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COMPREHENSIVE ANALYSIS OF MULTILAYERED ENVELOPE ASSEMBLIES OF LOW-STOREY DWELLING SEGMENT

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Abstract

The thermal performance and life cycle assessment (LCA) analysis of the popular multilayered envelope assemblies of the low-storey dwelling segment was performed. Five commonly used and appropriate "cost-quality" assemblies of the Ukrainian construction market were researched in a case study. The bullet point of the research was to figure out the "optimal" assembly type in terms of Global Warming Potential (GWP) (kg CO_2 equ./m^2), internal heat area capacity (kJ/m^{2}K) as dynamic thermal characteristic, u-value (W/m^{2}K) and the mass of the wall kg/m^2 as the steady state physical characteristics. These five types of multilayered wall assemblies, which were compared, are brick wall masonry insulated, D300 aerated concrete insulated, cavity brick wall masonry insulated, SIP wall as a quick construction system and strawbale wall in the type of structural timber frame with inner infill as more expensive natural building material. The Eco2soft tool and Excel spreadsheet for thermal mass calculus according to EN ISO 13786 were used for current research. Research revealed that assessing different criteria is still challenging for Multicriteria Decision Analysis (MCDA).

Keywords: LCA, thermal performance, comprehensive analysis, multilayered envelopes, wall assemblies

Introduction

Climate change and global warming all over the Earth are essentially impacted mainly by human activity, requiring the engineers to design an energy-effective and environmentally friendly product on the one hand, which could be demolished and recycled with minimum energy consumption on the second [1].

Such challenging and non-trivial circumstances formulate a new agenda which we face to cope with, which could probably be based on switching philosophy attitude from infant "quick and cheaper" solutions to short-term benefits without considering further consequences to the more thoughtful, matured, holistic causal relationship long-term approach with responsibility upon the next generations. Since the construction sector is the biggest user of land and fossil resources [2], as well as considered the main contributor to carbon emissions [3], the more thoroughly we need to design the envelopes which should live up to the aforementioned contemporary challenges [5, 6] and demands.

In this regard, by further upcoming multilayered envelope assessment criteria development [4], the new attempt to comprehensively evaluate both physical (opaque walling mass, kg/m^2), thermo-physical (u-value, W/m^{2}K), dynamic thermal performance under EN ISO 13786 (internal area heat capacity, kJ/m^{2}K) and GWP evaluation were made to suggest the "optimal" wall assembly.

As a case study, the most popular "cost-efficient" wall assemblies of the Ukrainian low-storey alternatives of the construction sector were compared, namely Wall A (full brickwork masonry+insulation), Wall B (aerated concrete+insulation), Wall C (cavity brick masonry wall+islulation), Wall D (strawbale panel wall) and Wall E (SIP with EPS insulator).

The numerical LCA analysis of proposed wall assemblies was performed in Eco2soft tool [7], and the calculation of the thermal mass of building components (namely the internal heat area capacity (kJ/m^{2}K) as dynamic thermal characteristic) was performed in downloadable Excel spreadsheet from HTflux [8].

Results of the research

Five types of multilayered wall assemblies were considered in the investigation of LCA analysis: Wall A (brickwork+insulation), Wall B (aerated concrete+insulation), Wall C (cavity brick wall+islulation), Wall D (strawbale wall by timber frame method of construction) and Wall E (SIP with EPS insulator). As the output results were taken into consideration, such indicators as Global warming potential – GWP-total, kg CO_2 equ./m² for an operational term of 100 years, As physic and thermo-physic parameters, the mass of 1m^2 of assembly u-value W/m^2K and internal heat area capacity (kJ/m^2K) as dynamic thermal characteristic were taken respectively. Cross-sections of considered multilayered assemblies are presented in Fig. 1 - Fig.5.

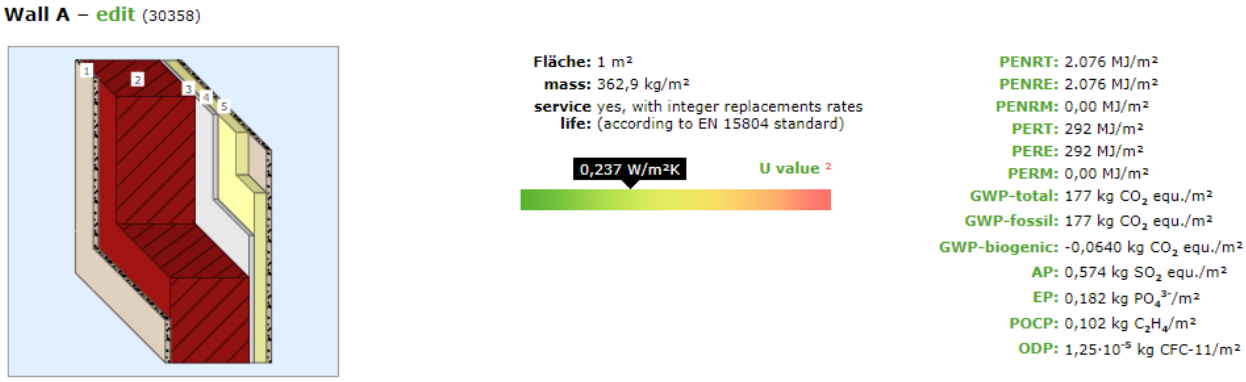

Fig.1. Characteristics of Wall A assembly

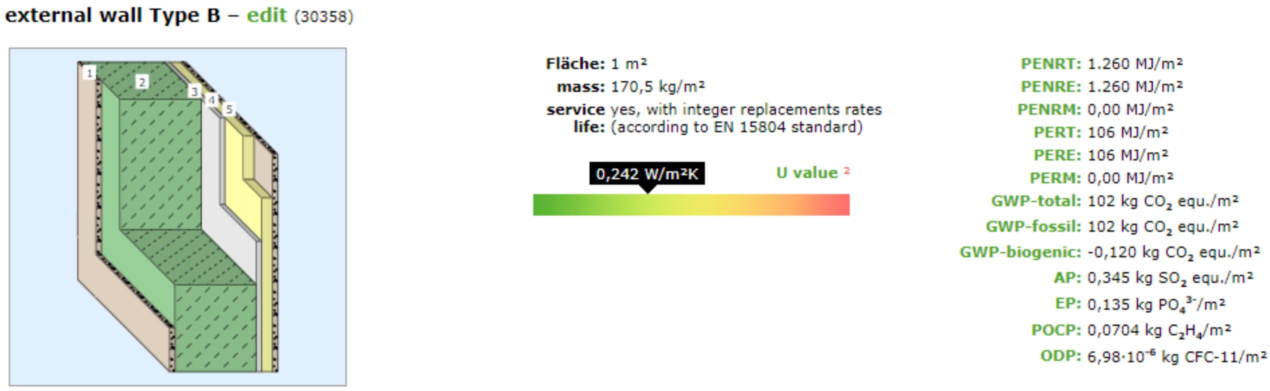

Fig.2. Characteristics of Wall B assembly

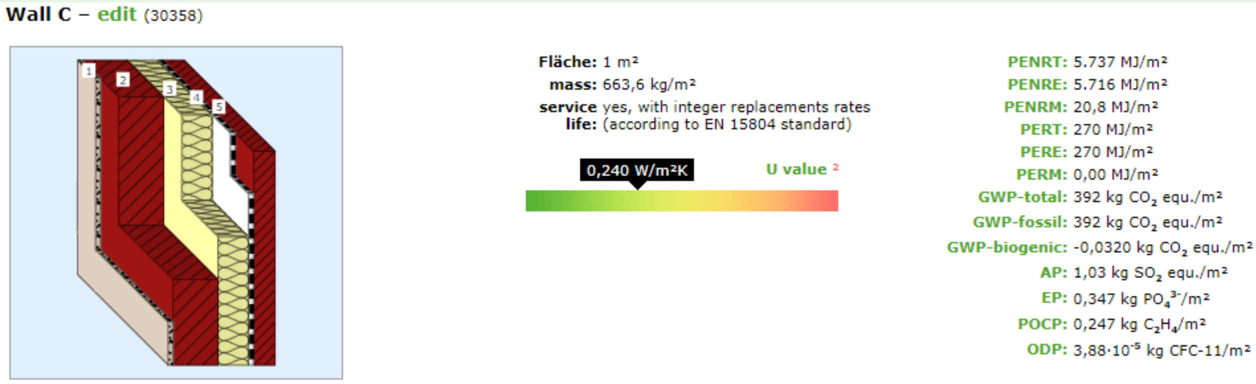

Fig.3. Characteristics of Wall C assembly

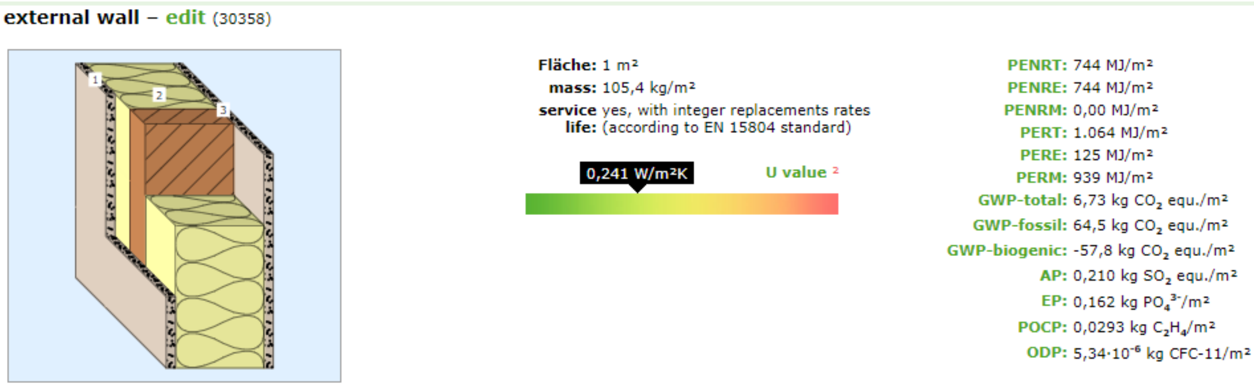

Fig.4. Characteristics of Wall D assembly

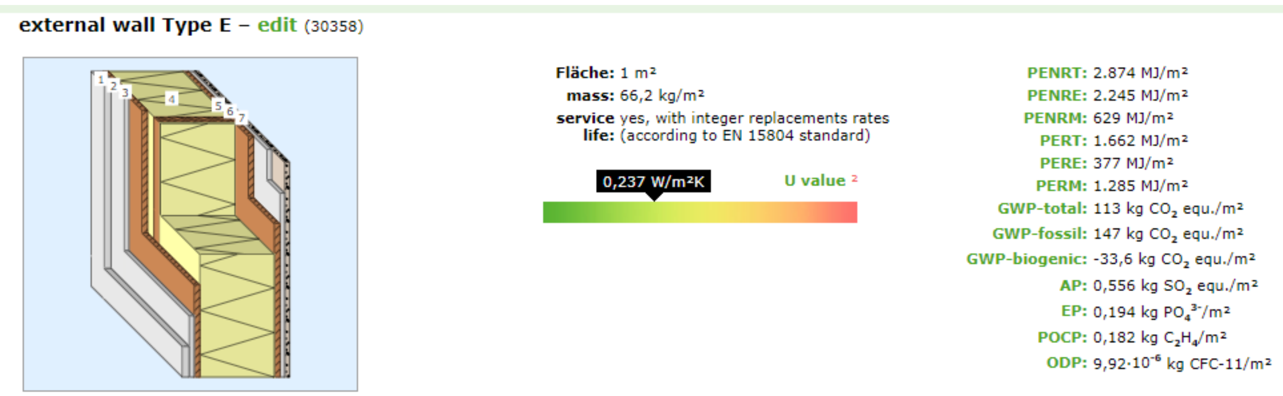

Fig.5. Characteristics of Wall E assembly

After performing all the necessary inputs, the results were arranged in Table 1.

Table 1 The thermo-physical, physical and economic characteristics of the wall assemblies

Criteria	GWP-total, kg CO_2 equ./m^2	Internal area heat capacity, kJ/m^2K	mass, kg/m^2	u-value, W/m^2K
Wall A	177	42.725	346.90	0.237
Wall B	102	35.947	170.50	0.242
Wall C	386	59.992	655.60	0.240
Wall D	6.73	40.028	105.40	0.241
Wall E	113	31.353	66.20	0.237

It should be noted that all the proposed assemblies (see Table 1) were chosen in such a manner with approximately equal *u-value*, which is the reciprocal value to *R*, m^2K/W to live up to the thermal resistance requirements of the current Ukrainian Code [9] for the first temperature zone.

Results reflect the ranking of each wall assembly in terms of the obtained data from 1 to 5 (where 1 is the best alternative in terms of proposed criteria, and five is the worst one, respectively), shown in Table 2.

Table 2 The comparison of wall assemblies ranking by different MCDA techniques

Criteria	GWP-total, kg CO_2 equ./m^2	Internal area heat capacity, kJ/m^2K	mass, kg/m^2	u-value, W/m^2K
Wall A	4	2	4	1
Wall B	2	4	3	5
Wall C	5	1	5	3
Wall D	1	3	2	4
Wall E	3	5	1	1

As it could be seen from the data obtained through the analysis, there is no evident “leader” in the proposed list of alternatives (Table 1) which can have the most thermal resistance, have the most considerable accumulating capacity (Internal area heat capacity - dynamic thermal parameter which describes the ability of a building component to buffer heat during a diurnal cycle and considered as one of the most important in terms of envelope’s thermal performance [10,11,12,13]).

The conducted research revealed that the unambiguous answer to the question “What is the best/worst multilayered envelope of the proposed?” is still a challenge in terms of the proposed criteria of multicriteria analysis. Additional data should be involved to proceed with the correct estimation, or other arbitrary unit analysis should probably be performed to determine the best/worst case of the proposed ones. All of the abovementioned is still true with the economic aspect, which should be considered and is out of the current research scope.

Thus, if the current analysis does not consider the additional data, the wall D can probably be the "moderate" optimal one in the investigation with minimal environmental polluting impact. Wall E can also be a "moderate" alternative with the poorest thermal accumulating capability. The traditional brickwork + insulation wall A, which has the notable mass and the most pollutant impact regarding the CO2 emissions with the most massive walls B and C, have the last acceptable results.

Thus, the current thesis was only an additional attempt at the comprehensive research process aimed at figuring out the prompt criteria/criterion for the "optimal" wall assembly definition in terms of Multicriteria Decision Analysis (MCDA). Further analysis should be conducted to reveal the main contributor to the comprehensive criteria for choosing the best wall assembly alternative.

Conclusions

The research shows that the problem of multicriteria assessment of multilayered envelopes is still challenging for each of the proposed multilayered assemblies with similar steady state parameter ***u-value***, different physical (mass), LCA (GWP-total), dynamic thermal performance (Internal area heat capacity) can be frustrating in the term of best assembly choice.

As stated in earlier research [4, 5, 13, 14], the best alternative for wall assembly should be chosen by a comprehensive analysis of different criteria comparison, which is still not revealed and doubtable. Thus, additional research should be conducted to verify the obtained results.

REFERENCES

1. United Nations Environmental Programme, "Buildings and Climate Change," Sustainable Buildings & Climate Initiative, Ed., ed. Paris: UNEP, 2009.
2. Dimoudi, A.; Tompa, C. Energy and environmental indicators related to the construction of office buildings. *Resources, Conservation and Recycling*, 2008, Vol. 53.P. 86-95.
3. Huang, Lizhen, et al. Carbon emission of the global construction sector. *Renewable and Sustainable Energy Reviews*, 2018, Vol.81. P 1906-1916.
4. Biks Y., Ratushnyak G., Ratushnyak, O. Energy performance assessment of envelopes from organic materials. *Architecture Civil Engineering Environment*. 2019. № 3: P. 55-67. DOI: 0.21307/ACEE-2019-036.
5. Kulkarni S. P., Karve S., Kulkarni P. Assessment of building envelope material for embodied energy to reduce global warming and ozone depletion potential. International Journal of Research and Analytical Reviews. 2019, Vol.6, Issue1. P. 778-788.
6. Wang J. J., Jing Y. Y., Zhang C. F., Zhao J. H. Review on multicriteria decision analysis aid in sustainable energy decision-making. *Renewable and sustainable energy reviews*. 2009. Vol. 13. №9. P. 2263-2278. DOI: 10.1016/j.rser.2009.06.021.
7. Eco2soft. Life style assessment for buildings. URL: https://www.baubook.at/eco2soft/?SW=27&lng=2 (Last accessed: 15.05.2022).
8. A brief guide and free tool for the calculation of the thermal mass of building components. URL: https://www.htflux.com/en/free-calculation-tool-for-thermal-mass-of-building-components-iso-13786/ (
Last accessed: 18.11.2023).
9. DBN V. 2.6-31: 2021. Thermal insulation and energy efficiency of buildings. [Valid from 2022-09-01]. Official publication. Kyiv: Ministry of Development of Communities and Territories of Ukraine, 2022. 27 p. (in Ukrainian).
10. ROSSI, Monica; ROCCO, Valeria Marta. External walls design: The role of periodic thermal transmittance and internal areal heat capacity. *Energy and buildings*, 2014. Vol. 68. P. 732-740.
11. GAGLIANO, Antonio, et al. Assessment of the dynamic thermal performance of massive buildings. *Energy and Buildings*, 2014, Vol. 72. P. 361-370.
12. BALAJI, N. C.; MANI, Monto; REDDY, BV Venkatarama. Dynamic thermal performance of conventional and alternative building wall envelopes. *Journal of building engineering*, 2019, Vol. 21. P. 373-395.
13. Stazi F. Thermal Inertia in Energy Efficient Building Envelopes. Butterworth-Heinemann, 2017. DOI: 10.1016/B978-0-12-813970-7.00001-7.
14. Basińska M. The use of multicriteria optimization to choose solutions for energy-efficient buildings. *Bulletin of the Polish Academy of Sciences. Technical Sciences*. 2017. Vol. 65, №. 6. P. 815-826. DOI: 10.1515/bpasts-2017-0084.

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