FLAT ROOF MONITORING AND CONTROL

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ABSTRACT

The flat roof is a part of the building envelope, normally located above the last floor of the building. It protects the building from the outside's complex effects of climate, and the roof also participates in creation of the internal artificial environment. It is one of the key, but also the most critical parts of the building. In addition to proper design, the correct choice of materials and quality of implementation, and maintenance is very important for the operation works. How to maintain and control especially waterproofing layer, which is usually covered by other layers? There are several systems that can be used to monitor a damp-proof membrane. This paper contains methods for monitoring and control, and comparison with the alternative of zero monitoring.

Key words: *flat roof, leak, monitoring, maintenance,*

1 INTRODUCTION

Roof structure is one of the technically most challenging parts of the building. Paradoxically, although physical properties are constantly improved and the amount of available materials increases, there are still a lot of roof defects. Many of them carried over from the past mistakes and transmitted to today's design solutions.

One of the main purposes of a roof is to resist the water. Two broad categories of roofs are flat and pitched. Flat roofs slope up to 10° or 15° but are built to resist standing water. [3]. Disorders of flat roofs usually have one (or more) of the following causes: inappropriate design of this roof (details, dimensions and method of drainage), improper selection of materials, poor quality implementation and failure of technological disciplines (weather effects), defects of used materials, changes the boundary conditions that affect the roof surface (e.g. changed operation of the building), neglected maintenance (reduced service life of materials), and incidents (accidents). More than any other style, flat roofs need to be monitored regularly since there is no way for water to be naturally put away.

Disorder of flat roof means complete or partial loss of any of its functions - waterproofing, thermal insulation and aesthetic. The loss of waterproofing function usually varies also thermal properties of roof coating and sooner or later the aesthetic characteristics. For that reason, the most serious defect is to damage the integrity of the waterproofing layer which leads to loss of waterproofing function, e.g. the roof is leaking [7].

Leaking roofs and defective flashings are common and sometimes difficult to diagnose and resolve. The main reason flat roofs are difficult to diagnose is because water can flow long distances before it penetrates into the building. It can be a mistake to patch a roof directly above a leak. The professional flat roof maintenance is the best way to avoid damage.

The primary objective of roof maintenance is to maximize the useful life of the existing roof system and minimize repair cost. It is important to inspect and to monitor the roof system to prolong its life and to plan the eventual roof system replacement.

Maintenance method should be prescribed by the manufacturer of the roof waterproofing materials in the project documentation, and agreed with the implementation company because professional flat

roof maintenance is very important for the life of the roof cladding. Regarding the roof, which execution moves in the hundreds of thousands of Euros, the cost of maintenance is negligible.

The basic maintenance activities should include the regular cleaning of the roof and the roof control by a professional company, at least twice per year to prolong the life of a roof system. It sounds simple, but the situation in real-life is quite different in Slovakia. Regular flat roofs maintenance is rarely carried out. Based on data from 2003, the total area of roofs in Slovakia was 280 million square metres [6]. It is expected that this amount has risen over 300 million square meters yet. At present, it should be considered of at least 40% share of flat roofs from this area, if not more. In practice, this would represent about 120 million m^2 flat roofs in Slovakia. Based on established data, it is estimated that about 70% of this amount is fault [5]. In building practice in Slovakia, only the problems are solved, not preventive maintenance. If any defect occurs on the roof, especially leaks, then the professional company will diagnose and resolve the problem. But it is late to deal with the roof system after defects occur because it costs much more money than to execute the regular professional monitoring and maintenance of flat roofs.

There are several simple methods to control and monitor the waterproofing layer that is on the top of the roof system. But how to do it when the waterproofing layer is covered by other layers? In this paper, there are described some possible monitoring systems with their work principles and their comparison with the zero-monitoring alternative.

2 MONITORING AND CONTROL SYSTEMS AND HOW IT WORKS

Several methods [1] have been used in attempting to locate roof leaks after they have occurred. These methods have been in place for several years. To date, these standard testing methods have consisted of the following: the simplest – construction observation, then is used flood testing, and several non-destructive test methods, including electronic impedance testing, infrared thermal imaging, and nuclear testing and electronic leak detection (ELD). From these methods, electronic leak detection will be described in details and the comparison is also done for ELD and other non-destructive methods are mentioned very briefly.

Electronic impedance testing identifies leaks using an alternating current signal to measure dielectric constant changes in the roofing material because of moisture below the membrane.

Infrared cameras allow technicians to scan roof surfaces for temperature differentials that signify moist areas through changes in thermal conductivity or evaporation.

2.1 Electronic leak detection system

Electronic leak detection (ELD) is also known as electronic field vector mapping. Electric field vector mapping uses a wire loop around the perimeter of the roof surface to introduce an electric potential between the structural deck and a selected roof area which is sprayed with water. The electric field potential caused by a conductive path to any roof membrane damage is then traced to the breach using a voltmeter and a pair of probes. There are two common methods of ELD: low voltage and high voltage.

2.1.1 *Low voltage method of ELD*

Often referred to as the “wet test”, this method is ideal for use on any flat or low-pitched roof to identify defects in exposed membrane or ballasted systems. This test is performed in wet conditions (rainfall) or with a hosed down wetted test area.

A pulse generator emits pulses with a voltage of 40V which are conducted onto the roof structure via a wire ring circuit. Since all roof membranes are to certain extent non-conducting, the electrical pulse chooses a path across the moisture to where the leak is located and then flows over the damp roof in all directions to reach the ring circuit.

We can now determine the currents direction of flow and trace it back to its source. This source is exactly the spot where moisture is penetrating the roof membrane.

2.1.2 *High voltage method of ELD*

This method is often referred to as the "dry test". This method is ideal for use on any flat or low pitched roof to identify defects in exposed membrane systems allowing for a quicker testing schedule identifying defects such as pinholes and punctures. This test can only be performed in dry conditions.

The testing equipment looks like a broom; it is a phosphor-bronze brush with the bristles that are small conductors. When the broom is swept across the membrane and over a breach, the circuit is completed, allowing current to flow. Detection of defects is by an audible tone and a visual spark from the search electrode (brush).

It can pinpoint every penetration on flat roof in an unbelievably quick, inexpensive and non-destructive way, allowing for the most accurate establishment of problem areas.

ELD, both methods, can be used on non-conductive membranes such as built-up roofs, modified bitumen, hot-fluid-applied rubberized asphalt, self-adhering polymer-modified roll goods, urethane, thermoplastic, and white EPDM (thermoset) membranes. ELD is not effective on black EPDM due to its conductive composition (carbon black) [8].

The structural roof deck must be conductive. This includes metal, concrete, composite, and lightweight cementitious decks. It is important to know if the roof assembly has a vapour retarder, as it will also act as an insulator just as the membrane does and break the current flow, masking the breach. But what can we do if there is no conductive layer below the waterproofing membrane, or if there is an insulator? In this case, it is possible to use the **conductive geotextile** as a conductive layer and put it below the waterproofing membrane.

Conductive geotextile is used under geomembranes and can be used also under the waterproofing membranes on the roof to ensure the electric discharge required for electrically-controlled leak-detection operations. Under particular conditions, electrically-controlled leak detection becomes impossible because of the above-mentioned insulation, in which case, the addition of this type of conductive geotextile becomes necessary.

3 COMPARISON APPLIED TO SELECTED FLAT ROOF

There is characterized selected flat roof, made new proposal of the roof with its layers that is necessary for leak detection system and made a choice of it. Then it is a comparison of both systems in chosen criteria.

3.1 Selected flat roof

For the comparison was chosen this roof system that consists of these next layers (see Table 1 – first column). The structural roof deck is reinforced concrete. The roof system was applied in the multifunctional building in Košice. In the second column, there is the roof system where the protective geotextile under waterproofing membrane was replaced by a conductive geotextile to ensure the electric discharge required for electrical leak detection.

Layer from Interior to Exterior	Price per unit [€]	Layer from Interior to Exterior	Price per unit [€]
Primer	the same	Primer	the same
Vapour barrier	the same	Vapour barrier	the same
Thermal insulation	the same	Thermal insulation	the same
Protective geotextile	1.01	Conductive geotextile	2.10
Waterproofing membrane	the same	Waterproofing membrane	the same
Protective geotextile	the same	Protective geotextile	the same
Gravel	the same	Gravel	the same

Tab. 1 The chosen roof system and the new proposal of the roof system

Only one layer was changed and for that reason it is important the difference between the price of the protective geotextile and the conductive geotextile. The common price of the protective geotextile is around 1.01 €/m^2 and the price of the conductive geotextile is 2.1 €/m^2. We can say that the difference is over 1 €. If we compare it with the price of a complete roof, this difference is negligible. Labour cost and labour intensity is similar in both alternatives and so they are not taken into consideration.

3.2 Evaluation of the zero-monitoring alternative

Zero monitoring alternative means, that maintenance and control the roof system are neglected and never been done. Only if the leak occurs then detection is executed and the roof needs to be repaired. But as was mentioned in text above it is difficult to find the pinhole because water flows a long distance from the point of breach the waterproofing membrane to the leaking area on the ceiling. It is considered by the leaking roof that it needs to dismantle minimally or more than 10% of the roof area and then re-implements this area. In practice, this causes the cost of dismantling the roof and its rebuilding.

Costs of implementation of selected roof were taken from the projected budget and are 76759.50 €. If we consider that the costs of dismantling and rebuilding the roof need to be higher than installation costs, for example by 1.5 times, then the costs of detection and reparation for one “incident” will be:

$$10\% * 76759.50 * 1.5 = 11513.93 €$$

But we can assume that during the life of waterproofing membrane more than one “incident” can occur and the costs of detection and reparation will increase.

3.3 Evaluation of ELD system alternative

At first it is necessary to choose electronic leak detection system for the selected roof. Then it can be evaluated the monitoring for the whole life expectancy of waterproofing membrane.

3.3.1 *Sensor DDS MIT for ELD to selected roof system*

For electronic leak detection was chosen Sensor DDS MIT. This technology was developed for the testing and quality control of exposed geomembranes including synthetic waterproofing membranes, liners and asphalt systems. The available systems are split into two broad sub-categories, FIXED and MOBILE. The Figure 1 shows the mobile system which it is used in the comparison with the alternative of zero monitoring.

Fig.1 SENSOR DDS MIT for electronic leak detection

3.3.2 *Cost of monitoring during the life*

The cost of monitoring is calculated at first per one year. It was considered to control the roof twice a year. The cost of electronic leak detection per one year:

- the area of selected roof is: 1205.6 m^2 (multifunction building in Košice),
- cost per measurement are: 0.225 €/ m^2, minimally 90 €/hour of labour
- labour intensity of detection is: 0.0025 Nh/m^2

Cost of measuring the whole roof per one year will be obtained:

$$1205.6 * 0{,}225 * 2 = 542.52 \text{ €}$$

If we consider the life of the waterproofing membrane 40 years, then total cost of measuring during its life will be:

$$40 * 542.52 = 21708.00 \text{ €}$$

And what about the cost of reparation if some breach of waterproofing membrane will be found by detection? Defects are precisely located by this system and so only the small area should be dismantled and re-built. As we consider that maximally or less than 1% of the roof area is touched, then the costs of dismantling and rebuilding will be:

$$1\% * 76759.50 * 1.5 = 1151.40 \text{ €}$$

3.4 Comparison

From the first point of view it may seem preferable the zero-monitoring alternative than installation ELD system. But the evaluation was done only for one “incident” – leak. If there are more “incidents” the costs of dismantling and rebuilding in zero monitoring alternative will be increased more quickly

than in ELD system alternative, approximately by 10 times. So, after third “incident” in both alternatives the costs will be higher in alternative of zero monitoring.

4 CONCLUSIONS

Comparison results are worth considering; I suspected that the price of regular monitoring and diagnosis of the roof coating is a good investment, but the cost calculations surprised me how it is possible that these systems are not used by the public, despite the alarming failure of roofs. I hope this short contribution will increase interest in the professional community, designers and contractors to ponder over this quite inexpensive solution.

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