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Y. S. Biks
O. G. Ratushnyak

ATTITUDE FOR ENERGY PERFORMANCE ASSESSMENT OF MULTILAYERED ENVELOPES

Vinnytsia National Technical University

Abstract

This study introduces the thermal performance criterion $C_{TPunsteady}$ *and* $C_{TPsteady}$ *as the parameters combining energy-efficiency evaluation for multilayered wall assemblies assessment for steady and unsteady-state. The proposed criteria focus on physical characteristics such as wall width, mass, internal heat capacity and u-value. The research identifies the "best" wall configuration, based on the* $C_{TPunsteady}$ *and* $C_{TPsteady}$ *criteria, as a 375 mm AAC D300 wall with Rockwool insulation. In contrast, the least efficient assembly was Wall type C, consisting of a 1300 kg/m³ brick wall masonry with Rockwool insulation. The paper highlights the importance of complex consideration of physical and thermal influencing factors for thermal performance assessment.*

Keywords: steady-state, unsteady-state, thermal performance, wall assemblies, the best alternative

Introduction

The many building materials and construction techniques in modern construction practice grab the attention of multicriteria decision analysis (MCDA) methods [1, 2]. The problem of the "best" choice from a wide variety of current energy-efficient envelopes on the building market is still challenging, not only regarding financial benefits [3, 4]. On the other hand, the" best" alternative is always a complicated mission due to the compromise for picking up the "best" alternative. The word best is taken in quotes here because, with a multicriteria evaluation of other real-life options, the alternatives belonging to the Pareto set could only be considered the "best" optimal alternative [5].

In the attempt to choose physical criteria that could easily be calculated in the predesign stage of the building construction, there were taken such criteria of thermal transmittance (*u*-value, W/m^{2}K) as the steady-state parameter, mass (*m*, kg/m^2) and internal area heat capacity (kJ/m^{2}K) as dynamic, unsteady-state thermal performance parameter under EN ISO 13786 [8] for the assembly comparison.

The calculation of the *u*-value proceeded according to the formula [6]:

$$u = \frac{1}{R_{tot}} = \frac{1}{\frac{1}{\alpha_{int}} + \sum \frac{\delta i}{\lambda_i} + \frac{1}{\alpha_{ext}}} \qquad (1)$$

where δ_i – the width of the *i*-th material;

R_{tot} – the total thermal resistance of the assembly;

where α_{int} is the heat transfer coefficient of the internal surface of the wall, α_{int} = 23 (W/m^{2}K) [6];

α_{int} is the heat transfer coefficient of the external surface of the wall, α_{int} = 8.7 (W/m^{2}K) [6];

The internal heat area capacity (kJ/m^{2}K) as a dynamic thermal characteristic was calculated using a downloadable Excel spreadsheet from HTflux [8].

The main scope of the present research is the attempt to determine the probable set of "best" alternatives from the set of possible parameter combinations. The current study should consider the restrictions on optimal assembly search solutions. As the countable restrictions, those parameters were considered such parameters as wall mass and u-value, which meets the national thermal resistance requirement, R = 4.0 W/m^{2}K for the first temperature zone of Ukraine [7] and wall width. The Excell Solver tool was used in the current research for the goal function optimisation - maximisation of the internal heat area capacity (kJ/m^{2}K) with simultaneous meeting with restriction conditions (Tab.1) meeting. The reference value for the mass restriction was taken from the total wall assembly mass made of brickwork 1400 kg/m^3 of hollow bricks on cement-sand mortar masonry insulated with 180 mm Rockwool board plastered with 20 mm on both inner and outer façade sides. The wall width was taken as 0.6 m.

Table 1 The considered restriction conditions for research

Characteristic	Restriction
Wall mass *m*, kg/m	≤700
Thermal transmittance (*u*-value), W/m^{2}K	≤0.25
Wall width, m	≤0.6
Internal plaster thickness, m	[0.01; 0.03]
External plaster thickness, m	[0.01; 0.05]
Insulation thickness, m	[0.05; 0.2]

Two possible types that reflect the multilayered wall's design schemes are considered: load-bearing walls without any insulation (less common in today's construction practice) and two-layered walls, which combine the load-bearing layer and insulation layer (widespread construction practice). The general outlook for a cross-section of considered assemblies is presented in Fig.1. For the current research, it is assumed that on both façade sides, the plaster layer is applied within the width of 10 mm for the inner and 30 mm for the outer façade.

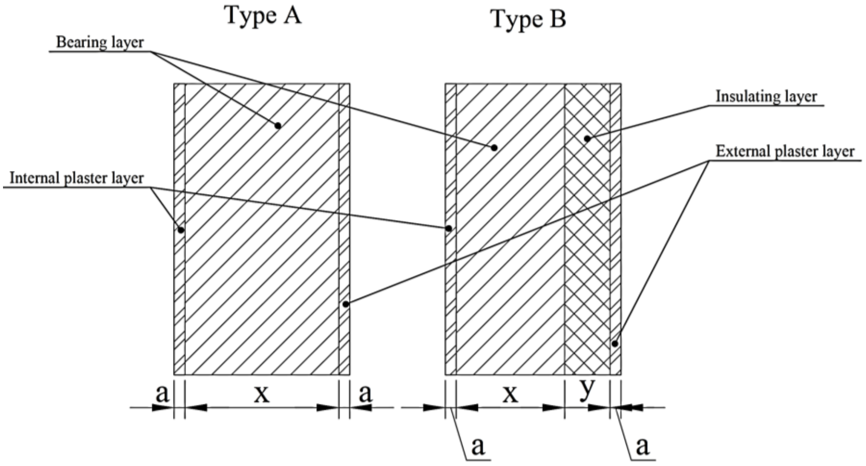

Fig.1 Cross-section of the researched assemblies

For current research, such multilayered assemblies were taken for analysis (Tab. 2).

Table 2 The thermal properties of wall material

Material		Material density *ρ,* kg/m^3	Thermal conductivity of the material λ, (W/m×K)	Specific heat capacity *c* (J/kgK)
Clay brickwork	Brickwork 1400 kg/m^3 of hollow bricks on cement-sand mortar	1600	0.58	880
	Brickwork 1300 kg/m^3 of hollow bricks on cement-sand mortar	1400	0.52	
	Brickwork 1000 kg/m^3 of hollow bricks on cement-sand mortar	1200	0.47	
Aerated autoclaved concrete	D150 [13]*	150	0.055	840
	D300 [13]	300	0.08	840
Hempcrete [13]		350	0.08	1700
Porotherm 44 [14]		747	0.14	880
Rockwool [13]		100	0.064	840

* - the thermal conductivity value λ= 0.06 W/mK assumed by extrapolation for AAC D200-D500 for exploitation regime "B".

There were six basic assembly types proposed for the current research:

- Wall A (Hempcrete);
- Wall B (Brickwork masonry + hempcrete as insulation material);
- Wall C (Brickwork masonry 1400/1300/1000 + Rockwool as insulation material);
- Wall D (Porotherm 44 + + Rockwool as insulation material);

- Wall E (AAC D300 + Rockwool as insulation material);
- Wall F (Brickwork masonry 1400+AAC D150 as insulation material).

The Microsoft Excel Solver performed the goal function search for the proposed wall types with restrictions under Tab. 1.

Results of the research

Table 3 represents the result of the proposed goal function solvage.

Table 3 The thermal properties of wall material

Wall type		Criteria			
		Assembly internal areal heat capacity, kJ/m²K	Assembly mass, kg/m²	Assembly thermal transmittance, W/m²K	Assembly width, m
Wall type A		45.605	275.298	0.149	0.501
Wall type B		63.217	569.000	0.190	0.590
Wall type C	1400 kg/m³	63.343	480.806	0.250	0.458
	1300 kg/m³	61.601	587.478	0.204	0.600
	1000 kg/m³	59.868	380.301	0.250	0.453
Wall type D		49.225	404.680	0.171	0.600
Wall type E		44.159	204.375	0.127	0.600
Wall type F		62.372	491.630	0.216	0.489

For further analysis, two criteria were proposed – the first one is unsteady-state thermal performance criteria, $C_{TPunsteady}$, which reflects the dynamic weather condition with unsteady-state behaviour for multilayered assembly in terms of mass, width and internal area heat capacity.

$$C_{TPunsteady} = \frac{Internal\ area\ heat\ capacity\ [kJ/m^2K]}{Wall\ mass\ \left[\frac{kg}{m^2}\right] \times Wall\ width\ [m]} = \left[\frac{kJ}{mKkg}\right] \tag{1}$$

and the second one of steady-state thermal performance criteria of $C_{TPsteady}$, which reflects the weather condition with steady-state behaviour for multilayered assembly in terms of mass, width and *R-value* (unit, opposite to *u-value*) as follows

$$C_{TPsteady} = \frac{R\ [m^2K/W]}{Wall\ mass\left[\frac{kg}{m^2}\right] \times Wall\ width[m]} = \left[\frac{m^3K}{Wkg}\right] \tag{2}$$

Table 3 reflects calculated $C_{TPunsteady}$ and $C_{TPsteady}$ for all the proposed wall types. The results are shown in Fig.2, Fig 3.

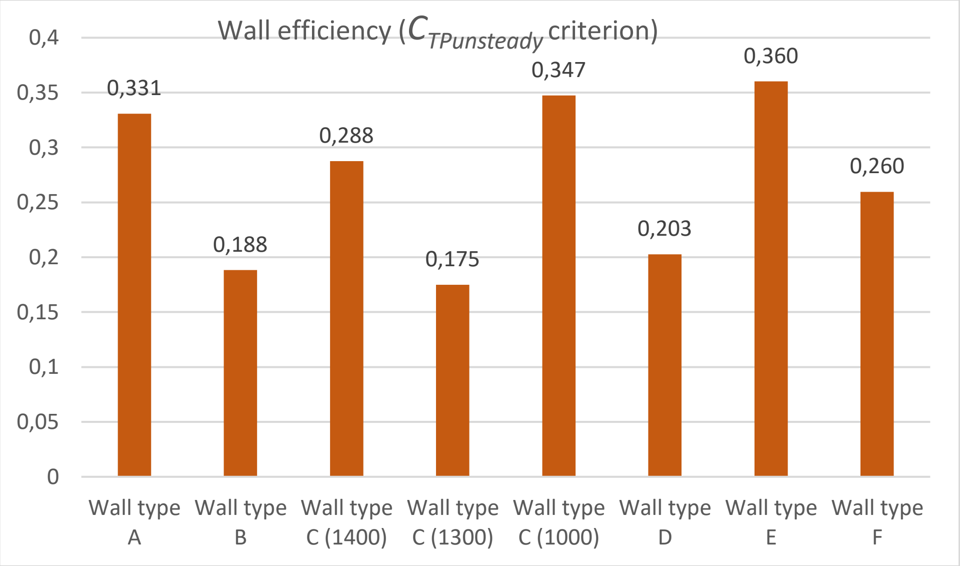

Fig.2 Thermal performance of the walls under proposed criterion $C_{TPunsteady}$

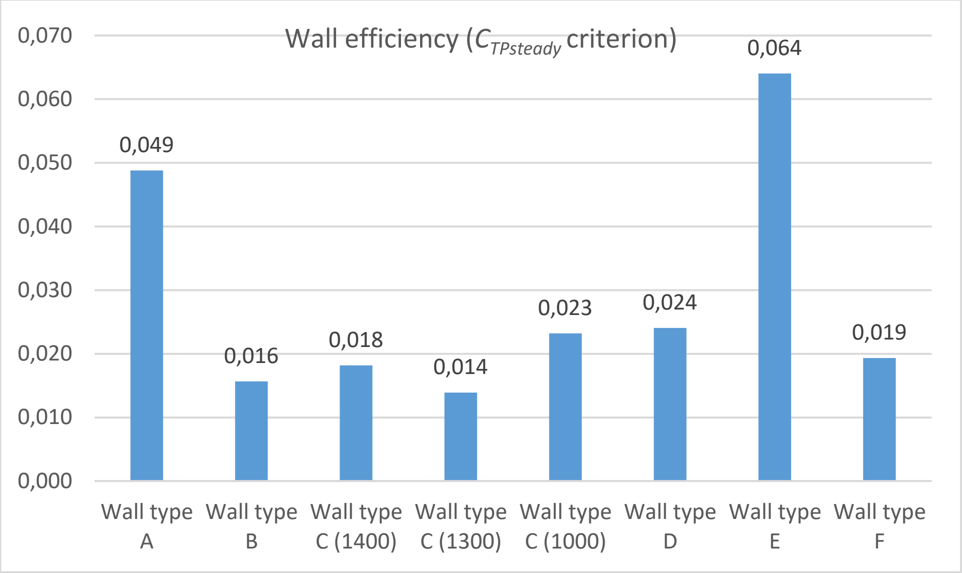

Fig.3 Thermal performance of the walls under proposed criterion $C_{TPsteady}$

From Fig. 2 and Fig. 3, it could be seen that for both unsteady and steady temperature states, Wall E could be considered the "best" assembly, and Wall A has slightly lower values in terms of proposed criteria. Meanwhile, suppose only a single parameter is taken into account. In that case, the evident "best" assemblies for unsteady-state are Wall C (1400), Wall B and Wall E with quite close values of 63.343 kJ/m²K, 63.217 kJ/m²K and 62.372 kJ/m²K respectively (Tab. 3). For the u-value for steady-state, the results are different – Wall E, Wall A and Wall B could be considered as the "best" assemblies in terms of thermal transmittance - 0.127 W/m^{2}K, 0.149 W/m^{2}K and 0.190 W/m^{2}K respectively (Tab. 3).

The "worst" assembly in both cases is Wall C with 1300 kg/m^3 brick wall masonry + Rockwool insulator density.

Conclusions

According to the proposed materials, criteria, and evaluation method, the "best" alternative analysis revealed that the "best" assembly for both steady and unsteady-state consists of a 200 mm AAC bearing layer, which is insulated by 200 mm of EPS. The choice of the "best" decision for the multilayered wall, in general, is still challenging and non-obvious and needs extra information for a compromise decision, which should be made after the comprehensive result analysis.

The current research is the further step of the general research [15] aimed at defining the optimal envelope under the proposed thermal performance criteria. Further consideration of significant physical and thermal behaviour influence factors needs to be considered for validation and revealing of possible most sufficient ones for the "best" assembly-seeking challenge.

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Biks Yuriy S. – PhD, Associate Professor, Department of Construction, Urban Economy and Architecture, Vinnytsia National Technical University, Vinnytsia, email: biks@vntu.edu.ua

Ratushnyak Olga G. – PhD, Associate Professor, Department Of Enterprise Economics and Production Management, Vinnytsia National Technical University, Vinnytsia.