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THE CORRELATION BETWEEN ASSESSMENT OF ENVELOPES ENERGY EFFICIENCY BY DIFFERENT MCDA METODS

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Abstract

The Multi Criteria Decision Analysis (MCDA) techniques was proposed in assessment of envelope's energy efficiency potential. There were compared eight types of non-load bearing wall assemblies for commercial building. The best correlation was found in comparison of Grey Relation Analysis method with TOPSIS by Entropy weighting method – 0.962, the worst one was observed in comparison of TOPSIS evaluations techniques (with weights calculated by Analytical Hierarchy Process and Entropy method) –0.288.

Keywords: AHP, GRA, TOPSIS, MCDA methods, energy efficiency potential, assessment. wall assemblies

The huge amount of building materials in modern construction practice forces to make a choice using multi-criteria decision analysis (MCDA) methods [1, 2]. The problem of choice from variety of energy efficient envelope's alternatives is still the challenge [3, 4]. Therefore, in this thesis is conducted the attempt of comprehensive assessment of key thermal performance characteristics as well the cost value of envelopes. Such types of walls are considered in comparison assessment: hempcrete, brick wall + external insulation, cavity wall, autoclaved aerated concrete (AAC) + insulation, strawbale panel, SIP (plywood+ecofiber), hempcrete+straw and energy efficient block. The ISO 13786:2017 [45] determined unsteady state thermal performance characteristic as decrement factor *f*, the internal area heat capacity (kJ/m^{2}K), the thermal transmittance (u-value), Savin criterion Sa [6] which combines the economical, climate and thermal performance parameters of the wall assembly have been taken into consideration as key influence factors. The MCDA assessment of envelope's energy efficiency was conducted by three methods – Analytic Hierarchy Process (AHP) [7], Grey Relation Analysis (GRA) [8, 9] and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method with obtaining of weighting coefficients by AHP and by Entropy method [2]. All of the proposed envelopes were chosen in terms of non-loadbearing energy effective wall types for commercial buildings. The climate conditions (heat-degree days) for numerical modeling were taken as for the First Temperature Zone of Ukraine, in particular for the city of Vinnytsia. The average costs of wall assemblies' material and tariff of energy generation (UAH/kWh) were taken from the appropriate data from Internet resources. The cross sectional compositions of wall types shown below in Fig. 1, Fig. 2.

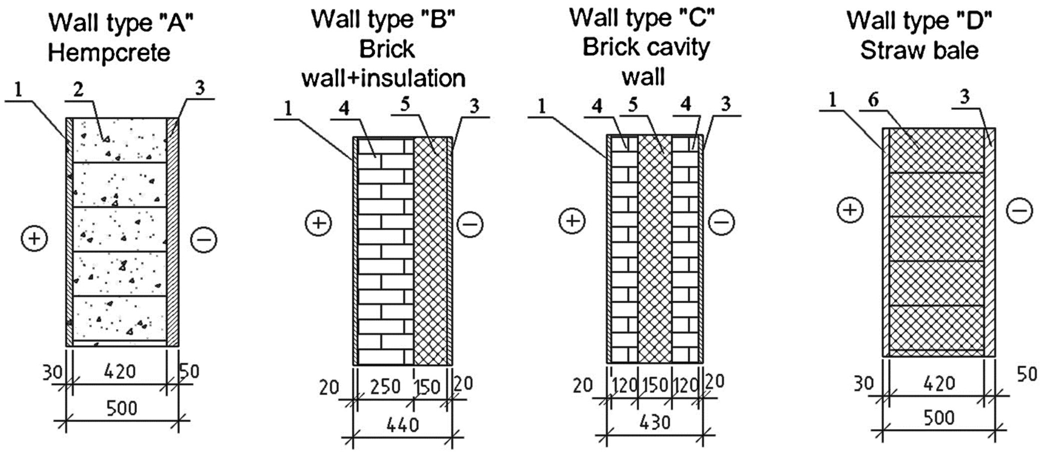

Fig 1. Considered wall types compositions «A»-«D» (1 – internal lime-sand plaster, 2 – hemcrete, 3 – external lime-sand plaster, 4 – honeycomb brick, 5 – mineral wool, 6 – strawbale panel, 7 – autoclaved aerated concrete (AAC), 8 – plywood, 9 – ecofiber)

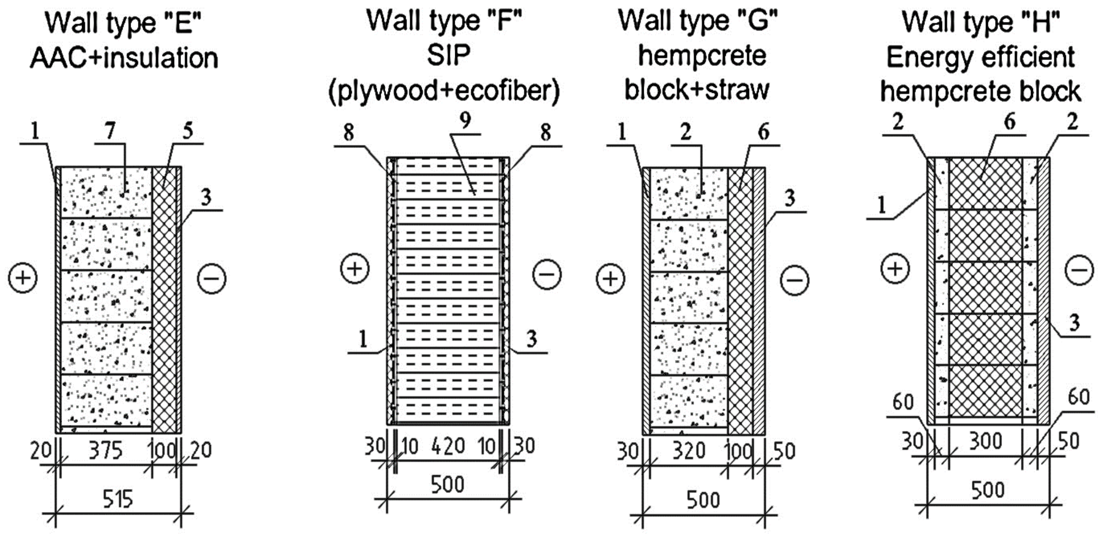

Fig 2. Considered wall types compositions «E»-«H» (1 – internal lime-sand plaster, 2 – hemcrete, 3 – external lime-sand plaster, 4 – honeycomb brick, 5 – mineral wool, 6 – strawbale panel, 7 – autoclaved aerated concrete (AAC), 8 – plywood, 9 – ecofiber)

The basic physic-mechanical and thermal properties of materials presented in Table 1.

Table 1 The thermophysical, physical and economic characteristics of the envelope's material

Building material	The specific heat capacity c_i, J/kgK	The thermal conductivity λ_i, W/mK	Density ρ_i, kg/m^3	The average cost* of material Q, €/m^3
Hemcprete	1700	0.065	350	75.36
Strawbale panel	1675	0.07	80	75.96
Honeybrick (Porotherm 38)	880	0.133	750	118.78
Mineral wool (Rockslab 150 mm)	840	0.0395	26	31.84
AAC (Aerock EcoTerm D300)	840	0.1	300	50.81
Plywood	2400	0.18	600	325.55
Ecofiber	1880	0.06	55	45.22
Lime-sand plaster	840	0.81	1600	36.17

* - cost of materials assumed on average prices from Ukrainian Internet resources based on exchange rate 1€ = 33.34 UAH.

All of methods allow to arrange the alternatives and could be applied as decision support tools in decision making (DM) process of choosing the best alternative in terms of multi-criteria assessment. For more objective analysis, there resulting integral evaluations of proposed wall assemblies were compared by three MCDA methods – AHP, GRA and TOPSIS (weighting of criteria was performed by AHP and Entropy method).

Calculated values for criteria is presented in Table 2.

Table 2 Predefined Criteria for MCDA assessment of envelopes energy efficiency potential

Wall type	The thermal transmittance of the envelope (u-value), W/m2K	The decrement factor, f	The internal areal heat capacity of the envelope, kJ/m^{2}K	Mass of the wall m, kg/m^2	Savin criterion, Sa	Cost of the wall materials, €/m2
Wall type "A" (Hampcrete)	0.1488	0.0067	45.605	275.00	0.732	34.41
Wall type "B" (Brick +insulation)	0.1727	0.0760	43.030	255.40	1.102	34.54
Wall type "C" (Brick cavity wall)	0.2325	0.1708	73.640	499.90	0.335	21.00
Wall type "D" (Strawbale)	0.1598	0.2336	41.769	161.60	1.106	34.66
Wall type "E" (AAC+insulation)	0.1224	0.0673	34.933	180.40	0.853	26.74
Wall type "F" (SIP plywood+ecofiber)	0.1362	0.2541	49.877	131.10	0.879	27.57
Wall type "G" (Hempcrete block+straw)	0.1513	0.0125	45.590	248.00	1.100	34.47
Wall type "H" (Energy efficient block)	0.1565	0.1150	46.455	194.00	1.103	34.59

Results of the obtained values is presented as follows in Fig.2.

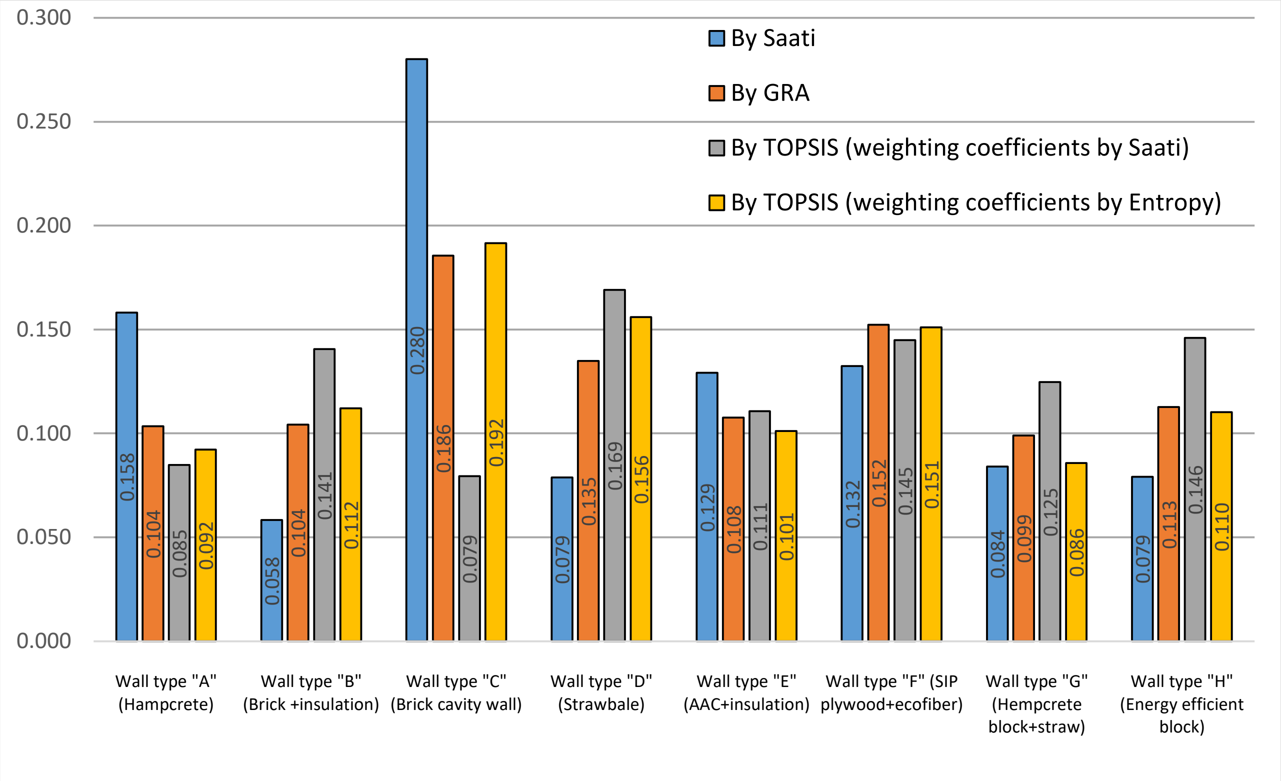

Figure 2. Assessment of energy efficiency for assemblies by different methods

Conducted research has shown, from the one hand, that the best choice isn't obvious by all four MCDA assessment methods, as well that contenders to the best envelope type according to applied MCDA methods are Brick cavity wall (the best rank by AHP, GRA and TOPSIS based on AHP weights) and Strawbale wall (the best rank by TOPSIS based on entropy method of criterion weight calculation). The worst assemblies are not identified by majority of compared results of values by MCDA methods. From the other hand the best positive correlation has GRA with TOPSIS method (weighted by Entropy) -0.962, and the worst correlation has TOPSIS method performed by two weighting techniques – AHP and Entropy – -0.288 (see table 3).

Table 3 Correlation between MCDA methods of envelopes energy efficiency potential's assessment

Between method	and method	Correlation coefficient
AHP	GRA	0.792
AHP	TOPSIS (weghts by AHP)	-0.895
AHP	TOPSIS (weghts by Entropy)	0.658
GRA	TOPSIS (weghts by AHP)	-0.463
GRA	TOPSIS (weghts by Entropy)	0.962
TOPSIS (weghts by AHP)	TOPSIS (weghts by Entropy)	-0.288

The possible reason for such differences could be explained by evaluation attitude in techniques - AHP is considered as the subjective method with pairwise comparison matrixes, while GRA and TOPSIS is objective method of comparison.

It is obvious, that the final decision-making in the best alternative choice should be accepted in case of minimal differences between MCDA evaluation techniques.

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