; on the other hand, solar gains are poor under these conditions.

2.1.4 Influence of the U-value of the internal layer

For Trombe walls and Ventilated envelope element with external absorber, the U value of the internal wall should be increased, to increase the improvement.

When the absorber is internal, the U-Value of this internal element present an optimum value to maximize the improvement, this is because a high U-value increases both, looses and gains but in different amounts depending on the climate, the U-value and solar gain factor of the external transparent element. This makes that this point must be verified in each particular case. In addition, it is necessary to consider that this element works like a thermal energy accumulator, so the thermal inertia is another characteristic to be taken into account in order to obtain a good design.

2.1.5 Influence of the position of the absorber

The improvement obtained by elements with internal absorbers is approximately twice than elements with external absorbers. This is easily understood by the fact that in the second, a big proportion of the absorbed energy is taken by the external air. The elements with external absorber, can be justified by cost analysis, or because this external absorber has another function, like photovoltaic solar panel.

2.2 Transparent insulation

2.2.1 Influence of the thickness of transparent insulation layer

Transparent Insulation has a theoretical maximum value of improvement at a very wide thickness. This occurs when the sum of losses reduction, plus solar gains reach its maximum value.

If the manufacturing technologies would produce a decrease in the cost of transparent insulation (TI), the optimum thickness could be achieved.

2.2.2 Influence of the U-value of the internal layer

Transparent insulation increases improvement values if the internal wall increases the U-value. It means that, transparent insulation works better with no insulated walls.

2.2.3 Influence of the incident angle of solar radiation

The incident angle of solar radiation affects strongly the behavior of the transparent isolation, so they must have south orientation. The improvement decreases quickly for directions different than south (Fig. 5).

3. TRADITIONAL SOLUTIONS

3.1 Opaque insulation

Opaque insulation shows in general, lower improvement values when it is compared with the previous options. The reason is clearly visible, because these element only acts in the direction of reduce transmission losses, while the others have twice effect, reduce losses and take solar energy. On the other hand this technique does not require solar energy incidence.

3.1.1 Influence of the thickness of insulation

As it is well known, the improvement is asymptotic with the increase of thickness insulation (Fig. 6).

3.1.2 Influence of the climate

Improvement for opaque insulation shows a strong dependency of the climate (Fig. 7). The benefit is higher in cold climates.

3.2 Improve glazing

3.2.1 Influence of the orientation

Change simple glazing for double or low emissive glazing, shows an important improvement that is especially important in cold climates, and

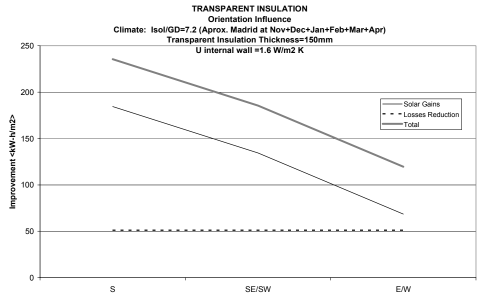

Figure 5: Influence of the angle of solar radiation.

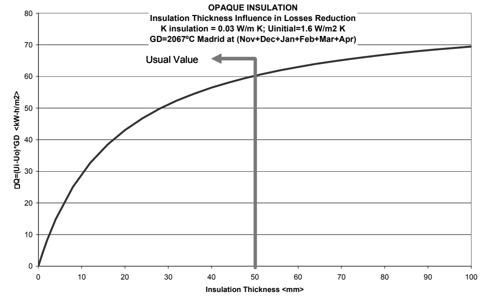

Figure 6: Influence of the thickness of insulation.

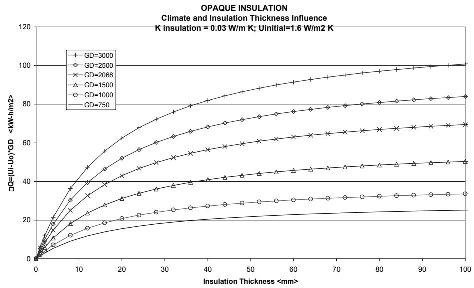

Figure 7: Influence of the climate as a function of degree-days (GD in the figure).

in north directions.

This behavior is the sum of transmission losses and solar gains, so, for north direction solar gains are low because the incidence is diffuse, while the losses are the same than in south orientation. Solar gains in south orientation are compensated partially by the losses, but these gains are affected by the utilization factor strongly than in north direction. The Figure 8 shows the result of changing a simple glazing by a double or low emissive glazing.

4. CASE STUDY

4.1 Case study description

The settlement that we are going to study is located in the district of Villaverde, Madrid, in the centre of Spain, and is called San Cristóbal de los Ángeles. This group of houses was built between the 50’s and 60’s as social dwellings in the frame of a public program.

Figure 9 shows the layout of the blocks with their main axis in the north-south or east-west directions.

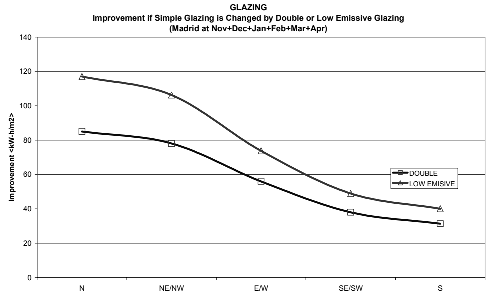

Figure 8: Influence of the glazing orientation.

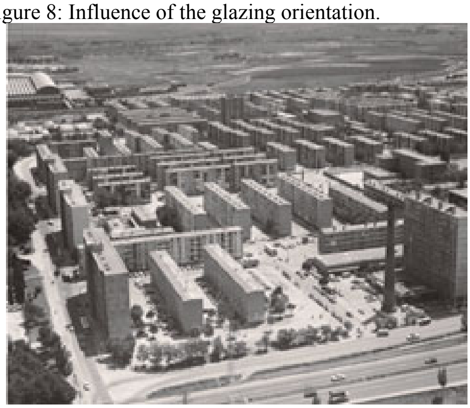

Figure 9: Bird view of the existing settlement.

4.2 Evaluation of present situation

The evaluation of the present situation in terms of energy consumption was done using thermal simulation software developed by the Department of Termotecnia of the University of Seville. This software has the same calculation engine that the official program for the National Building Regulations.

Figure 10 shows an image of the model of the typical building.

Figure 11 shows the energy demand of the building with its main axis to the east-west direction (object building), in comparison with the maximum energy demand allowed by the National standards (standard building).

4.3 Possible global scenarios

Taking into account the analysis developed in the chapters 2 and 3, we can propose the next global scenarios.

4.3.1 Heating scenarios

For the building with its main axis in the north-south direction the three scenarios are: improv-

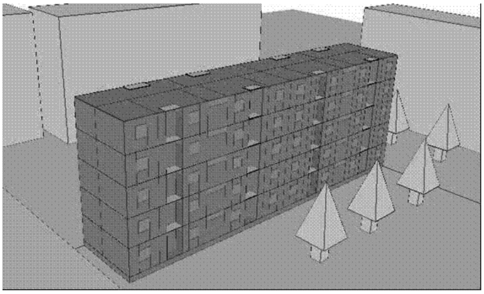

Figure 10: Image captured from the simulation program.

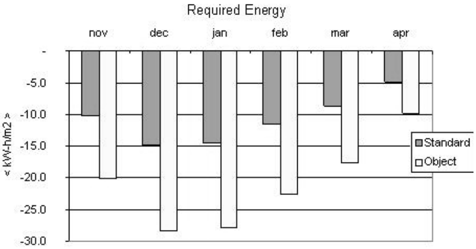

Figure 11: Demanded energy.

ing the glazing, improving the glazing in addition to adding opaque insulation to the walls, and all the previous plus the installation of a Trombe wall in the south gable (Fig. 12).

For the building with its main axis in the east-west direction the three scenarios are: improving the glazing, improving the glazing in addition to adding opaque insulation to the walls, and all the previous plus the installation of transparent insulation in the south façade (Fig. 13).

4.3.2 Cooling scenarios

The use of night ventilation is proposed in order to take advantage of the outdoor temperatures. This measure is useful in summer when the outdoor temperature is lower than the indoor temperature, refreshing not only the air, but also walls and storeys (elements with thermal inertia) making the building less hot than outdoor during the day time thanks to the “heat storage” effect.

This measure can be implemented with or without an electronic device that controls the openings of the windows as a function of the outdoor temperatures, in the present case study this technique is going to be implemented without any kind of electronic control, thus the only requirement will be to open the windows during the night.

Figure 12: Situation of the Trombe wall.

Figure 13: Situation of transparent insulation.

4.5 Evaluation of global scenarios

4.5.1 Evaluation of heating scenarios

Figure 14 shows the reduction in energy demand in each one of the scenarios for the building with its main axis in the north-south direction.

The Table 1 shows the energy savings obtained after the implementation of each one of the global scenarios described.

The Table 2 shows the energy savings obtained after the implementation of each one of the global scenarios in the building with its main axis in the east-west direction.

4.5.2 Evaluation of cooling scenarios

The Figure 15 shows that with 12 Air Changes per Hour, it is possible to reduce the mean temperature of the building in 2ºC for both typologies of buildings. This decrease can be up to 4ºC in the worse zones.

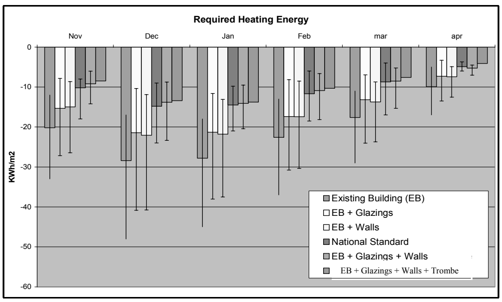

Figure 14: Evaluation of global scenarios.

Table 1: Energy savings.

Scenario	*Energy savings (kWh/yr)*
Improve glazing (G)	32858
Improve walls (W)	31324
National standard	66352
Improve glazing + walls	64182
G + W + Trombe wall	73980

Table 2: Energy savings.

Scenario	*Energy savings (kWh/yr)*
Improve glazing (G)	40435
Improve walls (W)	31925
National standard	64309
Improve glazing + walls	72286
G + W + T. Insulation	93822

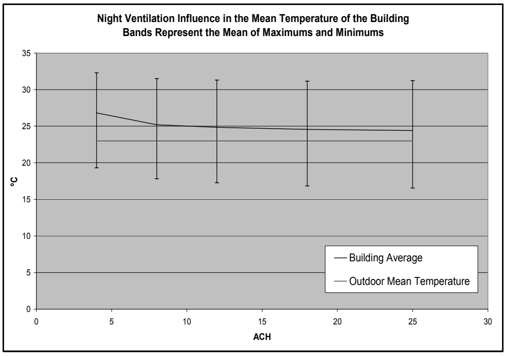

Figure 15: Influence of night ventilation in the mean temperature of the building as a function of the air changes by hour.

5. CONCLUSIONS

Along the development of this work, we have showed that is it possible to study different measures –traditional and passive-individually and then produce design guide-lines of their individual application. Using this guide it is possible to joint several of these "well-designed" measures in order to obtain the best solution in the rehabilitation of existing buildings.

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