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ASSESSMENT OF ENVELOPE'S THERMAL PERFORMANCE BY DIFFERENT MCDA TECHNIQUES

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Abstract

The assessment of the thermal performance of multilayered envelopes was performed by different techniques of Multi-Criteria Decision Analysis (MCDA). There was a proposed integral index of thermal performance as a comprehensive evaluation parameter. As key influence criteria were taken into consideration as follows: the u-value of the envelope W/m^{2}K, the dimensionless decrement factor of the envelope f, the internal areal heat capacity of the envelope k1, kJ/m^{2}K according to ISO 13786:2017, the cost of the wall material, UAH/m^2 and the mass of the wall kg/m^2. There were compared eight types of wall assemblies from natural materials: hempcrete, adobe, strawbale panel, earthbag, cordwood, SIP, hempcrete+straw and compositional building thermo-block. The comparison of the alternatives was proceeded by such MCDA techniques as AHP, TOPSIS, Grey relation analysis (GRA) and Criteria Importance Theory (CIT). Conducted research revealed that only two of eight wall types could be approximately defined as "medium" and "best" ones in proposed terms of thermal performance – Wall from SIP and Wall from Cordwood. respectively.

Keywords: thermal performance, MCDA, TOPSIS, GRA, CIT, weighting method, wall assemblies

Introduction

The huge amount of building materials in modern construction practice forces us to make a choice using multi-criteria decision analysis (MCDA) methods [1, 2]. The problem of choosing from a variety of energy-efficient envelope's alternatives is still the challenge [3, 4]. On the other hand, in case of doubtful results of the alternative comparison, the decision-maker has to verify the obtained results from one MCDA technique with another one to get an appropriate level of alternative ranking scale. The criteria weight's calculating methodology could significantly affect the final choice by decision-maker. Therefore, in this thesis is proposed the attempt of thermal performance by several popular MCDA methods. There were taken five influence criteria according to the proposed model: ISO 13786:2017 [5] decrement factor *f*, the internal area heat capacity *k*1 (kJ/m^{2}K), the thermal transmittance (*u-value*), mass *m* and the cost of materials of the wall assembly *Q*.

Results of the research

Eight types of multilayered wall assemblies were considered in the investigation of thermal performance assessment: hempcrete, adobe, strawbale panel, earthbag, cordwood, SIP (plywood+ecofiber), hempcrete+straw and energy-efficient block. The MCDA assessment of envelopes energy efficiency potential was conducted by AHP [7], GRA [2], TOPSIS [2] and CIT [8, 9] methodology of MCDA techniques. The method with predefined weights of criteria by Analytic Hierarchy Process (AHP) [7] and by Entropy method [2]. The cross-sectional compositions of wall types shown below in Fig. 1.

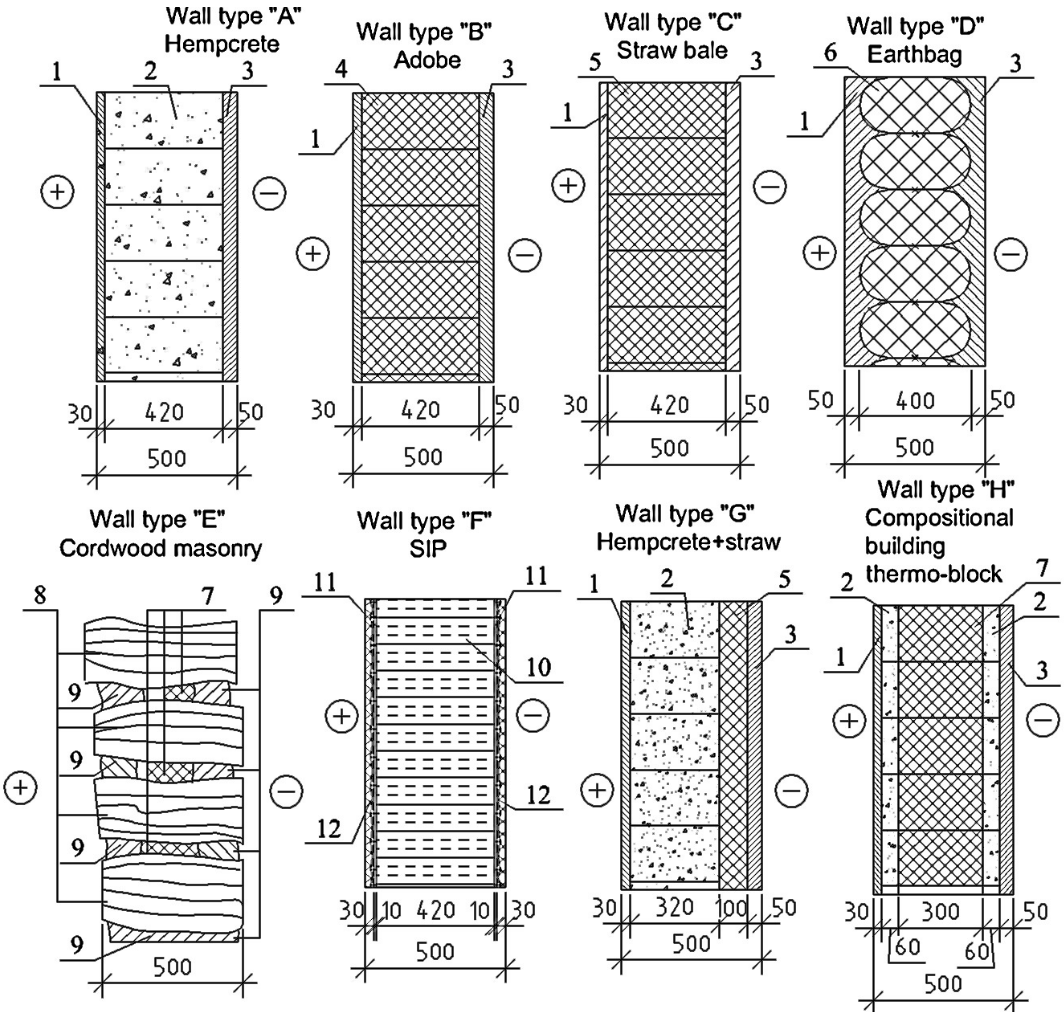

Fig. 1. Cross-sectional scheme of considered wall types (1 - internal lime-sand plaster, 2 - hempcrete, 3 - external lime-sand plaster, 4 - adobe, 5 - strawbale panel, 6 - earthbag, 7 - chopped straw as an insulator, 8 - cordwood, 9 - lime-sand plaster, 10 - eco fibre, 11 - lime-sand plaster, 12 - plywood)

General data, arranged and calculated for each criterion (steady-state parameter u-value, unsteady-state parameters *f* and *k*1) according to the assumed marking [] and calculating methodology [] is presented in Table 1 for further investigation.

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

Assembly type	*Q*, UAH/m^2	*m*, kg/m^2	*u-value*, W/m^2K	*f*	*k*1, kJ/m^2K
Wall "A"	1146.00	275.00	0.15	0.0067	45.61
Wall "B"	358.50	716.00	0.77	0.0586	59.46
Wall "C"	1154.40	161.60	0.16	0.2336	41.77
Wall "D"	360.00	880.00	1.51	0.1219	68.53
Wall "E"*	810.00	272.00	0.24	0.0506	64.20
Wall "F"	918.00	131.10	0.14	0.2225	57.00
Wall "G"	1148.00	248.00	0.15	0.0119	45.59
Wall "H"	1152.00	194.00	0.16	0.1394	46.77

It should be noted, that two different techniques were applied for criteria weight's calculation in the TOPSIS MCDA method: previously obtained ones by AHP pairwise comparison methodology [7] and by Shannon Entropy methodology [2]. After proceeding with an assessment of thermal performance by different techniques, the ranking of each wall assembly from 1 to 8 (where 1 is the best alternatives in terms of proposed criteria, 8 is the worst one, respectively) was made (Table 2).

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

Assembly	Rank of alternative					
	AHP	GRA	TOPSIS (weights by AHP)	TOPSIS (weights by Entropy)	CIT(considering the relative importance of criteria)	CIT (clarified criteria data)
Wall "A" (Hempcrete)	6	2	3	2	5	5
Wall "B" (Adobe)	2	5	1	7	1	1
Wall "C" (Strawbale panel)	7	8	8	6	8	8
Wall "D" (Earthbag)	1	6	6	8	2	3
Wall "E" (Cordwood)*	3	1	2	3	3	2
Wall "F" (SIP plywood+ecofiber)	4	4	5	5	4	4
Wall "G" (Hempcrete+straw)	5	3	4	1	5	5
Wall "H" (Energy efficient block)	8	7	7	4	7	7

The conducted research has shown, that there is no definite answer to the question: "What is the "best/worst" wall assembly from the proposed"? Only two of eight wall types could be defined as "medium" and "best" thermal performance. Those alternatives are wall type "F" (rank 4 and 5) and Wall "E" from the cordwood masonry has interchangeable rank from 1 to 3, which could be considered by the decision-maker as one of the best alternatives, according to the considered criteria (Table 1). The present thesis is only part of the general investigation process, which is aimed at the optimal wall assembly definition in terms of the thermal performance criteria. Further analysis should be conducted to reveal the key role of specific criteria weight changing on the priority arrangement of the best wall alternative.

Conclusions

Both the MCDA type and criteria weighting technique plays a significant role in decision-making. The best alternative of wall assembly should be chosen by comprehensive analysis of different MCDA techniques evaluations. In the case of ambiguous ranks of compared alternatives by different MCDA methods, additional research should be done for verifying the obtained results.

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