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THERMAL ANAYSIS OF A VENTILATED NON-HOMOGENOUS LIGHT WOOD FRAME WALL

BY

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Abstract. Light wood framed buildings and elements are very popular in the construction of homes in the United States and some parts of Europe but they have been less used in Romania. Therefore there is a few data about their thermal behaviour in thermal conditions of our country and no catalogue of thermal bridges for these type of structures is available.

This article presents the thermal analysis of a wood frame wall panel with an exterior ventilated wood cladding from thermal pre-dimensioning to thermal analysis using RDM6 and Fluent 6.3 software.

The adjusted thermal resistance has been determined using different methods and obtained results have been compared. The existence of free convection inside the channel has been highlighted in both the warm and cold seasons.

Key words: wood frame wall; thermal analysis; ventilated channel; energy efficiency.

1. Introduction

1.1. Details of the Building

The analysed building is a parish house located in the Copou area of the city of Jassy, Romania, having a 271.45 m^2 footprint and a height regime of B + GF + 1F.

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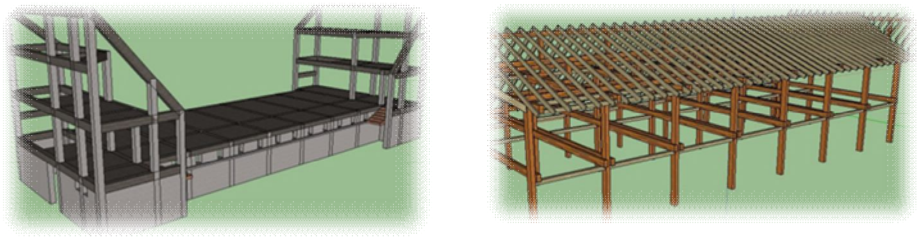
The structural members consist of the following (Fig. 1):

a) basement – reinforced concrete spatial frames and perimetral reinforced concrete shear walls;

b) ground and 1st Floor – outer reinforced concrete spatial frames and inner frame structure made of glue laminated timber;

c) monolith reinforced concrete slab over basement;

d) roof made of glue laminated timber and metal sheets covering.



a *b*

Fig. 1 – Structural spatial frames made of *a* – reinforced concrete and *b* – glue laminated timber.

The enclosure elements are:

a) basement – reinforced concrete shear walls and autoclaved cellular blocks;

b) ground and 1st Floor – autoclaved cellular blocks masonry between reinforced concrete columns and light wood frame walls.

1.2. Details of the Wood Frame Wall

The wood frame walls are non-load bearing walls that serve only for functional partitioning or enclosing towards the exterior. These walls take only their own weight and lack continuity on the height of the building. They can be suppressed without harming the integrity of the rest of the structure.

The computation will be made on a typical wall frame (Fig. 2) located between two glulam columns with no window openings. The frame height is considered between the upper wood beam of the frame and the reinforced concrete beam component of the basement structure.

A typical cross-section of the wall, in horizontal and transversal cross-section is presented in Fig. 3, where: *1* – gypsum board; *2* – water vapor barrier; *3* – mineral wool; *3'* – sill; *4* – chipboard panel; *5* – breathable foil; *6* – wood strip (2 cm thick); *7* – wood boards jointed tongue and groove.

The structural analysis was performed in the ultimate limit state and serviceability limit state (according to Eurocode 5). The wood non-load bearing frame wall and its elements (wood panels, strips, studs and plates) fulfilled the requirements of mechanical resistance set up in “Law no. *10*/1995 (amended by Law no. *123*/2007)”.

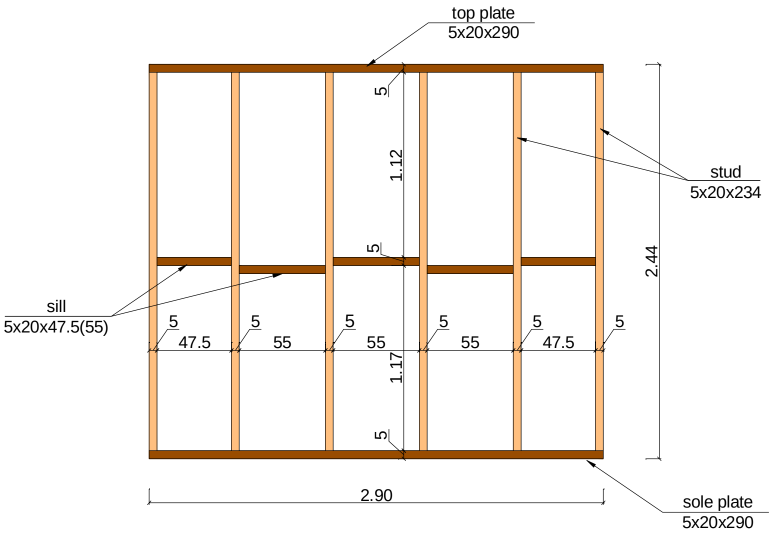


Fig. 2 – Structure of a typical wall frame.

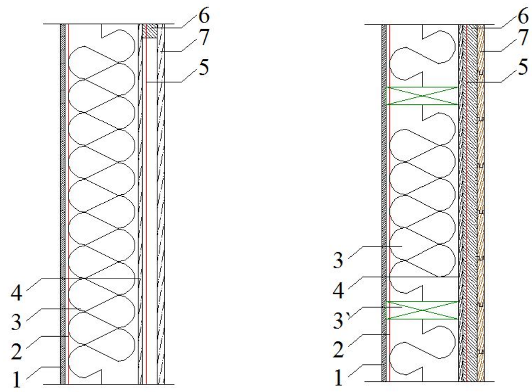


Fig. 3 – Typical cross-section:
a – transversal; *b* – horizontal.

2. Thermal Analysis

2.1. Thermal Pre-Dimensioning

According to Romanian Norm C107/1-2005 (Annex E), an air layer is considered to be very well ventilated if the inlet area exceeds 1,500 mm^2 / linear meter. If so, the 1D thermal resistance calculus will not take into account thermal resistance of the air layer nor the thermal resistance of the outer wood cladding. The exterior superficial thermal resistance will be equal with the corresponding interior superficial thermal resistance.

In the pre-dimensioning stage, the adjusted thermal resistance of the frame wall is computed as geometric mean, using the 1D thermal resistance of the constitutive elements and their corresponding area. The adjusted thermal resistance is determined by the equation:

$$R' = R_1 \cdot \%A_1 + R_2 \cdot \%A_2 , \quad (1)$$

where: R_1 is 1D thermal resistance through the mineral wool, [m^2.K/W]; $\%A_1$ – mineral wool percentage from the total area of the wall; R_2 – 1D thermal resistance through studs (sills), [m^2K/W]; $\%A_2$ – studs (sills) percentage from the total area of the wall.

Consequently, the 1D thermal resistance will be computed on two different cross-sections, through the mineral wool and the studs or sills (Table 1). Afterwards the corresponding areas A_1 and A_2 are computed.

Table 1
Determination of 1D Thermal Resistance

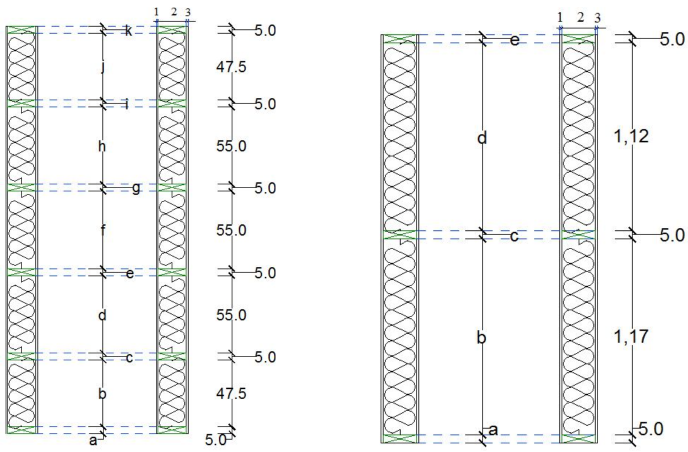
No.	Layer	Thickness d, [m]	Thermal conductivity λ, [W/m.K]	Thermal resistance R, [m^2.K/W]
	Interior-facing surface			0.125
1.	Gypsum board	0.0125	0.41	0.03
2.	Water vapor barrier	0.003	–	–
3.	Mineral wool	0.20	0.04	5.00
3’.	Stud (sill)	0.20	0.17	1.17
4.	Chipboard panel	0.012	0.13	0.09
5.	Breathable foil	–	–	–
6.	Ventilated air layer	0.02	–	–
7.	Wood panels	0.02	0.17	–
	Exterior-facing surface			0.125

The adjusted thermal resistance of the frame wall becomes:

$$R' = 5.37 \times 84.14\% + 1.55 \times 15.86\% = 4.76\ \text{m}^2.\text{K/W}.$$

Norm C107/2005 gives a simplified method for determining the adjusted thermal resistance of a non-homogenous construction element that is based on the division of the element in layers, parallel with its faces and in zones, perpendicular to it.

For the considered wall frame, the layers and zones used in the calculus are presented in Fig. 4.



a *b*

Fig. 4 – Different layers and zones from the simplified method in:
a – horizontal; *b* – transversal cross section.

The adjusted thermal resistance is computed with the 1D thermal resistance of each homogenous layer for both horizontal and transversal cross-sections. The resulted total value is obtained as a geometric mean on the height and width of the wall

$$R' = \frac{4.21\times 2.90 + 4.60\times 2.44}{2.90 + 2.44} = 4.38\ \text{m}^2.\text{K/W}.$$

2.2. RDM6 Computer Simulation Program

RDM6 software was used to run a thermal analysis on the wood frame wall and temperature distributions and thermal fluxes under steady-state loading conditions have been obtained.

The FEM model of the wall is presented in Fig. 5.

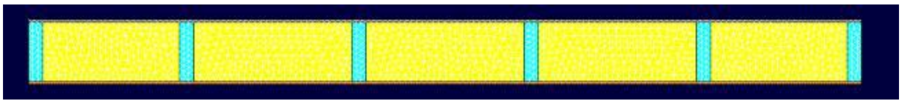
The adjusted thermal resistance of the wall is computed using:

$$R' = \frac{\Delta T}{q}, \tag{2}$$

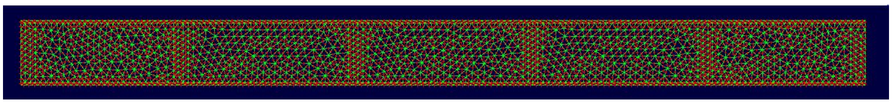
where: ΔT is the indoor-outdoor temperature difference, [K]; q – average heat flux through the cross-section obtained using RDM6 software, [W/m^2].

As previously mentioned, the adjusted thermal resistance is computed as a geometric mean on the height and width of the wall:

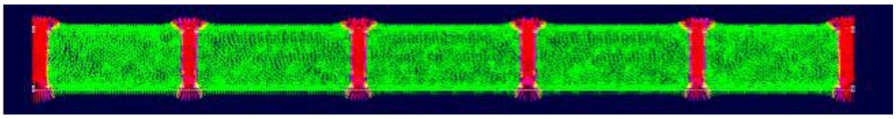
$$R' = \frac{4.16\times 2.90 + 4.40\times 2.44}{2.90 + 2.44} = 4.30\ \text{m}^2\text{K/W}.$$



a



b

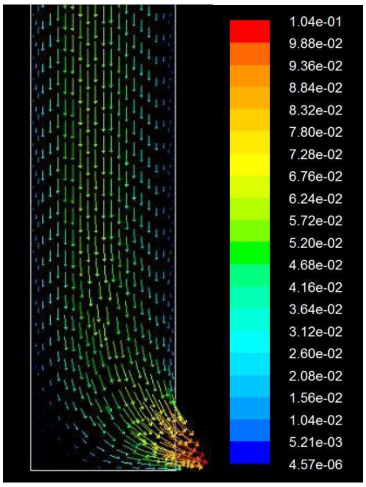


c

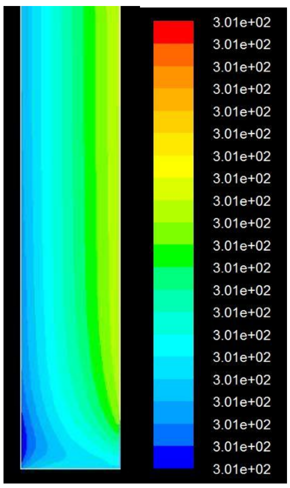
Fig. 5 – Computer simulation of the horizontal section: *a* – model components; *b* – discretization of the element; *c* – heat flux density.

2.3. Airflow Analysis

A ventilated wall system is obtained when the outer wood cladding is spaced from the insulation layer, yielding a space that allows air movement



a

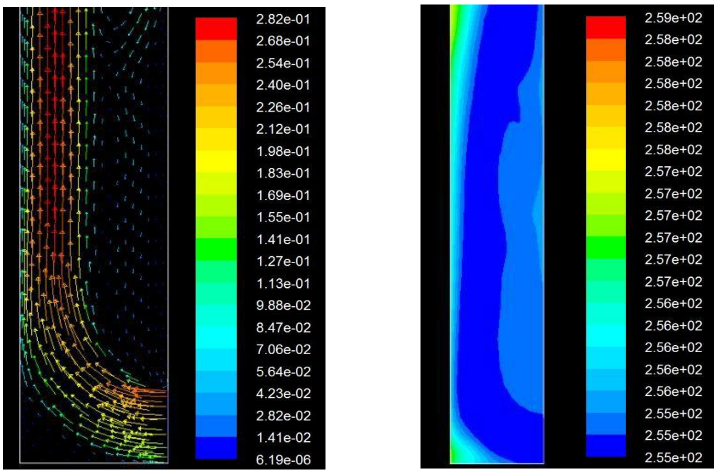


b

Fig. 6 – *a* – Velocities vectors and *b* – temperatures distribution at the lower level of the channel in summer.

upwards, causing, in summer, the removal of accumulated heat under the influence of sunlight, while ensuring in winter the ventilation and drying of thermal insulation by preventing condensation inside the wall structure.

In winter, the obtained velocities have greater values than in summer due to much bigger temperature differences that lead to a greater and more turbulent flow (Fig. 7).



a *b*

Fig. 7 – *a* – Velocities vectors and *b* – temperatures distribution at the lower level of the channel in winter

Airflow analysis is required in order to evaluate if the type of construction system allows free air movement inside the channel. If unrestricted flow exists, than the channel is considered to be very well ventilated and the thermal computation will be made accordingly to Norm C107/1-2005 (Annex E).

4. Conclusions

Thermal analysis of a non homogenous wall is a laborious task especially if the linear heat transfer coefficients cannot be taken from thermal bridges catalogues. The "simplified method for determining the adjusted thermal resistance of non-homogenous building elements" proposed by Romanian norms is time consuming but has a good reliability, with differences of 1.8% compared to RDM6 obtained values. The approximate method used in the pre-dimensioning stage had an error of 8.68%, making it a less reliable but a faster analysis tool.

The computational fluid dynamic software – FLUENT 6.3 has shown that ventilation occurs inside the channel, as characterized by the values of the flow parameters: air velocity and temperature.

It can be said that the ventilated frame wall system represents a very good solution for the perimetral enclosure of buildings because:

a) it corresponds in terms of structural strength and stability requirements;

b) it allows the structural members to behave as a spatial frame without introducing additional stiffening;

c) it reduces energy consumption by providing good thermal protection;

e) has a much higher durability than the usual wooden walls as ventilation permanently maintains the wall and the glulam columns in a dry state, keeping their physical properties in the original state;

f) it is easy to put into work.

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ANALIZA TERMICĂ A UNUI PERETE NEOMOGEN CU STRUCTURĂ UŞOARĂ VENTILATĂ

(Rezumat)

Clădirile şi elementele din lemn de tip „framing” sunt des utilizate în construcția caselor atât în Statele Unite ale Americii cât şi în unele părți ale Europei dar sunt mai puțin utilizate în România. Prin urmare există puține informații legate de eficiența lor energetică în condițiile climatice ale țării noastre. Mai mult, nu există cataloage de punți termice care să ofere coeficienții liniari de transfer termic pentru astfel de structuri.

Acest articol prezintă analiza termică a unui panou de perete neomogen cu structură uşoară ventilată plecând din faza de predimensionare şi continuând cu partea de simulare numerică cu ajutorul programelor de calcul RDM6 şi Fluent 6.3 şi de calcul prin metoda simplificată propusă de Normativul C107/2005.

Rezistența termică corectată a peretelui a fost determinată folosind metode diferite iar rezultatele au fost comparate. A fost evidențiată curgerea aerului în interiorul canalului atât în sezonul cald cât şi în cel rece.