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REDUCING THERMAL ENERGY CONSUMPTION IN EXISTING BUILDINGS

BY

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Abstract. Climate changes, more evident recently, coupled with geostrategic changes to EU borders recommends member states to step up efforts to acquire energy autonomy in a higher percentage. Therefore, EU is trying to increase energy efficiency in buildings and especially by reducing energy consumption for heating and cooling the inner spaces. Performance levels increase in time for achieving the targets on the resources saving specific of the two major steps in 2020 and 2050. Following the last summit of the UN members emerged a third step for 2030 when the share of energy use from renewable resources must reach 40% of total energy consumption. These goals are unachievable without converting existing buildings into "Passive houses".

In this direction, the paper presents an evolution in performance levels for thermal protection, expressed by the minimum required thermal resistance of the envelope elements. It also presents the results of some attempts to bring four residential buildings in Moldavia area of Romania at the "passive house" level of energy efficiency, through additional thermal insulation of envelope elements, without interference with architectural compliance and / or structure of buildings.

Key words: buildings; passive house; energy certificate; thermal insulation.

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1. Introduction

Climate change, more evident recently, coupled with geostrategic changes to EU borders recommends member states to step up efforts to acquire energy autonomy in a higher percentage (IPCC, 2013). European concerns about the impact of reducing energy consumption from fossil fuels have materialized, over time, in legislative measures that impose increasing the thermal protection of buildings and renewable energy exploitation. The targets were set for 2020 and 2050 by two known directives (http://ec.europa.eu/ clima/policies/package/index_en.htm). This year, following UN summit held in New York, a new threshold is set with fixed limits traced for 2030, when at least 27% of total energy consumption must come from renewable resources (http://ec.europa.eu/clima/policies/2030/index_en.htm). The residential sector across Europe, occupies a large share in the energy balance of each country (30%,...,40%) (http://www.europeanclimate.org/...).

Given the fact that most countries from the temperate zone have a poorly thermal protected buildings stock, it was acted in following directions:

a) development of national rules on the level of envelope elements thermal protection, leading to reduced fuel consumption;

b) development of norms regarding the calculation of primary energy specific consumption and energy performance class;

c) the assessment of Energy Performance Certificate as an instrument of buildings energy classification in operational or project phases;

d) development of rules on renewable energy exploitation;

e) studies on passive house.

All these elements intended to lead at reducing energy consumption for heating in winter time and reducing dependence on fuel resources of other countries. In Romania, the path is in the same direction with small gaps caused by the characteristic evolution of the economy and the construction sector.

2. The Reduction of Heating Energy Consumption

In our country the reduction of heating energy consumption is a main objective given the long period of the heating season ($D12 \geq 186$ days) (C 107-2005) and the general evolution of the climate, with extreme maximum and minimum. Dramatic effects are manifested both for power plants and for the users, who are overwhelmed by heating costs.

On the evolution of the thermal protection level are known a series of steps when this parameter was not a mark in the work of buildings design as energy was relatively cheap and subsidized by the state. However, at that time, until 1984, in Romania was more important the concern for structural safety and especially for major earthquakes (Table 1) (Vasilache, 1998).

Table 1

The Evolution of Minimum Thermal Protection Level $R_{o,\mathrm{nec}}$ and R'_{nec}, [m².K/W]

National prescription - Romania		Exterior walls			Roofe terrace		
		Climate zone					
		I	II	III	I	II	III
STAS 6472/61 – $R_{\mathrm{o,nec}}$		0.67	0.73	0.79	0.89	0.97	1.06
STAS 6472 / 68 – $R_{\mathrm{o,nec}}$		0.56	0.62	0.67	0.72	0.78	0.85
STAS 6472 / 75 – $R_{\mathrm{o,nec}}$		0.71	0.77	0.83	0.06	0.16	0.25
STAS 6472/3-89 – $R_{\mathrm{o,nec}}$		0.84	0.92	1.00	1.07	1.18	1.29
NP15/84 – $R_{\mathrm{o,nec}}$		1.16	1.20	1.25	1.46	1.55	1.63
C107/97 R'_{nec}	Until 1/01/1998	1.20	1.20	1.20	2.00	2.00	2.00
	After 1/01/1998	1.40	1.40	1.40	3.00	3.00	3.00
	After 2011 - residential buildings	**1.80**	**1.80**	**1.80**	**5.00**	**5.00**	**5.00**

Between 1984...1997 it start the concerns for energy saving and respectively for improving thermal protection, but with modest results, because the evaluations of thermal resistance takes into account only the structure of envelope elements specific to the current field without the influence of thermal bridges, although there was much research on thermal bridges. In 1997, a fundamental change of vision has occurred with the adoption of C107 series, which address corrected average thermal resistance of the envelope elements, taking into account the influence zones of linear and punctual thermal bridges and presents an algorithm for assessing the thermal protection of the building as a whole, (Table 1). After 1997, it have been made a series of energy auditing works of housing and accommodation aimed at highlighting class energy performance and the need for thermal protection works.

In Europe, the energy crisis of the 70s and lack of major earthquakes showed concern for saving energy in buildings; thus, before 1980, appear the first regulations for standardizing the average corrected thermal resistance of buildings and for minimum required thermal resistance, with the following values:

a) external walls – R'= 2.00...2.50 m².K/W;

b) roofs – R' = 3.30...4.00 m².K/W;

c) windows and exterior doors – R'= 0.55...0.59 m².K/W;

d) elements for less heated areas (hallways, unheated basement etc.) – R' = 2.00...2.50 m².K/W.

After 1997, in our country appear the first pilot buildings with higher level of thermal protection and low heating energy consumption of about 100 kW.h/m^2.y. By increasing the minimum required thermal protection level it has been reduced the specific heating energy consumption to 70 kW.h/m^2.y, specific to the performances class „A” (MC001 – 2009).

Complex calculations that take into account the influence of thermal bridges are based on national standards, developed in line with those developed in France and Germany and on research conducted in Romania regarding climate data, current thermal bridges, evaluation of free contributions, etc.

National thermal modernization programs proved necessary, but in some cases were not fully completed due to lack of interest and lack of occupants involvement.

Specific legislation has evolved greatly on the required level of thermal protection of all buildings that must provide hygrothermal comfort in conditions of rational specific consumptions and for the development of certification and energy auditing work.

3. Passive House. Research and Applications in Europe

EU targets on reducing maximum environmental impact of buildings, in operational phase, caused by the fossil fuel consumption, it referring also at the application of the passive house concept. Research conducted over a period of 21 years showed the following performance characteristics (Casten Grobe & Christian Rienass, 2002).

1º The envelope is very well insulated and thermal bridges are carefully adjusted to arrive at U = 0.12 W/m^2.K (limit values being 0.10...0.15 W/m^2.K), using conventional insulation of 30 cm thickness.

2º Ventilation rate is reduced to the minimum allowable and offset by space occupancy control, air quality and heat recovery from exhaust air.

3º Exploitation of renewable energy.

4º Specific heating energy consumption between 10...25 kWh/(m^2·y).

Passive house projects applied so far in Europe, in different climatic zones, were aimed at achieving minimum energy consumption by using thermal insulation. Economy obtained under current conditions of the Central Europe climatic conditions (Te = –12^{o}C) is 90%. For example, the passive house characteristic studied in Germany, compared with the low-energy house, shows a concern for reducing of all the energy consumptions and the continued growth of the thermal performance of the envelope (Table 2).

The application of passive house projects has some major obstacles, represented by:

a) higher thickness for thermal insulation made of conventional materials (mineral wool, polystyrene) with thermal conductivity of 0.044...0.048 W/mK, about 30...60 cm;

b) important period for amortization of investment in passive house compared to the energy savings obtained, about 20...25 years;

c) punctual details to correct thermal bridges.

Table 2
Energy Performance of the Passive House and the Low – Energy House

	Dwelling type		
Characteristics	G95	LEH	EPH
Annual energy requirements – heating, [kW.h/m^2.y]	50	35	15
Annual energy requirements – ventilation, [kW.h/m^2.y]	15	15	15
Annual energy requirements – DHV, [kW.h/m^2·y]	40	35	15
Total annual energy requirements, [kW.h/m^2·y]	105	85	45
Specific thermal load, [W/m^2]	50	40	20
Corrected thermal permeability U', [W/m^2.K]			
– exterior walls	0.5	0.2	0.1
– ground plate	0.6	0.2	0.1
– roof	0.3	0.2	0.1
– windows	1.4	1.3	0.8

G95 – regulation in Germany 1995; LEH – low energy house; EPH – energy passive house.

4. Achievements in Passive House Field Applied in Romania

The difficulties mentioned above regarding the passive house projects implementation led to reduced number of applications. The first negative impact is the high initial investment followed by constructive solutions with thick thermal insulation above the current applied level. For this reason the concept, although performing, is rarely chosen as a solution by designers and/or beneficiaries.

Research conducted worldwide on insulation materials with thermal conductivity under 0.04 W/m.K can be a opening, if required thermal insulation thickness would be reduced to 10,...,15 cm and still obtaining the overall thermal envelope permeability U = 0.10...0.12 W/m^2.K.

5. Transforming the Existing Buildings Stock Into Passive Houses

Preoccupations for reducing environmental impacts and achieving higher energy classes, close to passive house levels, resulted in the analysis of the real possibilities to turn four existing buildings in passive houses. The objectives are:

a) energy analysis of existing buildings;

b) application solutions of increasing thermal protection level of the envelope;

c) thermal energy analysis of modernized buildings;

d) determining energy class after energy modernization;

e) comparison with a passive house.

It were analyzed four residential buildings with different height, made on locations in different climate zones, respective three individual houses and one collective dwelling, having a height of between 2 and 5 levels. Their characteristics are shown in Table 3, where thermal insulation thicknesses, adopted to reduce the specific consumption of thermal energy, are presented.

Table 3
Individual and Collective Residential Buildings. General Information

Building		Individual dwelling	Individual dwelling	Individual dwelling	Individual dwelling
Buildings height		SB+GF+F	SB+GF+4F	GF+1F	GF+Attic
		SB – heated	GF – comercial spaces		
Emplacement		Iaşi (III)	Vrancea	Roman	Rădăuți
$N_{12}^{\theta i}$, [K.days]		3510	3350	3700	4080
1.	Exterior walls above ground + thermal insulation	Hollow bricks masonry +20 cm ins.	AAC masonry. and concrete +20 cm ins.	AAC masonry.. +20 cm ins.	Hollow bricks masonry +30 cm ins.
2.	Sub-base walls	Reinforced concrete +15 cm ins.	–	–	–
3.	Slopping -roof	+40 cm ins.	–	30 cm ins.	30 cm ins.
4.	Roof Terrace	+45 cm ins.	+ 60 cm ins.	–	
5.	Ground plate (lower floor)	+15 cm ins.	50 and 20 cm ins.	15 cm ins.	+30 cm ins.
6.	Exterior Joinery	Stratified wood + 3*g* + 2 e-low	PVC + 2*g* e-low	Stratified wood + 3*g* + 2 e-low	Stratified wood + 4*g* + 2 e-low
1.	Exterior walls above ground, [m^2]	264	626	177,23	196
2.	Sub-base walls, [m^2]	38.9	–	–	–
3.	Slopping –roof, [m^2]	90.3	–	87.13	91.5
4.	Roof Terrace, [m^2]	46.7	260	–	–
5.	Ground plate (lower floor), [m^2]	90.3	260	87.13	106.35
6.	Exterior Joinery, [m^2]	56.0	90	37.12	26.97
Heated volume, [m^3]		691	2,096	531.52	476.02
Heated surface, [m^2]		224	767	174.3	176.33

Solutions proposed included the adoption of the thermal insulation (with λ = 0.04...0.05 W/mK) of 20...30 cm in the outer wall, 30...60 cm in the roof structure, 15...50 cm to the lower floor and exterior joinery with R = = 0.55...1.50 m^{2}K/W.

Were determined:

a) unidirectional thermal resistance *r*, [m^2.k/w];

b) average thermal resistance corrected with the effects of thermal bridges *r*, [m^2.k/w];

c) global coefficient of thermal insulation *g*, [w/m^3.k];

d) annual heating energy requirements, [kW.h/m^2.year];

For the comparative analysis it was considered the condominium building, placed in Vrancea with five levels occupied by dwellings with favourable compaction (A/V = 0.59 m^{-1}). In table four the thermal protection criteria used for the very low energy house are presented, seeing that it is very hard to accomplish a thermal resistance *R* or *R′* close to 10 m^2.K/W.

The results are shown in Table 4. It is noted that the use of high thickness of thermal insulation is not sufficient to achieve the level of passive house, being necessary also to reduce heat loss through space ventilation. However, this cannot be achieved by reducing ventilation rate, with direct effect on indoor air quality, the renewal of the air is a condition more than necessary to maintain comfort, but rather by increasing the outdoor air temperature introduced in rooms and heat recovery of the exhaust air.

Table 4

Energy and Thermal Performance of Analyzed Buildings

Buildings		Individual dwelling	Individual dwelling	Individual dwelling	Individual dwelling	P.House criteria
Buildings Height		SB+GF+F	SB+GF+4F	GF+1F	GF+Attic	SB+GF+4F
Unidirectional thermal resistance $R = R_o$, [m^2.K/W]						
1.	Exterior walls above ground	7.24	5.5	6.87	8.97	–
2.	Sub-base walls	5.80	–	–	–	–
3.	Slopping -roof	9.70	–	8.26	9.54	–
4.	Roof Terrace	12.21	14.36	–	–	–
5.	Ground plate (lower floor)	6.84	11.02	6.96	8.02	–
6.	Exterior Joinery	–	–	–	–	–
Corrected thermal resistance *R′*, [m^{2}K/W]						
1.	Exterior walls above ground	4.47	2.8	3.51	4.1	4.5
2.	Sub-base walls	3.5	–	–	–	–
3.	Slopping -roof	5.1	–	6.71	6.44	–
4.	Roof Terrace	9.8	5.30	–	–	6
5.	Ground plate (lower floor)	5.9	3.71	5.32	6.0	6
6.	Exterior Joinery	1.25	0.55	1.25	2	1.5
Ventilation rate *n*, [1/h]		0.50	0.50	0.50	0.50	0.5
G, [W/m^3.K]		0.383	0.36	0.373	0.36	0.269
G_N, [W/m^3.K]		0.49	0.45	0.54	0.54	0.45
Annual heating energy requirements, [kW.h/m^2.y]		**46.32**	**40.60**	**72.3**	**43.2**	**20.3**
Energy Class (Mc 001)		**A**	**A**	**B**	**A**	**A**

7. Conclusion

The reduction of heat loss of building was achieved by obtaining relatively high corrected thermal resistance of 2.8,...,4.41 m^2.K/W for the wall, 5,...,6 m^2.K/W for the roof, 3.7,...,6 m^2.K/W on the lower floor and 0.55,...,1.50 m^2.K/W for windows. Insulation thicknesses adopted are the one recommended for our country. It is worth mentioning that was not sufficient to achieve a passive house level. Performance class obtained corresponds to the current classification and can recommend some buildings for low-energy category. Romania is characterized by long heating season which requires higher thermal resistance of the envelope elements than Germany or France. A negative impact it was the very large volume of thermal insulation required for conventional insulation with thermal conductivity λ = 0.04,...,0.05 W/m.K. Introducing on the construction market of superior materials with $\lambda \leq 0.01$ W/mK could help implement this concept in Romania. The level of protection required exceeds the limits used in our analysis and it is situated at the one presented in Table 2.

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REDUCEREA CONSUMULUI DE ENERGIE TERMICĂ ÎN CLĂDIRI DE LOCUIT EXISTENTE

(Rezumat)

Schimbările climei, din ce în ce mai evidente, dublate de modificările de natură geostrategică la granițele Uniunii Europene recomandă accelerarea eforturilor statelor membre în vederea dobândirii unei autonomii energetice într-un procentaj cât mai ridicat. În acest sens, se încearcă creşterea eficienței energetice în domeniul construcțiilor şi în special diminuarea consumului de energie pentru încălziea sau răcirea spațiilor. Nivelurile de performanță cresc în timp pentru a conduce la îndeplinirea țintelor privind economia de resurse specific celor două praguri din anii 2020 şi 2050. În urma ultimului summit al țărilor membre ONU s-a conturat un prag pentru anul 2030 când ponderea utilizărilor energiilor provenite din resurse regenerabile trebuie să ajungă la 50% din consumul total de energie. Aceste deziderate sunt imposibil de îndeplinit fără transformarea clădirilor existente în „Case passive”.

Pe această direcție, lucrarea prezintă o evoluție în timp a nivelurilor de performanță privind protecția termică, exprimate prin valorile minime impuse rezistențelor termice ale elementelor de anvelopă. De asemenea, sunt prezentate rezultatele unor încercări de a aduce patru clădiri de locuit din zona Moldovei la nivel de „Casă pasivă”. Se menționează faptul că încercările fac parte din cercetările unor masteranzi ai Facultății de Construcții şi Instalații din Iaşi, publicate în lucrările lor de disertație.