Interaction between Theory and Practice in Civil Engineering and Construction
Edited by Komurlu, R., Gurgun, A. P., Singh, A., and Yazdani, S.

ISBN: 978-0-9960437-2-4

OPTIMIZATION OF FLAT ROOF THERMAL RENOVATION TECHNOLOGIES

RUTA MINIOTAITE

Dept of Civil Engineering Technologies, Kaunas University of Technology, Kaunas, Lithuania

The created methods and the logical scheme of an alternative selection based on it, allow for the adoption of decisions that optimally satisfy the technical parameters of roof repairs and the financial possibilities of a builder in each concrete case. It is here suggested that one selects a rational version of roof repairs in a step-by-step way by assessing the alternatives with the help of multi-criteria decision methods. Each stage has pre-selected assessment criteria, decision methods and created database. The initial stages include the following steps: the assessment of the condition of the roof following the developed methods, the expected price of the work and preliminary selection of alternatives. By using the method of mathematical analysis – efficiency value analysis – the most economically and technologically efficient option of thermal renovation was determined. The reconstruction of non-usable flat roof is optimal in technical, economic and humidity exposure terms. The price of this roof construction is not the minimum price, but duration of construction work, resistance to humidity exposure are optimal.

Keywords: Technology of renovation, Analysis of workability.

1 INTRODUCTION

Recently renovation and modernisation of buildings is a hot topic in Lithuania. Various programmes are implemented, people are encouraged to explore renovation possibilities and renovate their homes. Renovation means the improvement and modernization of buildings and living environment, the creation of new quality. It is a separate part of reconstruction work that involves a complex of construction and installation works aimed at improving the physical, mechanical, aesthetic and other operating properties of the present building in order to achieve better energy. Renovation involves the renewal of building structures, interior, exterior, insulation of the building envelope and other work requested by the customer in order to improve the present properties of the building (Bieksa *et al*. 2011).

Renovation is not defined in technical regulations of construction work; therefore buildings are renovated in accordance with technical regulation of construction "Types of construction of the building" (STR 1.01.08 2002). According from this regulation renovation of a building can be treated as reconstruction of the building.

Depending on the roof structure, the building may lose up to 30 – 35% heat through the roof. Therefore, renovation of the building should start from the roof (Rapceviciene 2010). Roofing technologies and materials used in twenty year old and older building are outdated; the insulation used those days does not meet the current requirements for roof structures. All roofs that were not renovated using new generation roofing materials are in very poor condition: the rood deck is uneven, there are blisters and cracks in bitumen cladding, the seams between the roof cladding and other roof elements are leaky. Building are loosen big amount of energy through the roofs.

Renovated roofs must meet the currently applicable structural requirements according to the Regulation "Structures of buildings. Roofs" (STR 2.05.02 2008) and energy efficiency requirements according to the Regulation "Energy efficiency of buildings. Certification of energy efficiency" (STR 2.01.09 2012).

The main roof repair and heat insulation renovation technologies are described in the recommendations "Flat roofs repair methods and solutions" (R 26-00 2000) approved by the Ministry of Environment of the Republic of Lithuania.

Both newly-built and renovated roofs must meet the minimum requirements set forth in construction regulations. First of all the roofs must be weatherproof and resistant to design loads. They must be designed, build and maintained in accordance with the essential requirements for the building, i.e. they must be mechanically resistant and intact, the structure must meet fire safety, hygiene, health, environmental and operation requirements, roofs must ensure protection from noise, save energy and heat. The roof structure must satisfy the flammability B_{roof}(t1) class, whereas the heat transfer coefficient of a renovated roof must be at least $U_{n.r.}$=0,20W/m$^{2}\cdot$K (STR 2.05.01 2013).

Thermal renovation is the best method for renewing a flat roof. Before starting a flat rood renovation, the condition of the roof must be evaluated and appropriate constructional solutions must be selected. The most feasible method of renovation is selected after considering the present condition of the roof, the present conditions of work, financial resources and the desirable additional roof performance properties.

The most common problem of old flat roofs is "confined" humidity. The pressure of accumulated water vapour is confined in the structure and produces blisters in the roof coating. These blisters deteriorate the performance of the roof. Renovation must ensure proper ventilation of roofing layers.

The goal of this paper is to analyze the methods of thermal renovation of flat roofs taking into account the materials used, roof structures and roofing technologies as well as conduct the integrated analysis of selected technological alternatives by means of efficiency value analysis.

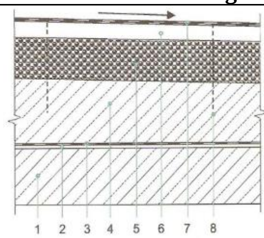
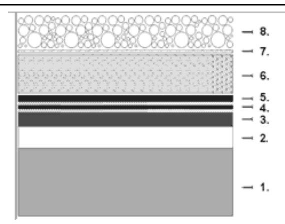
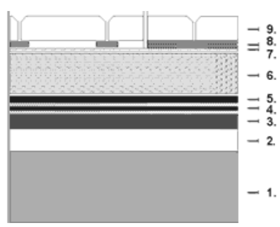
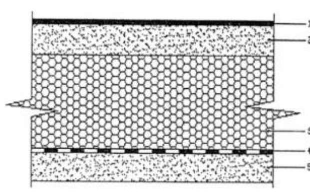
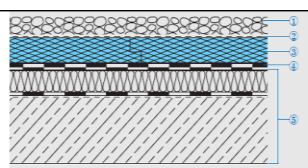
2 EVALUATION AND OPTIMIZATION OF FLAT ROOF RECONSTRUCTION

Design solutions of construction processes can be evaluated by different methods. According to the number of criteria used they are divided into single criterion and multiple criteria solutions (Juodis 2005). In order to find the best solution, a multiple criteria optimization of selected structural solution alternatives must be done.

2.1 Initial Data for Multiple Criteria Evaluation of Alternative Solutions for Flat Roof Reconstruction

Five structural alternatives for the thermal renovation of a flat roof are selected. The selection is followed by economic and humidity calculations, workability analysis, and the most rational variant are determined. Structural solutions of reconstructed roofs are presented in Table 1. For building a terrace or a roof garden, additional loads for bearing structures should be considered. The price of such roofs is also higher.

Table 1. Structural solutions of reconstructed roofs.

Alternative	Structural drawing	Structural layer, materials
Alternative 1 Not used flat roof		1 Existing reinforced concrete slab 2 Surface levelling layer 3Present sound insulation 3 Present heat insulating porous concrete slab 4 Lower polystyrene foam layer 5 High performance polystyrene foam layer 6 Roof waterproofing with protective layer
Alternative 2 Flat roof in use		1 Roof base layer 2 Surface levelling layer 3 Old bitumen cladding 4 Lower Superbase Ultratorch layer 5 Upper Superbase Ultratorch layer 6 Thermal insulation – extruded polystyrene 7 Filtering layer from geotextile 8 Gravel or concrete slabs
Alternative 3 Reverse roof		1 Roof base layer 2 Surface levelling layer 3 Old bitumen cladding 4 Lower Superbase Ultratorch layer 5 Upper Superbase Ultratorch layer 6 Thermal insulation – inverse type 7 Filtering layer from geotextile 8 Load distributing layer 9 Concrete slabs
Alternative 4 Not used flat roof		1 Bearing structure 2 Old bitumen cladding 3 Lower thermal insulation layer – polystyrene foam plates (EPS 80, EPS 100) 4 Upper thermal insulation layer – thermal insulation plates *5* Upper layer of reinforced bitumen waterproof plates
Alternative 5 Flat roof in use		1 Breakstone /gravel Ø 16/ 2 Geotextile filtering layer 3 STYROFOAM 300 4 Final new waterproof layer 5 Old roofing layer

2.2 Using Efficiency Value Analysis to Find the Effective Structural Solution for the Reconstructed Flat Roof

The efficiency value analysis is the assessment of solutions basing on a set of criteria. This method can be applied both with dimensional and non-dimensional values, therefore, the solutions can be evaluated in terms of different criteria: technical, legal, economic, social etc.

Method evaluation algorithm:

- A set of evaluation criteria is formed;
- A relative weight to each criterion is assigned;
- Values of criteria are found;
- The efficiency value from 0 to 10 points is assigned;
- The numerical value of efficiency is determined;
- Total efficiency value of alternative solutions is determined.

Different criteria are not equally important in the evaluation of alternative constructional solutions, therefore the significance of criteria in relation to each other is taken into account during the evaluation.

The following criteria were selected to evaluate the workability of flat roof insulation renovation methods:

Technical – economic criteria (C):

C1 – The price of 1 m^2 of the roof, EUR,

C2 – Fire resistance of roof structure (1 – not resistant, 5 – resistant),

C3 – Complexity of roof structure installation (1 – complicated, 5 – not complicated);

C4 – duration of building 100 m^2 of roof structure by a team of 6 builders (in days);

Criteria for the evaluation of humidity regime of a roof structure:

C5 – vapour resistance factor of thermal insulation;

C6 – amount of condensed vapour per year (g/m^2).

Combinations of evaluation criteria are done to optimize the alternative structural solutions:

Combination 1. Technical – economic criteria (*CR1, CR2, CR3, CR4*).

Combination 2. Criteria evaluating humidity regime of the roof structure (*CR5, CR6*).

Program DOFTHERM has been used to calculate the moisture regime of the roof constructions. It determined the variation of moisture condensation by changing insulation thickness, the type and the roof cover. The analysis determined the changes in the moisture content of the roof structure when changing internal relative humidity and air temperature.

Evaluation of technological alternatives for roof renovation by means of efficiency value analysis using the determined importance of criteria is presented in Table 2. Figure 1 illustrates graphical comparison of alternative roof renovation technologies by technical-economic criteria. Figure 2 illustrates graphical comparison by humidity regime criteria.

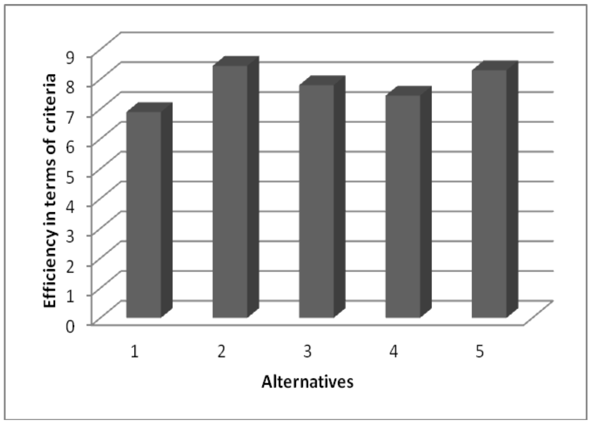


Figure 1. Technical-economic comparison of alternative roof renovation technologies.

After the optimization of structural solutions for flat roof reconstruction by applying the sets of criteria of efficiency value analysis it was found that Alternative 4 was the most optimal (bearing structure, old bitumen cladding, lower thermal insulation layer from polystyrene foam (EPS 80, EPS 100), upper thermal insulation layer from heat insulating slab, top layer made of reinforced bitumen waterproof sheets). This alternative is optimal in technical-economic and humidity regime terms. The cost of this roof structure is not minimum price but the time of installation, resistance to external fire and weather exposure is optimal.

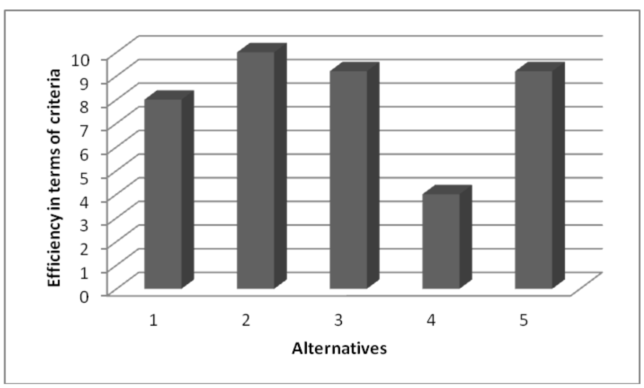


Figure 2. Comparison of alternative roof renovation technologies by humidity regime criteria.

3 CONCLUSIONS

Thermal renovation is the most effective for flat roofs. This renovation involves the laying of additional layer of thermal insulation in order to achieve the thermal resistance value required by current construction standards. New high quality construction materials and technologies ensure the durability and reliability of roofs for few decades.

The effect of moisture must be evaluated in the construction of flat roofs because moisture migration and condensation causes serious problems: moistening of thermal insulation, reduced thermal resistance, destruction of heat insulation structure, moulding due to condensate thawing, damage of rolled cladding structure.

The analysis of the efficiency value of alternative design solutions showed that the reconstruction of not used flat roof (Alternative *4*) is optimal in technical-economic and humidity regime terms. The price of this alternative is not the lowest but the timing of construction work, resistance to external fire and moisture are optimal.

Table 2. Evaluation of alternative design solutions according to the first set of reconstructed flat roofs.

Criteria	**Relative weight, %**	**The value of criteria / Alternatives of roof renovation technologies**				
		1	**2**	**3**	**4**	**5**
C1	0.50	194,48	245,51	242,98	240,99	261,31
C2	0.25	5	4	5	4	5
C3	0.15	3	2	2	3	2
C4	0.10	5	9	8	7	8
C5	0.40	1	2	1	0	1
C6	0.60	5	0	0	2	0

Table 2. Continued.

Criteria	**Efficiency values (0-10)**					**Efficiency in terms of criteria**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
C1	5	10	8	7	9	2.5	5.0	4.0	3.5	4.5
C2	10	9	10	9	10	2.5	2.25	2.5	2.25	2.5
C3	6	4	4	6	4	0.9	0.6	0.6	0.9	0.6
C4	10	6	7	8	7	1.0	0.6	0.7	0.8	0.7
					AMOUNT	6.9	8.45	7.8	7.45	8.3
C5	8	10	8	1	8	3.2	4.0	3.2	0.4	3.2
C6	8	10	10	6	10	4.8	6.0	6.0	3.6	6.0
					AMOUNT	8.0	10.0	9.2	4.0	9.2

References

Bieksa, D., Siupsinskas, G., Martinaitis, V., Jaraminiene, E., Energy efficiency challenges in multi-apartment building renovation in Lithuania: *Journal of Civil Engineering and Management*, 17(4), 467-475, 2011.

Juodis, A., *Mathematical modeling and optimization of construction processes*. Technologija, Kaunas, 2005.

Rapceviciene, D., Evaluation of multi residential house renovation efficiency: *Science – Future of Lithuania*, 2(2), 83-89, 2010.

Recommendations R 26-00, Methods and solutions of repairing flat roof structures, 2000.

Technical regulation of construction STR 2.05.01:2013, Design of the Energy Performance of Buildings, 2013.

Technical regulation of construction STR 2.01.09:2012, Energy efficiency of buildings. Energy efficiency certification, 2012.

Technical regulation of construction STR 2.05.02:2008, Structures of the building. Roofs, 2008.

Technical regulation of construction STR 1.01.08:2002, Types of construction of the building, 2012.