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POSSIBILITIES OF MODERNIZATION OF FLAT ROOFS

RUTA MINIOTAITE

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

In Lithuania, there are about 40 million square meters of flat roofs, such as roofs of apartment houses, public and industrial buildings and other. Subject to the construction of the roof, the building can lose as much as up to 30-35% of the heat through the roof partition. Therefore, the renovation of roof is among the primary works in the renovation of buildings. Condition of flat roofs which were installed 20 or more years ago is poor, as there were used old technologies, poor materials and insulation of roof does not meet today's requirements. Today about 70% of all roofing works consists of the renovation work. However there are often made mistakes, not used options of roof's modernization. The purpose of this work is to analyze the renovation techniques of flat roof used in Lithuania and typical mistakes of renovation, as well as describe the emerging option for modernization of flat roof.

Keywords: Renovation of buildings, Engineering problems, Technical and technological solutions.

1 INTRODUCTION

The renovation and modernization of buildings has recently become a particularly widely discussed topic in Lithuania – various programs are conducted and the residents are encouraged to be personally interested in the methods of renovation and to renew their homes. Renovation is considered as a separate part of reconstruction works, which includes a complex of construction and installation works aimed at improving the physical, mechanical, aesthetical and other performance characteristics of the building in order to achieve higher energy performance.

There is no definition of renovation in construction technical regulations, therefore, the performance of building renovation works is based on construction technical regulation STR 1.01.08:2002 "Types of Construction Operations in Construction Works" (2002).

Subject to the construction of the roof, the building can lose as much as up to 30-35% of the heat through the roof partition. Therefore, the renovation of roof is among the primary works in the renovation of buildings. The technologies and materials that were used for the installation of roofs 20 years ago, if not earlier, are now considered archaic, the insulation of roofs of that time does not comply with the requirements applicable to the modern-day roof constructions. Almost all roofs covered with ruberoid, if they have not yet been renovated by using new generation roofings, are of very poor quality: the substrate of the roof is uneven, the blisters and tears are present in the bitumen coat, non-hermetic seams are present between the roofing and other roof

elements (funnels, hatches, chimneys), buildings are characterized by considerable thermal losses through the roof.

The renovated roofs should meet the constructional requirements applicable to such roofs according to STR 2.05.02:2008 "Constructions of Buildings. Roofs" (2008) and energy requirements according to STR 2.05.01:2013 "Design of the Energy Performance of Buildings" (2013).

In 2000, the Ministry of Environment of the Republic of Lithuania approved the recommendations R 26-00 "Methods and Solutions of the Repair of Flat Superposed Roofings". These recommendations (R 26-00 2000) stipulate various methods of repair and renovation of flat roofs by comparing them and determining their advantages and disadvantages. However, these recommendations do not cover the new roof renovation methods, which are not yet very popular in Lithuania, but can be no less effective as compared with the time-tested technologies.

Both the newly installed and the renovated roofs should meet the minimum requirements of the construction regulations. First of all, the roof should be resistant to the atmospheric impact and design impacts of maintenance. It should be designed, built and used to meet the fundamental constructional requirements, i.e., be mechanically resistant and stable, the construction should meet the fire safety, hygiene, health, environmental and use requirements and ensure noise protection, energy consumption and thermal preservation, etc. The roof should meet *B roof (t1)* combustion class, whereas the heat transmission coefficient for the renovated roof should not be more than $U_{N.r.} = 0.16\ W/(m^2xK)$.

The aim of this paper is to analyze the methods of the renewal and thermal renovation of flat roofs in terms of the used materials, roof constructions and work technologies, describe the roof modernization possibilities emerging during the renovation.

2 METHODS OF RENOVATION OF FLAT ROOFS

The best solution of the renovation of roof is the removal of all old roof coats and installation of a new roof. However, due to high operational costs and expenses, it is rarely used. Pursuant to the recommendations approved by the Ministry of Environment of the Republic of Lithuania (R 26-00 2000, http://lt.lt.allconstructions.com), there are three methods of roof renovation, which are presented in Table 1 below. The best method of roof renovation should be selected in view of the wearing of roofing and its construction as well as in view of the current thermal characteristics.

In order to save the funds, the works are usually limited to the minor roof repair, i.e., the roof is renovated without removing the old roofing. One layer of hot melt roofing coat is usually glued on the old ruberoid. However, such method not only fails in solving old roof problems, i.e., irregular inclinations, removal of accumulated moisture, high thermal losses, but also delays the repair of roof for no more than 4-5 years.

Table 1. Roof renovation methods.

Renovation Methods	Technology of Works	Advantages	Disadvantages
Without the removal of the old roofing	The defects of old roofing are repaired, i.e., blisters, tears, etc. and a new coat is laid.	Low operational costs. Low expenses.	All old roof defects remain: surface unevenness, unrepaired inclinations, high thermal conductivity of the roof.
Removal of the old roofing	The old roofing is removed, the substrate is reinforced and leveled, the new layer of roofing is laid.	The roof substrate is repaired: inclinations, smoothed surface, etc.	The costs are almost twice as high as in case of the first renovation method. Sufficient thermal insulation of the roof is not ensured. Considerable operational costs.
Thermal renovation	Thermal insulation layer is placed on the repaired old roofing coat and a new roofing coat is placed on it.	Reduced thermal conductivity of the roof, leveled roof substrate, repaired inclinations. Improved roof ventilation conditions.	Considerably higher operational costs and expenses than in case of the first renovation method.

Table 2. The main thermal renovation methods.

Technology of Works	Conditions of the Installation Environment	Advantages	Disadvantages
	Installation of a single-layer bitumen coating		
The additional necessary thermal insulation is laid on the prepared old roofing and the bitumen roofing is mechanically fastened on it. The overlapping roof stripes are glued by using hot air.	It is possible to work in low temperatures if the additional means are taken, however, it is necessary to consider the temperature of the substrate. The substrate should be dry. The bitumen coating remains flexible in temperatures down to -25 ^{0}C.	Mechanically resistant, elastic coating, which is flexible even in low temperatures. Low material costs as compared with two-layer bitumen coatings.	A relatively high number of seams is formed (the width of coat roll – 1 m). The performance characteristics of the roof are highly dependent on the quality of installation of layers.
	Installation of a two-layer bitumen coating		
The additional necessary thermal insulation is laid on the prepared old roofing and the under layer of bitumen roofing is mechanically fastened on it. Finally, the upper layer of coating is melted.	It is possible to work in low temperatures if additional means are taken, however, it is necessary to consider the temperature of the substrate. The substrate should be dry. The bitumen coating remains flexible in temperatures down to -15 ^{0}C.	Mechanically resistant, elastic coating, which is flexible even in low temperatures. Used for a long period of time, therefore, are tested and the waterproof characteristics of the coating are well known.	Considerable material costs. The performance characteristics of the roof are highly dependent on the quality of installation of layers.

Table 2 (continued). The main thermal renovation methods.

Technology of Works	Conditions of the Installation Environment	Advantages	Disadvantages
	Installation of the PVC coat		
The additional necessary thermal insulation is laid and fastened to the substrate of the prepared old roofing, whereas the prepared PVC film, i.e., of respective dimensions, is laid on it and can be mechanically fastened, ballasted or fully adhered.	In temperatures lower than + 10 ^{0}C, it is possible to work by using the additional measures, however, it is also necessary to consider the temperature of the substrate. It remains flexible in temperatures down to – 30 ^{0}C.	Durability (20 – 30 years). Laid in one layer. Resistant to the UV rays, negative impact of atmospheric phenomena, tearing, natural ageing. Installation during winter period is also possible, the flexibility is maintained in temperatures down to - 30 ^{o}C. It is 50 times more permeable to water vapor than to bitumen coatings.	It is irresistible to bitumen materials or those having resins, organic solvents, oils, fats. In case of contact with styro-foam, the detachable glass fiber layer is necessary.
	Installation of layered thermal insulation slabs		
The thermal insulation slabs made of polystyrene foam and bitumen coating and of a necessary thickness are placed on the prepared old roofing substrate. The bitumen coatings are fitted on the roof coat with pins or glued with special bituminous glue, the overlaps are melted with a gas burner and finally the upper layer bitumen coating is hot melted.	It is possible to work in low temperatures if the additional measures are taken. It is possible to work with bituminous adhesives for gluing slabs and the under layer of bitumen coating in temperatures down to -50 °C. The bitumen coating remains flexible in the temperatures down to -15 °C. It is possible to work under variable weather conditions.	The thermal conductivity of roof is reduced. Minimum weight, resistance to compression, stable dimensions. Since the polystyrene absorbs almost no water and is covered with the bitumen coating, the works can be performed under varying weather conditions. The costs are reduced up to 30%. Low work costs.	Polystyrene foam is not resistant to high temperatures, melts and shrinks in case of direct contact with fire. The protection from the long-term impact of direct sunrays is necessary. Brittle.
	Installation of the EPDM roofing membrane		
The additional necessary thermal insulation is laid and fastened to the substrate of the prepared old roofing, whereas the prepared EPDM membrane, i.e., of respective dimensions, is laid on it and can be mechanically fastened, ballasted or fully adhered.	It is possible to work in temperatures lower than +40 ^{0}C after taking additional measures, the seams can be performed in temperatures down to -15 ^{0}C. The coat remains flexible in temperatures down to – 45 ^{0}C.	Durability (20 – 40 years). The strength and elasticity of coat does not vary. The coat is resistant to the UV rays. The minimum number of seams is formed. The speed of installation – up to 1,000 m^2 of roof can be coated per day.	The EPDM roofing membrane is less resistant to tearing. Specially trained workers are necessary.

The third type – thermal renovation – is the best variant, because it includes not only the repair of roof leak tightness problems, but also improves the thermal and other performance characteristics and ensures the compliance with modern requirements applicable to roof constructions. However, there are several methods of performance of thermal renovation of the roof (www.statybostaisykles.lt). These methods are different in terms of used materials, installed roof construction, work technology, therefore, in case of specific works, it is possible to select the best version according to the current roof condition and work conditions and the most suitable according to the quality-price ratio. The main thermal renovation methods are presented in Table 2.

3 POSSIBILITIES OF MODERNIZATION OF FLAT ROOFS

When renovating the roof, it is necessary to ensure its reliability and durability and also to use the possibility to modernize it by providing new appearance and expanding the limits of use.

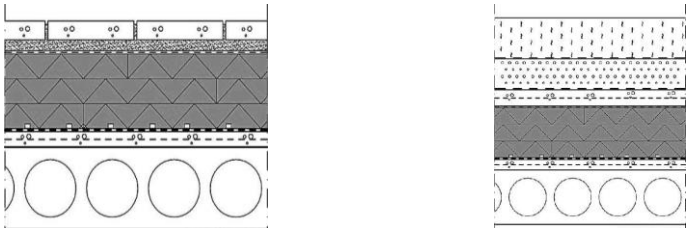
If permitted by the roof bearing constructions, the renovated roof can be turned into the usable roof, i.e., the terrace, thus, creating the additional spaces for leisure and other activities. The installation of such roof is more complex than of ordinary flat roof, because the terraces are exposed to higher loads, therefore, the layers of the roof must be protected not only against moisture, but also against mechanical impact. In such case, it is purposeful to install the insulated reverse roof (Figure 1), where the thermal insulation layer is laid on the ordered waterproofing coat. In such case, the waterproofing layer is additionally protected against rapid temperature variations, sunrays and mechanical loads. The thermal insulation layer requires the use of high load-bearing extrusion polystyrene foam slabs. The bottom slab is placed on the waterproofing layer and is usually fitted with water drain channels for the elimination of water (http://lt.lt.allconstructions.com). The insulation layer is covered with a filtrating layer – a diffusive membrane or geotextile. Subject to the purpose of the roof, the top layer can be made of tiles, washed gravel or reinforced concrete.

One version of usable roof is the planted roof (Figure 2), which is relatively rare. It is usually related to high costs, which are necessary for the installation and maintenance of planted roofs. It shall be noted, however, that the planted roofs, as compared with ordinary roofs, have many advantages and additional possibilities of use. It can be a measure to improve ecology, which is particularly important in the metropolitan cities, as well as an opportunity to use these areas for commerce: cafes, tennis courts, etc.

The planted roofs have many practical and economic advantages. The planted roof minimizes the noise up to 50 dB and the pass of noise both from the inside and outside of the building. The planted roof has a longer service life due to lower variation of extreme temperatures, impact of UV rays and chemical impact. The planted roof is characterized with better thermal insulation properties allowing to save the energy costs. The soil layer performs the role of thermal accumulation coat – the vaporizing moisture cools the building during the day and the heat in the soil does not allow the building to cool down during the night.

After the installation of the planted roof, the costs are reduced by approx. 20-30% and are rather used for heating and conditioning of premises. The heating of the surface of roofing is lower than of ordinary surface by 2-3 times. The green roof can be considered as a “solid waterproofing system”, which, in case of fire, protects the

building from the spread of fire with the same efficiency as the roof with gravel chippings.



(a) (b)

Figure 1. (a) The principal scheme of used roof. From the top to the bottom: concrete tile or other coat (60-80 mm), leveling layer (≥40 mm, geotextile, thermal insulation layer, waterproofing, leveling and inclination forming concrete layer (≥60 mm, inclination >1:80), substrate of the roof (www.finnfoam.lt). (b) The principal scheme of a planted roof. From the top to the bottom: plants, vegetative soil (≥ 200 mm, geotextile, thermal insulation layer, waterproofing, leveling and inclination forming concrete layer (≥ 60 mm, inclination >1:80), substrate of the roof (www.finnfoam.lt).

4 CONCLUSIONS

The best method of renovation of flat roofs is thermal renovation. Before starting the renovation of a flat roof, it is necessary to consider its condition and to select proper constructional elements. The best method of renovation is selected in view of the current condition of a roof, working conditions, financial possibilities and the desired additional roof performance characteristics.

The most common problem of old flat roofs is "trapped" moisture. Due to the pressure of accumulated water vapor, which cannot make its way out of the construction, the blisters can be formed in the roof coat and, as a result, impair the performance characteristics of the roof. Thus, it is important to ensure a proper ventilation of roof layers during the renovation.

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