

REGARDING NEW CRITERIA OF MULTILAYERED ENVELOPE THERMAL PERFORMANCE

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Abstract

The C_{TPL} thermal performance criterion has been introduced to evaluate energy-efficient, multilayered wall assemblies regarding the dynamic parameter and embodied energy. This criterion considers such physical characteristics as internal areal heat capacity, decrement factor, and embodied energy for the particular multilayered assembly. The study focuses on defining the CTPL criterion solely based on physical characteristics of the thermal performance and energy consumption.

According to the numerical research, the optimal wall configuration was a 420 mm Hempcrete wall, while the least efficient was Wall Type E, consisting of wood-chip cement bonded block. Further studies should incorporate additional influencing factors, verification processes, and validation methods to clarify the feasibility of assessment criteria.

Keywords: internal area heat capacity, thermal performance, multilayered assemblies, energy efficiency, dynamic characteristic.

Introduction

Modern construction practice employs a variety of building materials and techniques, drawing attention to multicriteria decision analysis (MCDA) methods [1, 2]. Thus, the issue of the most suitable energy-efficient building envelope in terms of thermal, mechanical, and economic performance remains a significant challenge for engineers and developers who aim to construct dwellings aligned with sustainable development principles, which LCA parameters could evaluate under EN 15978:2011 [3].

The comparison process inevitably involves trade-offs among alternatives, making selecting an optimal solution inherently complex. The term optimal is used in this context because, as in a multicriteria evaluation of real-world issues, only the alternatives belonging to the Pareto set can be regarded as optimal, which in a particular case is literally equal to the “best” solution [4, 5]. To make a proper choice of multilayered envelope, comprehensive analysis is to be performed, where different criteria as physical, mechanical structural and economic (as the initial investment cost, for instance) came into the play, often as contradictive competing parameters, should be performed at the early design stage [5, 6]. The scope of this paper is to deal with physical parameters only, which are described as follows.

Materials and research methods

For current specific physical parameters that were easily quantifiable to facilitate decision-making during the predesign stage of building construction were considered. Five multilayered assemblies were used to numerically model their dynamic, steady-state, and life cycle assessment characteristics. These characteristics include thermal transmittance (U -value, W/m^2K) as the steady-state parameter, internal area heat capacity (k_1 , kJ/m^2K) and decrement factor f , which are the dynamic thermal performance parameters of wall assemblies under EN ISO 13786 [7] and main influencer of envelope winter and summer behaviour [6]. The embodied energy (PENRT Primary energy non-renewable – total, $PENRT MJ/m^2$) was also considered as LCA criteria [8].

The value of the thermal resistance is inversely to the u -value calculation under the formula [9]:

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

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, $\alpha_{int} = 23 (W/m^2K)$ [9];

α_{int} is the heat transfer coefficient of the external surface of the wall, $\alpha_{int} = 8.7$ (W/m²K) [9];

The internal heat area capacity (kJ/m²K) as a dynamic thermal characteristic was calculated using a downloadable Excel spreadsheet from HTflux [12].

The multilayered assemblies taken into consideration are:

- Wall A (Hempcrete);
- Wall B (Aerated autoclaved concrete (AAC) D300 + Rockwool as insulation material);
- Wall C (Insulated concrete formwork (ICF) block);
- Wall D (Hollow brickwork masonry (Porotherm 38) + Rockwool as insulation material);
- Wall E (Wood-chip cement bonded block);

The main thermal performance characteristics of the materials are presented in Table 1.

Table 1 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)
ICF block	Wood-chip cement-bonded concrete	475 [12]	0.09 [12]	1300* [13]
	EPS W15 silver [14]	15.9	0.031	1450
	Reinforced concrete [10]	2300	1.86	840
AAC D300 [9]		325	0.095	840
Hempcrete [11]		340	0.071	1000
Porotherm 44 [17]		747	0.14	880
Rockwool [8]		100	0.064	840
Clay-based plaster [10]		1800	0.80	880

* - Specific heat capacity is assumed as 1300 J/kgK as for cement-bonded boards made of wood chips (550 kg/m³).

The new thermal performance criteria C_{TPL} of a multilayered envelope was proposed for further analysis. According to the author, the C_{TPL} reflects the assembly efficiency in terms of internal area heat capacity and embodied energy.

$$C_{TPL} = \frac{\text{Internal area heat capacity [kJ/m}^2\text{K}]}{\text{PENRT [kJ/m}^2\text{]}} = \left[\frac{1}{K} \right] \quad (1)$$

Equation (1) reflects the amount of primary energy consumed by a multilayered assembly with a particular internal area heat capacity value. The given formula shows that the bigger the criteria, the better the envelope's dynamic thermal performance in terms of its embodied energy.

For all the researched envelopes, the internal area heat capacity and embodied energy for the considered thicknesses are represented in Table 2 and Table 3.

	Wall width d_{wall} , m	Internal plaster thickness d_{int} , m	External plaster thickness d_{ext} , m	Insulation width, d_{ins} , m	Thermal resistance at steady state, R -value, m ² K/W	Internal areal heat capacity $k1$, kJ/(m ² K)	Decrement factor f	PENRT, MJ/m ²
Wall type A	0.42	0.02	0.02	-	5.637	42.12	0.010	603*
Wall type B	0.48	0.02	0.02	0.14	5.366	38.95	0.137	1508
Wall type C	0.45	0.01	0.01	0.15	5.740	33.46	0.059	1016
Wall type D	0.56	0.02	0.02	0.14	5.601	45.07	0.009	1232
Wall type E	0.57	0.01	0.01	-	5.421	34.97	0.004	2438

* The value is calculated as embodied energy (EE) for 400 mm hempcrete wall [15].

Results of the research

After all the necessary data had been collected in Table 2, the proposed criteria C_{TPL} was calculated according to the equation (1). The results are shown in Fig.1.

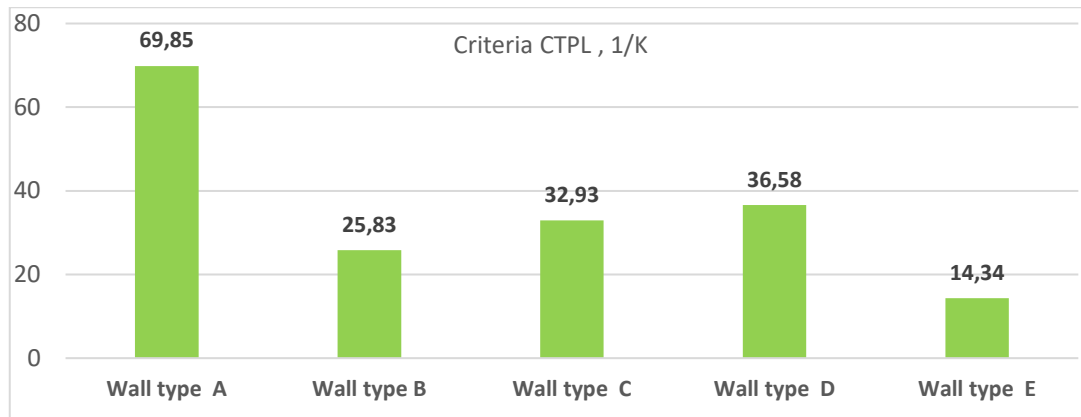


Fig.1 Thermal performance of the walls under proposed criteria C_{TPL}

Fig. 1 shows that Wall A (Hempcrete) has a significant advantage over the rest of the assemblies, with a CTPL value of 69,85 [1/K]. The lowest value is Wall type E (Wood-chip cement bonded block), with almost a fifth of the Wall A value of the proposed criteria—14.34 [1/K]. Walls C and D demonstrate nearly the same CTPL value—32.93 [1/K] and 36.58 [1/K], respectively. Wall B (AAC) shows slightly lower performance with only 25.83 [1/K]. From the recommended range of decrement factor value for optimal assemblies $f=0.04$ -0.08 [6], Wall type B doesn't fit the range with a higher value of 0.137, and Wall type A has the lowest decrement factor – 0.010 value. The rest of the assemblies could be considered acceptable regarding the recommended range.

The current research is an additional attempt at general research to define the optimal envelope under the proposed thermal performance criteria. Further analysis should be conducted to determine an affordable assembly in terms of thermal resistance, dynamic behaviour, and embodied energy performance.

Conclusions

According to the proposed criteria, the analysis of the five assemblies revealed that the hempcrete wall could be the most energy-efficient wall in terms of embodied energy, with a CTPL equal to 69.85 [1/K]. However, in terms of dynamic performance, this wall's decrement factor was found to be 0.01, which is much lower than the 0.04 value.

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