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EVALUATION OF THE THERMAL INSULATION PERFORMANCE OF THE GROUND FLOOR OF AN A++ CLASS PUBLIC BUILDING USING THE SAW METHOD

***Donatas AVIŽA*[a,b]**

[a] *Panevėžio kolegija/State Higher Education Institution, Lithuania*
[b] *Kaunas University of Technology, Lithuania*

Abstract. This paper investigates the Simple Added Weighting (SAW) method for evaluating the thermal insulation performance of the ground floor of an A++ class public building. Four alternative insulation materials (*ŠILPUTA EPS100; FF-EPS100S; FINNFOAM F-200; PAROC GRS 20*) were evaluated on the basis of six criteria: the compressive strength up to 10% deformation, the design value of thermal conductivity coefficient, the thickness of the thermal insulation layer, the cost (Q4 2023), the global warming potential (GWP) and the long-term water absorption of the insulation material. The results of the empirical research indicate that *FINNFOAM F-200* is the most effective thermal insulation material for the ground floor insulation of a nearly zero-energy public building. The highest relative performance score (0.87) was achieved by this material. Rock wool *PAROC GRS 20* is the least effective (0.51 points) alternative (from the four tested materials).
Keywords: thermal insulation layer; ground floor; nearly zero-energy public building; SAW method

INTRODUCTION

The European Commission through, via the EU Building Stock Observatory, has reported that the building sector is responsible for more than 40 % of the energy consumption and 36 % of greenhouse gas emissions, with the primary sources of emissions being construction, usage, renovation, and demolition. In the Net Zero Emission Scenario, the EU building sector, which currently comprises a significant portion of energy-inefficient buildings (approximately 75%), must reduce its carbon emissions by over 50% by 2030 and approach zero emissions by 2050 through decarbonization efforts (Fraska et al. 2023).

The new Energy Performance of Buildings Directive (EPBD) 2018/844 highlights the issue of energy efficiency in buildings and sets out certain requirements and objectives to be pursued. The aim is that both new and renovated buildings become zero-energy buildings, which have high energy efficiency, and in which renewable energy sources meet the greatest energy demand (Indre Siksnelyte-Butkiene et al. 2021). In Lithuania, nearly zero-energy buildings are required to meet the standards of A++ Class (STR 2.01.02:2016) buildings.

A wide range of scientific analysis of nearly zero energy buildings is available in the scientific literature (Abrahamsen, et al. 2023; López-Ochoa et al. 2023; Zhang, 2023; Jiang, 2023 and others). However, there is a lack of information on the multi-attribute evaluation of the performance of thermal insulation materials for ground floors in public buildings. Therefore, a typical ground floor detail of an A++ public building will be further investigated in this study. After the empirical analysis, the most effective ground floor insulation alternative will be identified.

The aim of this study is: to assess the performance of the thermal insulation layer of the ground floor of a class A++ public building using the SAW method.

The objectives of the research are:

1. Investigate the use of the SAW methodology for multi-attribute analysis.
2. Create a research model using a typical ground floor detail of an A++ public building.
3. Perform a multi-attribute evaluation study of the effectiveness of four different thermal insulation materials against six criteria.

Research methods: review of technical and scientific literature; empirical analysis; SAW method.

THE SAW METHOD

The Simple Additive Weighting (SAW) method is considered one of the most straightforward and widely adopted methods in decision-making. MacCrimmon (1968) summarized the method's rules. The Simple Additive Weighting (SAW) approach is categorised as a method for decision-making that incorporates quantitative measurements (Simanavičienė, 2011). Other researchers (Podvezko et al., 2014; Kraujalienė, 2019) have outlined the advantages and disadvantages of the SAW approach (Table 1).

Table 1

Advantages and disadvantages of the SAW decision-making method (Kraujalienė, 2019)

No	Advantages	Disadvantages
1	This tool is able to compensate among variables	The SAW method may be applied when all the variables are maximized (or transformed into maximized variables) before analysis.
2	Intuitive method for decision-makers; the way of measuring is quite simple and does not require several computer programs or tools.	All the values of the variables should be positive. The calculation depends on the type of transformation that converts them into positive dimensions.
3	This tool integrates the values of variables and weights into a single magnitude.	The largest dimension of the variable of the SAW tool maybe about unity, while the smallest dimension may reach the 0.
4	The calculation algorithm of this method is not complex and can be implemented without using a simple computer program or computer tools.	Estimates obtained by the SAW method do not always reflect the actual condition. The result may not follow logic because the measures of one particular variable are very different from other variables.
5	Normalized evaluation values help visually calculate differences between alternatives.	The SAW tool is based on normalization, reducing variables, and converting them into maximization.
6	This tool is suitable to evaluate a single alternative.	The result obtained may not be logical.

The Simple Additive Weighting method is one of the most common multi-attribute decision-making (MADM) methods. Finding the weighted sum of the performance ratings for each alternative considering all attributes is the basic concept of the SAW method (Taherdoost, 2023). Evaluating the efficiency of a SAW involves a number of successive steps (Simanavičienė, 2011; Wardana et al. 2020):

Step 1: Initial decision matrix *P* is established (1):

$$P = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}; \quad (1)$$

where $i = 1, \dots, m$, and $j = 1, \dots, n$.

Step 2: All members of the decision matrix *P* to be maximised are normalised using Equation (2):

$$\overline{x_{ij}} = \frac{x_{ij}}{x_j^{max}}; \quad (2)$$

and those that need to be minimised – according to the Equation (3):

$$\overline{x_{ij}} = \frac{x_j^{min}}{x_{ij}}. \quad (3)$$

Step 3: Finding the weighted sum of the performance ratings by using Equation (4):

$$A = \left\{A_i \middle| \max_i \sum_{j=1}^{n} q_j^* \cdot \overline{x_{ij}}\right\}; \quad (4)$$

where $q_{j,}^*$ $(j = \overline{1,n})$ – significance values for the indicators; $\overline{x_{ij}}$ – is the normalized decision matrix.

Step 4: Ranking of the alternatives. The highest value obtained is the most efficient alternative.

THE RESEARCH MODEL

The research model was created by using a typical ground floor detail of an A++ public building. The area of heated floor – A= 300.00 m²; the perimeter of the heated floor – P=112.00 m. The tested layer – no 4 (Figure 1).

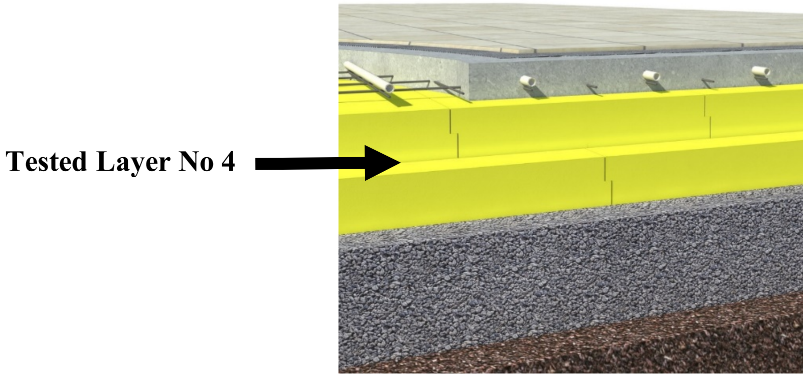

Figure 1. **The research model – the ground floor detail of an A++ class public building (for the explanation of layers, see Table 2). Source: https://finnfoam.lt/**

Following the Technical Regulations of Construction STR 2.01.02:2016 was calculated: a) the required heat transfer coefficient of an A++ Class public ground floor – U=0.14 W/m²K and b) the thickness of different thermal insulation materials.

Table 2

The Ground Floor Layers

No	Name of the layer	Thickness, mm
1	Floor covering	20
2	Tile Adhesive Mat	-
3	Reinforced concrete layer	80
4	Thermal insulation material (Tested layer)	170-210
5	Compacted gravel or crushed rock	-

In this study, four different thermal insulation materials – conventional polystyrene, graphite polystyrene, extruded polystyrene, and rockwool panels – were tested.

The SAW (Simple Additive Weighting) method was chosen for the multi-attribute assessment of the effectiveness of the four different thermal insulation materials against six criteria.

THE RESEARCH METHODOLOGY AND OUTCOMES

In the first step, a primary decision-making matrix (Table 3) is compiled and four different thermal insulation materials (*ŠILPUTA EPS100; FF-EPS100S; FINNFOAM F-200; PAROC GRS 20*) are assessed against six criteria derived from the technical specifications: compressive strength up to 10% deformation, design value of thermal conductivity coefficient, thickness of the thermal insulation layer, cost (as of Q4 2023), the global warming potential (in A1-A3 stages) and the long-term water absorption of the insulation material. The significance of all attributes is assumed to be equal (0.167).

Table 3

Primary Decision-making Matrix

Tested alternatives/ Significances	**Attributes**					
	The compressive strength up to 10% deformation, kPa	***The design value of thermal conductivity coefficient, W/(m·K)***	***The thickness of the thermal insulation layer, mm***	***The cost of the insulation material (Q4 2023), €/m²***	***The global warming potential (A1-A3), kgCO2e /m²***	***The long-term water absorption, WL, %***
ŠILPUTA EPS100	100.00	0.041	190.00	11.71	11.80	5.00
FF-EPS100S	100.00	0.036	170.00	15.81	11.46	3.00
FINNFOAM F-200	200.00	0.038	180.00	22.87	13.72	0.70
PAROC GRS 20	20.00	0.045	210.00	19.66	23.11	3.00
Significance	0.167	0.167	0.167	0.167	0.167	0.167

In the second step, the primary decision-making matrix is normalized (Table 4).

Table 4

Normalized decision-making matrix

Tested alternatives/ Significances	Attributes					
	The compressive strength up to 10% deformation, kPa	*The design value of thermal conductivity coefficient, W/(m·K)*	*The thickness of the thermal insulation layer, mm*	*The cost of the insulation material (Q4 2023), €/m²*	*The global warming potential (A1-A3), kgCO2e /m²*	*The long-term water absorption, WL, %*
ŠILPUTA EPS100	0.500	0.878	0.895	1.000	0.971	0.140
FF-EPS100S	0.500	1.000	1.000	0.741	1.000	0.233
FINNFOAM F-200	1.000	0.947	0,944	0.512	0.835	1,000
PAROC GRS 20	0.100	0.800	0.810	0.596	0.496	0.233

In the next step, the weighted normalized decision matrix is formed (Table 5).

Table 5

Weighted normalized decision-making matrix

Tested alternatives/ Significances	Attributes					
	The compressive strength up to 10% deformation, kPa	*The design value of thermal conductivity coefficient, W/(m·K)*	*The thickness of the thermal insulation layer, mm*	*The cost of the insulation material (Q4 2023), €/m²*	*The global warming potential (A1-A3), kgCO2e /m²*	*The long-term water absorption, WL, %*
ŠILPUTA EPS100	0.084	0.147	0.149	0.167	0.162	0.023
FF-EPS100S	0.084	0.167	0.167	0.124	0.167	0.039
FINNFOAM F-200	0.167	0.158	0.158	0.086	0.139	0.167
PAROC GRS 20	0.017	0.134	0.135	0.099	0.083	0.039
Min./Max.	Max.	Min.	Min.	Min.	Min.	Min.

In the final step, the values are summed, and the alternatives are ranked (Table 6).

Table 6

Ranking alternatives

Tested alternatives	Sum of indicator values	Ranking
ŠILPUTA EPS100	0.73	3
FF-EPS100S	0.75	2
FINNFOAM F-200	0.87	1
PAROC GRS 20	0.51	4

Upon completion of the multi-attribute SAW evaluation study, the scores of efficiency was calculated for each thermal insulation material (Figure 2).

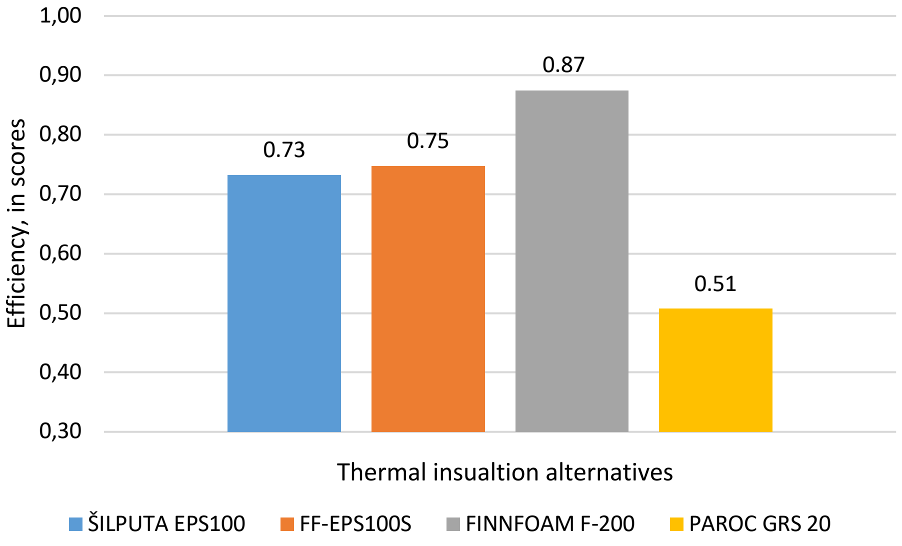

Figure 2. **The evaluation of the efficiency of the ground floor thermal insulation layer**

The empirical analysis reveals that, for a ground floor of a public A++ Class building, the most effective thermal insulation layer is the extruded polystyrene foam *FINNFOAM F-200*, while the least effective is rock wool *Paroc GRS20*, with a relative efficiency score of 0.51 points.

CONCLUSIONS

1. According to the SAW method, the empirical analysis showed that the most effective thermal insulation for the ground floors of A++ class public building, considering four material alternatives and six proportional indicators, is extruded polystyrene – *FINNFOAM F-200*. This alternative achieved the highest relative efficiency score of 0.87 points.
2. The least effective option among the four tested alternatives is rock wool – *Paroc GRS 20*, scoring 0.51 points. The difference between the best and worst alternatives is 41.38 percent.

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