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THE INFLUENCE OF STRUCTURAL-FUNCTIONAL CHARACTERISTICS OF PASSIVE HOUSES ENVELOPES ON ENERGETIC PERFORMANCES

R. MOLDOVAN[1] **G. DRAGOŞ**[1]

Abstract: *In view of the ever-growing energy demand, and of greenhouse emissions level, along with the increasing role of building construction structures, the energetic and environmental UE and national policies pursue the growth of their energetic and ecological efficiency. In this line of thinking the promotion of energetically efficient buildings becomes a priority with the initiation of passive houses building. The present paper aims at setting into evidence aspects of increasing energetic efficiency at passive houses enveloping level. Starting from the EU strategic, energetic and ecological objectives and from the passive houses characteristics, a case study has been initiated which pursues the influence of some functional-structural characteristics upon the energetic performances of passive houses.*

Key words: *passive house, envelope, energetic performance.*

1. Introduction

The ever-growing demand for energy and increase in greenhouse gas emissions effect (GHG) within the process of the rapid economic and social development along with the exhaustion of highly polluting primary energy resources, new policies and strategies had to be thought of at the EU-level. These will be focused on a sustainable development, energetic security and competitiveness which are to be carried out through [3,7]:

- An increase of energetic efficiency;
- A rational and efficient use of primary energy resources;
- Encouraging production of energy from renewable sources (RES);
- Diminishing environmental pollution due to greenhouse gas emissions.

The energetic and climatic objectives of EU included in “Europe 2020 Strategy” have in view: improving by 20% the energetic efficiency, the increase of the proportion of renewable sources of energy up to 20% of the total energy consumption and diminishing with at least 20% the GHG emissions as compared with the level of 1990 [6].

A remarkable role in promoting sustainable development of present societies is played by the sector of building constructions. Nowadays, about 40% of the total energy consumption of Europe goes with building sector. In this way about 36% of the total GHG emissions are due to this sector [4].

[1] Faculty of Building Services, Technical University of Cluj-Napoca.

The energetic and ecological objectives have brought about the designing of energetically efficient buildings, which limited their energy consumption by optimizations at envelopes and energy supply level. These will also contribute to diminishing environmental pollution by reducing greenhouse gas emissions and promoting technologies using RES. Among these types of buildings the passive houses are to be remarked.

2. Devising Passive Houses and their Structural and Functional Characteristics

The passive houses represent a top standard in the field of energetically efficient structures which aim at saving energy by strictly limiting consumption together with achieving increased comfort, the use of innovative recyclable building ecological materials and the use of renewable sources of energy.

The standard of passive house (established in 1995 in Germany) focuses on limiting energy consumptions and the provision of thermal and high quality inside conditions.

The maximized standard values are [8]:

- Specific heating demand $\leq$ 15 kWh/m^2 year or specific heating load $\leq$ 10 W/m^2;
- Specific cooling demand $\leq$ 15 kWh/m^2 year;
- Specific primary energy demand $\leq$ 120 kWh/m^2 year;
- Air changes per hour $\leq$ 0.6 (n50).

From the conceptual structural-functional point of view the designing of passive houses is based upon two principles: optimizing their component parts and diminishing losses. For meeting these principles one will aim at securing a compact volume, a proper orientation of building, a good thermal insulation, a proper tightness and heat recovery.

Achieving a compact enveloping by minimizing the S/V (surface/volume) ratio will lead to reducing energy losses to the exterior. It is recommendable that S/V ratio would be contained between 1 and 0.2 [1].

The orientation of passive houses, the sun light and shading have an essential role in minimizing heat losses. It is desired that most window lighted surfaces be southwardly oriented in view of increasing sun heating capacity in cold seasons as well as a possibility of controlling sun heat quantity, avoiding overheating of buildings.

One of the most important characteristics of passive houses is the provision of a high degree thermal insulation in view of reducing losses, in cold weather, to the exterior and in hot weather a reduction of heat flow to the interior.

The global heat transfer coefficients (U) characterizing the losses of heat through the construction elements will have to be limited to the following values [8].

- Wall, roof, floor: U $\leq$ 0.15 W/m^{2}K;
- Doors: U $\leq$ 0.8 W/m^{2}K;
- Windows: U $\leq$ 0.8 W/m^{2}K.

As the opaque elements of envelope are concerned the choice of some good insulating materials is recommended (thermal conductivity as low as possible), with the lowest possible impact upon the environment, or devising solutions of walling of low thermal inertia, with dynamic insulations or solutions dynamically adaptive [2].

For windows the triple glass panes are recommended with two layers of low emissivity, filling the spaces between glass panes with noble gases (Ar, Kr), the use of insulating frames and spacing profiles with warm edge.

The passive houses should be such insulated that the heat losses due to thermal bridges become negligible. In order to avoid the negative effects one recommends not to interrupt the thermal insulation, the windows have to be mounted onto the southern side and the heat loss coefficients φ in these sensitive points should not exceed 0.01 W/mK. Another characteristic of passive houses consists in providing a continuous tightness at the level of the whole envelope in view of avoiding air infiltration, condensation and building deterioration and at the same time diminishing losses of heat to the exterior.

For providing comfort and interior air quality, a system of double-flux mechanical ventilation should be mounted, having heat recovery from the exhaust air (see Figure 1).

This system could be coupled with systems meant to secure the energy needs of the building, such as earth-air heat exchangers (Canadian wells) and heat pumps.

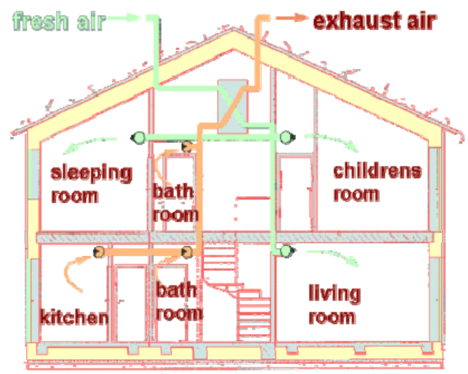


Fig. 1. *Mechanical ventilation with heat recovery in passive house [9]*

3. Case Study. Implementing the Model and Simulation Results

The improvements of energetic performances of passive houses depends on observance of designing and manufacturing principles (optimization of components and diminishing losses), turning to account of the renewable sources of energy and the selection of some efficient systems of energy supply, from energetic and ecological point of view.

In view of finding performant solutions of reducing energetic consumptions for heating and cooling, in conformity with passive houses standards (maximum 15 kWh/m^2 year), a survey was initiated, based on numerical simulations, starting from a model house with the following characteristics:

- Height regime: ground floor + first floor;
- Surface/volume ratio 0.74;
- Useful area 179.2 m^2;
- In view of using the value of solar energy the house was oriented so as most of the glazed surfaces to be on the south; 65% shaded degree;
- The windows with three glass panes and two layers of low emissivity, spacing profiles with warm edges and spaces between panes filled with argon; global heat transfer coefficient U = 0.72 W/m^2K;
- The external walls made of bricks insulated with mineral wool of 30 cm; global heat transfer coefficient U = 0.10 W/m^2K;

- Concrete plate over the last floor and mineral wool of 40 cm; global heat transfer coefficient U = 0.10 W/m^2K;
- Concrete plate over the soil and mineral wool insulation 30 cm thick, global heat transfer coefficient U= 0.11 W/m^2K;
- A mechanical ventilation system was provided with heat recovery (88% efficiency);
- In view of turning into value the geothermal energy a system of ground-water heat pump was chosen;
- The following limit values were imposed: 20ºC for heating and 26ºC for cooling.

The simulations were effected with Casanova Software, for Bucharest Romania. The following values have resulted for the model house:

- heat energy demand 12.5 kWh/m^2an (see Figure 2);
- cooling demand 7.7 kWh/m^2an (see Figure 3);
- primary energy demand for heating and cooling 30 kWh/m^2an (energy flow diagram for heating and cooling see Figure 4). The gains and losses are also set into evidence from the energy flow diagram both for heating and cooling periods.

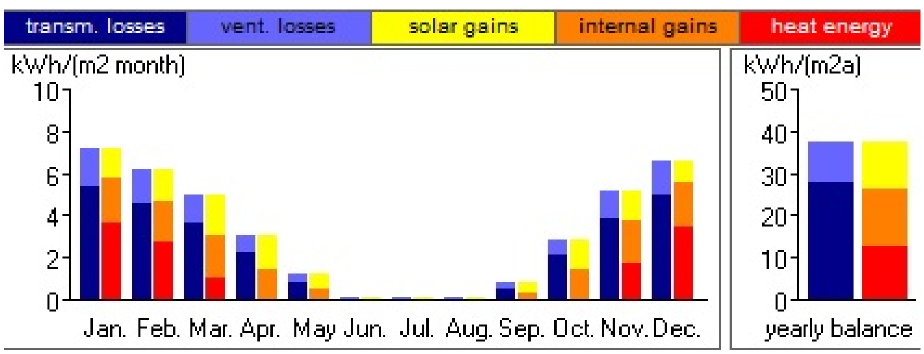


Fig. 2. *Heating energy demand. Monthly and yearly balance [5]*

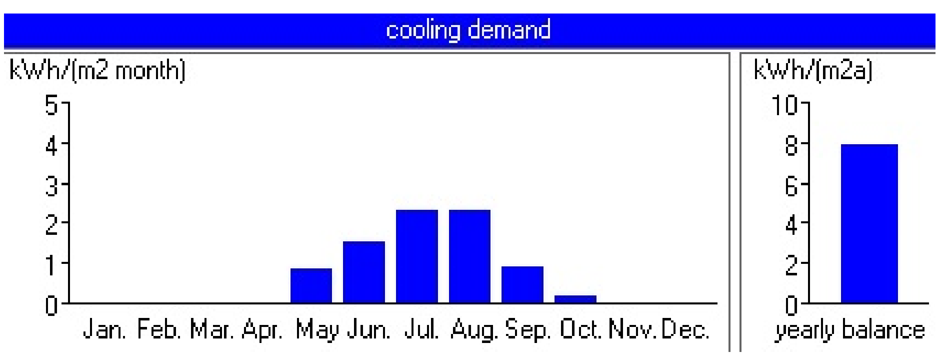


Fig. 3. *Cooling energy demand. Monthly and yearly balance [5]*

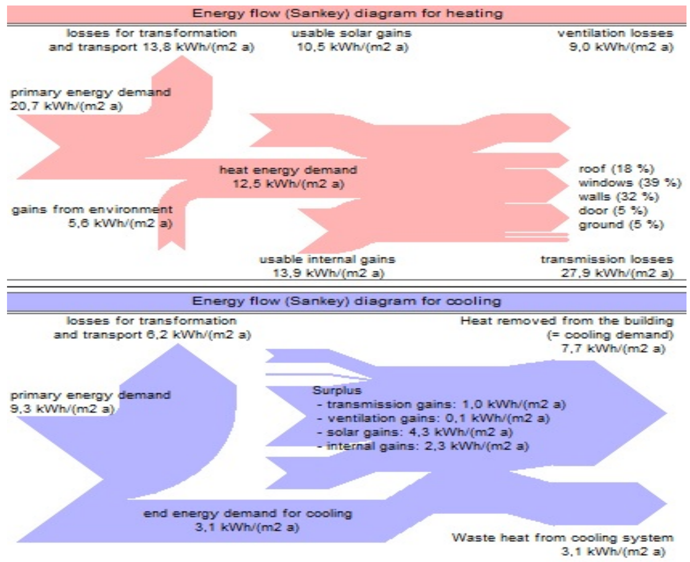


Fig. 4. *Energy flow diagram for heating and cooling [5]*

Starting from the constructive data of model house, the influence of the following parameters were analyzed upon energetic consumptions for heating and cooling:

- Different S/V ratios;
- Different orientations, extents of glazed surfaces, shading degrees;
- Different versions of making the windows characterized by different values of heat transfer coefficient U;
- Different thicknesses of external insulation of walls, plate for the last level and plate over the soil, characterized by different values of heat transfer coefficient U.

Considering that the first step in designing a passive house consists in choosing a project and a compact envelope, the following cases have been analyzed using the same useful surface and the same volume (see Figure 5a):

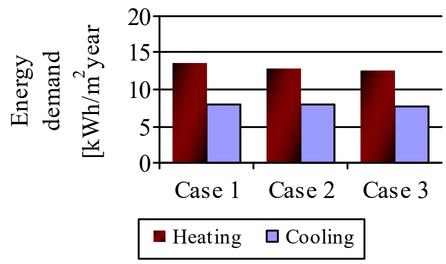
- Case 1: 7x16 m, S/V=0.77;
- Case 2: 8x14 m, S/V=0.76;
- Case 3: 10x11.2 m, S/V=0.74.

As a result of simulations one has noticed that along with decreasing S/V ratio and coming close to a square shape both energy for heating and cooling have been reduced.

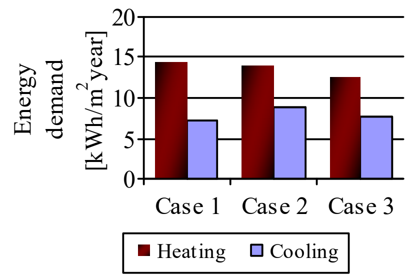
By a proper orientation of the building and a corresponding amount of glazed surfaces, the solar energy will be turned to good account, this passively contributing to diminishing energy consumption for heating and cooling. The influence of orientation and the amount of sunlit glazed surfaces upon energy needs for heating and cooling the model house have been analyzed for the following cases (see Figure 5b):

- Case 1: The small side on north and the following distributions: north 8%, south 11%, east 4%, west 33%;
- Case 2. The small side on north and the following distributions: north 11%, south 8%, east 33%, west 4%;

- Case 3. The long side on north and the following distributions: north 4%, south 33%, east 11%, west 8%.



(a)



(b)

Fig. 5. *The influence of S/V ratio (a) and of orientation and amount of glazed surface (b) upon the energy needs for heating and cooling*

As the simulations showed the orientation of the house with the largest glazed surfaces on the south results in the increase of solar gain thus diminishes the energetic need for heating. Reducing the glazed surfaces on the north, east and west, also leads us to diminishing energy consumption for heating.

In view of reducing the energetic needs for cooling the provision of some shading systems will be necessary. The influence of shading degree upon the change of energy needs for heating and cooling have been analyzed for the following cases (see Figure 6a):

- Case 1: 30%;
- Case 2: 42%;
- Case 3: 50%;
- Case 4: 77%;
- Case 5: 80%.

In conformity with simulations one observes that once the shading degree increases the energy needed for cooling decreases while for heating, increases. In view of limiting energetic consumptions for heating and cooling the model house to a maximum of 15 kWh/m^2 year (in conformity with the passive standards), the solar gains control will be required through adjusting the shading degree within 42%...72%.

One of the most important characteristics of passive houses is the securing of a high standard of thermal insulation at both opaque elements level of envelope and transparent ones (external windows). In a first stage, different constructive versions of windows have been analyzed (see Figure 6b):

- Case 1: double glazing, PVC frames, argon (Ar) interspaces, warm edge spacers, U=1.1 W/m^{2}K;
- Case 2: triple glazing, PVC frames, 2 low emissivity layers, Ar interspaces, warm edge spacers, U=0.72 W/m^{2}K;
- Case 3: triple glazing, wood frames, 2 low emissivity layers, krypton (Kr) interspaces, warm edge spacers, U=0.58 W/m^{2}K.

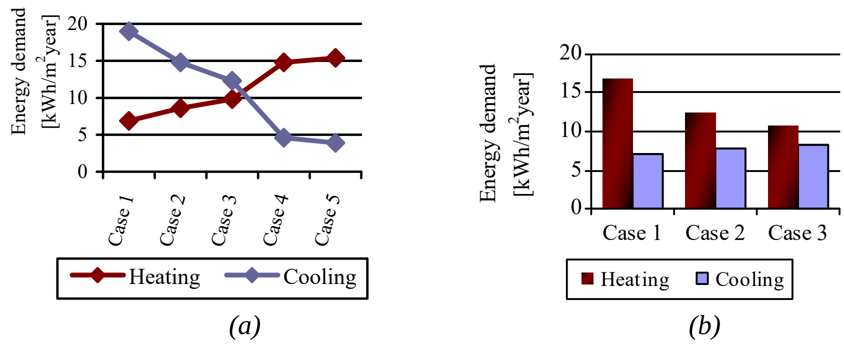


Fig. 6. *The influence of shading degree (a) and of window type (b) upon the energetic needs for heating and cooling*

In conformity with simulations, for limiting energetic consumption for heating and cooling (15 kWh/m^2 year) model passive house, choosing some systems of windows made of three layers of glass panes with two layers of low emissivity will be required. The space between the glass panes will be filled with Ar or Kr and spacing profiles with warm edge, characterized by a heat transfer coefficient U≤0.8 W/m^{2}K.

In the second stage the influence of the external insulation thickness was analyzed at wall level, of the plate over the last level and of the soil plate over the last level and of the soil plate, upon the energetic needs for heating and cooling the model house (see Fig. 7):

- Case 1: thermal insulation at wall, roof, floor slab level 20/25/20 cm, U=0.14/0.15/0.15 W/m^{2}K;
- Case 2: thermal insulation at wall, roof, floor slab level 25/30/25 cm, U=0.12/0.12/0.12 W/m^{2}K;
- Case 3: thermal insulation at wall, roof, floor slab level 25/35/25 cm, U=0.12/0.10/0.12 W/m^{2}K;
- Case 4: thermal insulation at wall, roof, floor slab level 30/40/30 cm, U=0.10/0.10/0.11 W/m^{2}K;
- Case 5: thermal insulation at wall, roof, floor slab level 35/40/35 cm, U=0.09/0.09/0.09 W/m^{2}K.

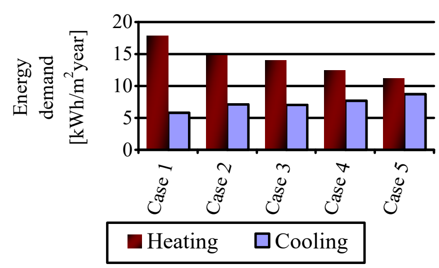


Fig. 7. *The influence of external insulation thickness upon energetic needs for heating and cooling*

As a result of simulations one observes that once the thermal insulation thickness increases at the level of the whole envelope the energy consumption for heating decreases while that for cooling increases. In view of limiting consumption at 15 kWh/m^2 year for the model house, the following thicknesses of thermal insulation will be required: for external walls and soil plate minimum 25 cm and for the plate over the last level (roofing) minimum 30 cm.

6. Conclusions

Starting from the fact that the energetic and ecological performances of passive houses mainly depend on the solutions of making the envelope; in order to limit energy consumption for heating and cooling at 15 kWh/m^2 year, for climatic zone II Bucharest, Romania, the following things are recommended: a shape as compact as possible with an S/V ratio as low as possible; the house should be so oriented that the largest sunlit surface be southward; the provision of shading systems; the use of some materials with the least impact upon environment (wooden window frames, external insulation of mineral wool), the use of and external insulation of minimum 25 cm at wall and soil plate level and minimum 30 cm at roof level; the choice of windows with three layers of glass panes, 2 layers of low emissivity, warm edge spacers and the space between panes filled with Ar or Kr.

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