Case study regarding the energy efficiency of green buildings envelope.

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Abstract. *Green buildings must use materials with a positive impact on the human being and environment while ensuring a high degree of thermal insulation. The structure of the exterior wall proposed by the authors was designed to meet as many requirements as possible: to have good insulating properties and a proper behavior to the diffusion of vapors, to comply with the requirements imposed by regulations regarding the thermal stability of the construction elements, to use environmentally friendly materials and also to have a light weight so that it can be prefabricated or used in modular constructions that require transport and manipulation.*

Key words: green buildings, wall structure, energy efficiency, thermal resistance, heat transfer.

1. Introduction

Considering the two challenges of the present, energy and the environment, the European Union endorsed within the largest research and innovation program Horizon 2020, several directions aimed at solving, at least partially, these problems. We specify that the program runs between 2014-2020 and has the political support of the European Parliament members and European leaders. It aims at international cooperation for smart and sustainable economic growth, provided that the safety of life and human health are respected and improved [1].

Thus, within the program can be identified several directions that refer to the field of construction, such as [1]:

- energy efficiency of buildings;
- construction of smart cities and regions;
- innovations regarding water and its management - as an existential vital source;
- implementation of renewable energies characterized by low CO_2 emissions.

The first of these directions aims at the rehabilitation of existing constructions, the construction of new buildings according to current architectural concepts, updated materials and technologies, as well as performant heating, ventilation, air conditioning and lighting systems, in order to ensure the comfort in buildings, all of these characterized by low energy consumption.

A relatively new concept, which fits very well on the requirements regarding the energy efficiency, which ensures to the habitants' optimal conditions of thermal comfort, having in addition beneficial psychological influences, is represented by the ecological or green buildings.

Ecological buildings represent more than a passive house or a house with low energy consumption. There are several definitions for an ecological building, but we can synthetically say that it is a building constructed and used in a responsible way with respect to the environment, throughout their entire life cycle, starting from the design phase, construction execution, and then on its operation, maintenance, renovation, including the demolition phase [2].

The authors proposed to debate in this paper some aspects regarding the composition structure of the exterior walls of the green buildings - as an integral part of the building envelope, being one of the strategies pursued by the designers of the green building concept.

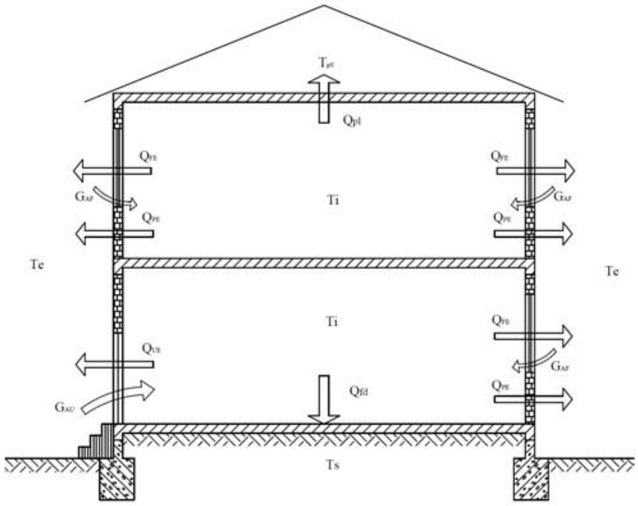
2. Aspects regarding the green building envelope

2.1. Overview about the green building envelope

The building envelope plays a significant role in achieving and maintaining the comfort conditions for a building in general and implicitly for a green building. Exhaustively, this separates the heated volume of the building from elements characterized by different temperatures, such as: outdoor air, soil (on floors in direct contact with the land), placed either above the level of the systemized land terrain or below this level, as well as on the walls in contact with the land), attached rooms of the buildings, not heated or much less heated, separated by the building through walls and / or floors, properly insulated (warehouses, basements or storage rooms, cellars, attics, loggias and balconies closed with exterior carpentry, etc.), spaces that are part of the building but which have other functions or destinations (commercial spaces on the ground floor of residential buildings, offices etc.), respectively other buildings, with adjacent walls separated by the building considered by joints [3].

The heat exchanges, with the exterior, of a residential building envelope can be schematically represented as in figure 1.

Following some statistics on heat loss through the building envelope, resulted that these have the following structure: about 35% through walls, 30% through roofs, 20% through glazed surfaces and about 15% through floors [1]. This information, even for guidance, is useful for having an overview of the choice of materials and solutions related to the envelope elements, so that the energy performance of the buildings can be improved.



Q_{PE} = heat loss through walls;
Q_{FE} = heat loss through windows;
Q_{UE} = heat loss through doors;
Q_{Pl} = heat loss through ceilings;
Q_{Pd} = heat loss through floors;
G_{AF} = cold air infiltration through windows;
G_{AU} = cold air infiltration through doors;
T_i = indoor temperature;
T_e = outside temperature;
T_{po} = attic temperature;
T_s = soil or basement temperature.

Fig. 1. Heat transfer in buildings.

2.2. Physical quantities that characterize the thermotechnics properties of the construction elements

One recalls the fundamental physical quantities to which references are made, when analyzing and characterizing the thermal transfer through the construction elements [3,4,5]:

- Specific thermal resistance [m²K/W] → defines the property of the materials through which the heat is transferred to oppose the propagation of heat losses. In the case of a construction element consisting of several homogeneous layers, it represents the sum of the convective resistances of the fluid media (air) in the vicinity of the element and the actual conductive resistance of the element. This is calculated with the formula:

$$R = R_{si} + \sum R_s + \sum R_a + R_{se} \qquad (1)$$

or explicitly,

$$R = 1/\alpha_i + \sum d/\lambda + \sum R_a + 1/\alpha_e \quad (2)$$

where,
Rsi, Rse represents superficial thermal resistances, calculated according to the direction and sense of the thermal flow (they are given in norms);
Rs represents the resistance of a homogeneous layer of a construction element;
Ra resistance of unventilated air layers;
$\alpha_{i,e}$ - coefficient of superficial surface heat transfer to the inside, respectively to the outside [W/m²K];
d - finished thickness of the wall [m];
λ - the thermal conductivity of the material [W/mK].

- Heat transfer coefficient (or transmittance) [W/m²K], frequently used both in thermotechnics calculations of construction and also in the catalogues of some companies that produce or sell construction materials, represents the reverse of the thermal resistance and is determined with the relationship:

$$U = 1/R \quad (3)$$

It reflects the heat transfer capacity, so the lower the U value is, the lower the transmission losses are.

2.3. Proposed solution for the structure of the exterior walls of a green building

The green buildings do not have special recommended values of the thermotechnical characteristics, they must be within the limits imposed by the standards for buildings with low energy consumption, namely the heat exchanges with the outside to be minimal and to be characterized by a thermal energy requirement below 30 kWh/m^2 year (in passive houses the target is 15 kWh/m^2 year).

To ensure a certain degree of interior comfort, the thermal resistance of the wall must exceed certain minimum values established by calculation, which implies the achievement of the comfort level. More specifically, the following conditions must be met (accomplished):

- avoiding condensation on the interior surface of the wall;
- avoiding discomfort due to cold wall radiation;
- compliance with certain technical-economic principles.

Green buildings must use materials with a positive impact on the human being and environment while ensuring a high degree of thermal insulation.

The concepts of green building and building life cycle are closely linked. The latter can have two approaches: temporal life cycle and physical life cycle. The temporal life cycle can be defined as a succession of events that take place over time while the physical life cycle refers to the flow of materials that transform along the various stages [6].

A wall structure proposed by the authors is presented in 3D representation in figure 2, respectively a section through the exterior wall in figure 3

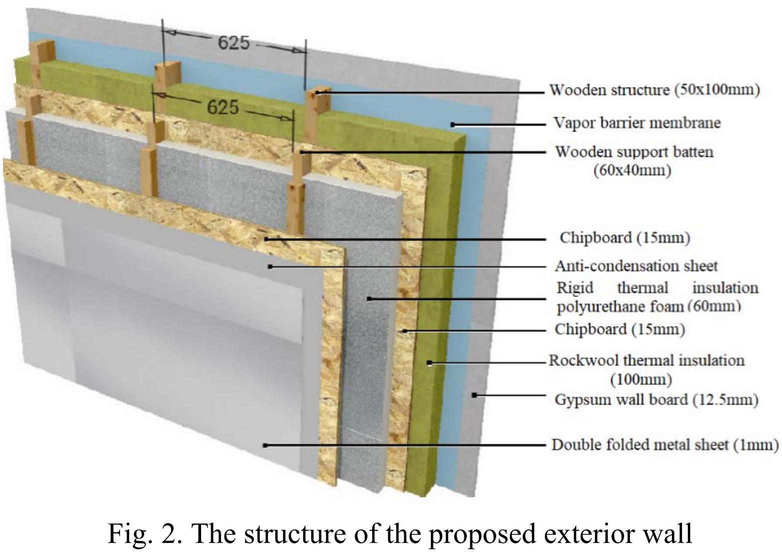


Fig. 2. The structure of the proposed exterior wall

This type of wall was designed for buildings with a light load-bearing structure, which can be made from metal profiles as well or wooden beams and the materials used for the wall structure have high thermotechnical properties even though the thickness of the exterior walls is relatively reduced. It is suitable in this way for modular buildings that must be transported from the place of production to the final site. The authors proposed this structure for a government funded project within the Start Up Nation Project, and besides the conception part - to which the authors contributed, it also benefits of a production line [7].

For the exterior finishing, in the present case, double folded was used, for aesthetic reasons being in accordance with current trends in architecture. In the same time, the metal sheet finishing ensures high resistance and easy maintenance.

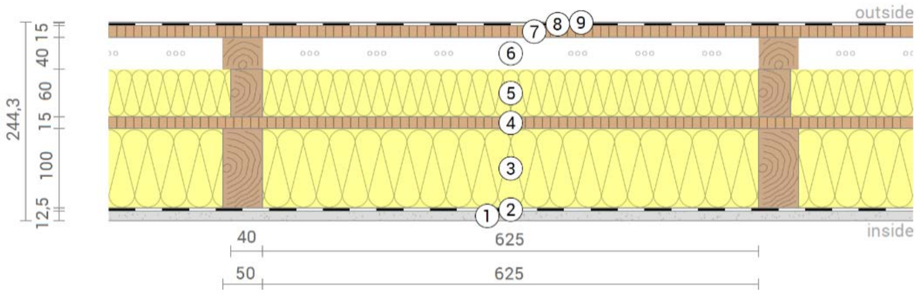


Fig. 3. Cross section through the exterior wall: 1. Gypsum wall board; 2. Vapor barrier membrane; 3. Rockwool thermal insulation; 4. Chipboard; 5. Rigid thermal insulation; 6. Ventilated air layer; 7. Chipboard; 8. Anti-condensation sheet; 9. Double folded metal sheet.

The following table shows the thermo-insulating properties of the materials that make up the outer exterior wall according to EN ISO 6946 [8].

Table 1.

Thermal resistance and conductivity of the wall components

Material	Thickness (cm)	Thermal conductivity (W/mK)	Thermal resistance (m^2K/W)
Thermal contact resistance inside (Rsi)			0.130
Gypsum wall board	1.25	0.350	0.036
Vapor barrier membrane	0.05	0.220	0.002
Rockwool thermal insulation 100mm	10.00	0.038	2.632
Wooden structure 50x100mm	10.00	0.130	0.769
Chipboard	1.50	0.130	0.115
Polyurethane foam	6.00	0.029	2.069
Wooden support batten	6.00	0.130	0.462
Thermal contact resistance outside (Rse)			0.130
Whole component	24.43		

Using the uBakus U-value calculator , a specific thermal resistance R = 4,436 m^2K/W, respectively a heat transfer coefficient U = 0.23 W/m^2K was obtained for the exterior wall in current field. Applying the relations 1, 2 and 3 very close values were obtained. Figure 4 shows the temperature variation in the successive layers of the wall obtained using the U-value calculator [9].

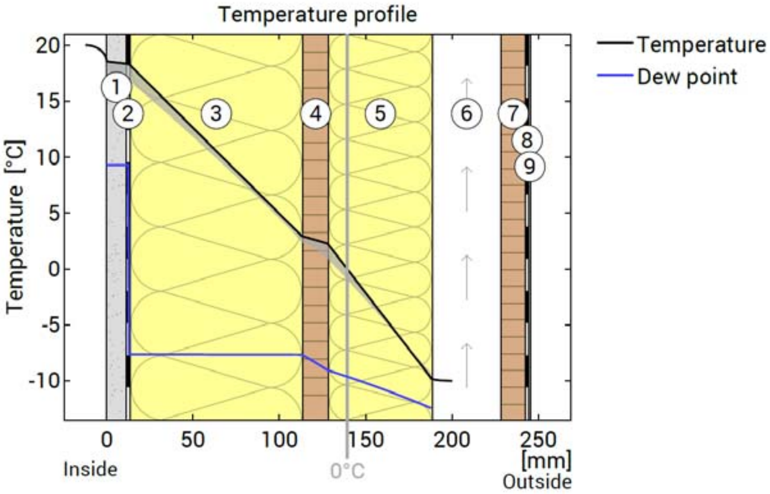


Fig. 4. Temperature variation in the exterior wall [9]

One observes that the temperature of the layers, respectively the temperature variation is above the dew point temperature, so that the solution is favorable, avoiding the occurrence of the structural condensation phenomenon.

Another important criterion which must be verified for an exterior wall is the moisture proofing.

The behavior of the outer wall to vapor diffusion has two components [3,4]:

- dew deposits on the interior surfaces of the construction elements of the envelope in the area of thermal bridges and at corners;
- water accumulation inside the construction element;

The uBakus calculator allows the simulation of the water accumulation behavior inside the constructive elements using the graphical method, as seen in figure 5.

In order to have a proper behavior, it is necessary that the humidity what accumulates in the cold season can evaporate in the warm season. Also, the relative mass humidity must not exceed an allowable value recommended, obviously being below the saturation limit.

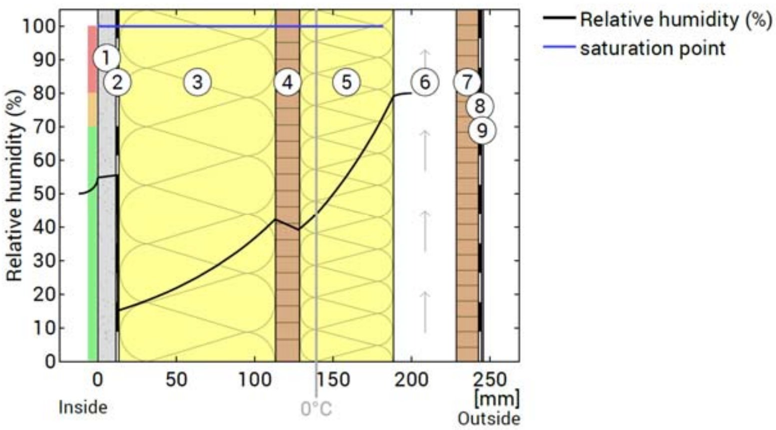


Fig. 5. Water accumulation behavior inside the constructive elements [9]

Another criterion of performance in the hygrothermal design of the buildings is the thermal stability of the closing elements that are characterized by [5]:

- the attenuation coefficient of the amplitude of the external air temperature oscillations;
- the phase shift coefficient of the ambient air temperature fluctuations.

The thermal stability represents the ability to maintain the amplitudes of the indoor air temperature variations and the interior surfaces temperature within permissible limits, required to respect the indoor thermal comfort conditions. This is verified both in winter and in summer. In figure 6, the oscillation of the internal and external temperature in the conditions of the warm season, during one day, was graphically represented. It is observed that the phase shift coefficient is 10.2 hours, which means that the heat wave reaches the maximum value in the first half of the night. One finds that for the group of residential buildings this wall complies with the condition imposed by the norm C107 / 7-2002, which must be at least 9 hours for exterior wall.

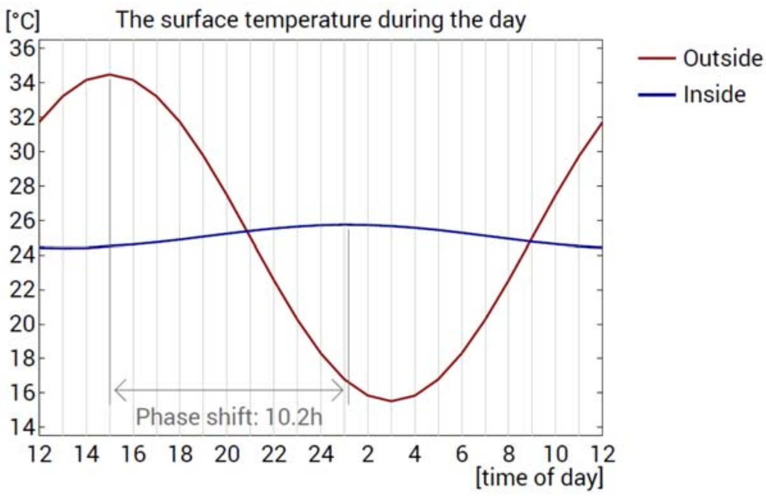


Fig. 6. Oscillation of the internal and external temperature [9]

3. Conclusions

In Romania there has been a reluctance regarding the constructions with wooden structure in the residential buildings. Masonry and concrete constructions were preferred. In the last period, with the implementation of the sustainable development concept, energy efficient houses, respectively green houses have gained the confidence of both developers and customers. This fact is accentuated by the efficiency of achieving the constructions, as well as by the well-being feeling offered to the occupants.

The authors proposed an exterior wall structure that was designed to meet as many requirements as possible:

- to have good insulating properties: ie a high specific thermal resistance, respectively a low thermal transfer coefficient; an important role belongs to the ventilated air layer;
- also, to have a proper behaviour to the diffusion of vapors, not allowing the accumulation of water in the wall structure;
- to comply with the requirements imposed by regulations regarding the thermal stability of the construction elements;
- to have a light weight so that it can be prefabricated or used in modular constructions that require transport and handling; The relatively small wall thickness also contributes to this requirement;
- to use environmentally friendly materials (wood) or which can be recycled or reused.

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