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LAYER THICKNESS OPTIMISATION OF MULTILAYERED ENVELOPE

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Abstract

The thermal performance criteria C_{TP} has been proposed as the assessment parameter, which could be considered when the decision-making demand for the energy-efficient multilayered wall assembly comes into the picture. As the parameters of the proposed criteria C_{TP}, the wall width, wall mass and wall's internal areal heat capacity were used. The current paper mainly emphasises the proposal of criteria which depend on physical characteristics only. The "best" wall assessed by C_{TP} criteria was made of 375 mm AAC D300 Rockwool insulated wall, and the "worst" wall assembly was Wall type C for 1300 kg/m^3 brickwall masonry + Rockwool as insulation material. Additional influence factors and verification and results validation should be provided when comparing criteria and assessment methods.

Keywords: 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 for the developer who intends to make a dwelling that complies with the sustainable development idea and not only wants financial benefits [3, 4]. On the other hand, the comparison is always a compromise between the alternatives, and, generally, it is pretty complicated to choose 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]. The decision maker must comprehensively analyse the solution that dominates others and offers the best overall compromise [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 as thermal transmittance (*u*-value, W/m^{2}K), mass (*m*, kg/m^2) and internal area heat capacity (kJ/m^{2}K) dynamic thermal performance under EN ISO 13786 [8] for the wall assembly.

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

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

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	≤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 Ukrainian construction practice) and two-layered walls, which combine the load-bearing layer and insulation layer (widespread Ukrainian construction practice). The general 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 range of 10-30 mm.

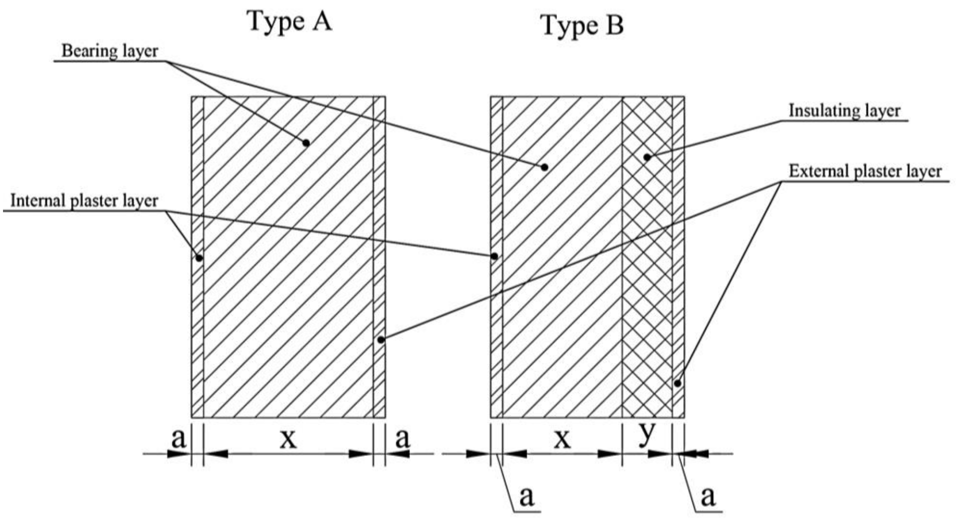

Fig.1 Cross-section of the researched assemblies

As an investigated multilayered assemblies, such alternatives are taken into research 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						
		Internal areal heat capacity (kJ/(m²K)	Mass of the assembly, kg/m^2	Thermal transmittance (W/m^{2}K)	Wall width, m	Internal plaster thickness,m	External plaster thickness,m	Insulation width, m
Wall type A		45.605	275.298	0.149	0.501	0.030	0.050	0.000
Wall type B		63.217	569.000	0.190	0.590	0.030	0.010	0.300
Wall type C	1400 kg/m^3	63.343	480.806	0.250	0.458	0.030	0.010	0.168
	1300 kg/m^3	61.601	587.478	0.204	0.600	0.030	0.010	0.200
	1000 kg/m^3	59.868	380.301	0.250	0.453	0.030	0.010	0.163
Wall type D		49.225	404.680	0.171	0.600	0.030	0.010	0.120
Wall type E		44.159	204.375	0.127	0.600	0.030	0.010	0.185
Wall type F		62.372	491.630	0.216	0.489	0.019	0.019	0.200

For further analysis, the thermal performance criteria of CTP were proposed. According to the author's attitude, the C_{TP} reflects the efficiency of assembly in terms of mass, width and internal area heat capacity as follows

$$C_{TP} = \frac{Internal\,area\,heat\,capacity[kJ/m^2K]}{Wall\,mass[kg/m^2]\times Wall\,width[m]} = [\frac{kJ}{mKkg}] \quad (1)$$

For all the proposed wall types in Table 3, the C_{TP} was calculated. The results are shown in Fig.2.

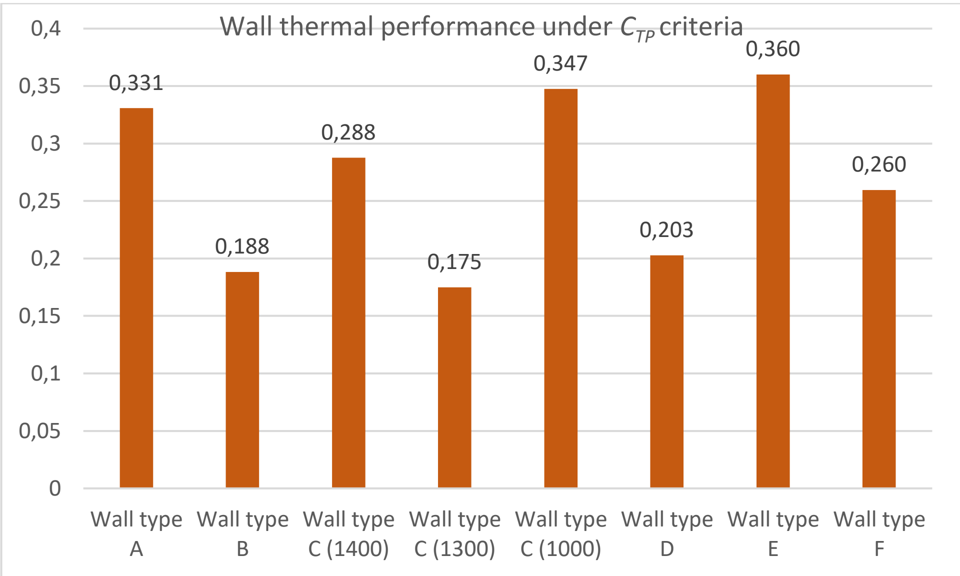

Fig.2 Thermal performance of the walls under proposed criteria C_{TP}

From Fig. 2, it could be seen that Wall E could be the "best" assembly, as well as Wall C and A, which demonstrated slightly lesser values. The "worst" assembly is Wall C with 1300 kg/m^3 density of brickwall masonry + Rockwool insulator.

The current research is only an additional part of the general research aimed at defining the optimal envelope under the proposed thermal performance criteria. Further influence factor analysis should be conducted to validate and reveal the possible correlation of considered criteria to include only the most sufficient ones in the "best" wall alternative seeking.

Conclusions

According to the proposed materials, criteria, and evaluation method, the analysis of the “best” alternative revealed that the “best” assembly 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 challenging and non-obvious and needs essential information for a compromise decision, which should be made after the comprehensive result analysis.

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