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THE IMPORTANCE OF THE SYSTEM FOR COLLECTION AND ELIMINATION OF WATER VAPOUR IN A FLAT ROOF STRUCTURE

BY

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Abstract. Roofs must meet resistance requirements to mechanical action, thermal insulating, waterproofing and acoustic, fire resistance, durability, economy and aesthetics. Following the site visits made to the rehabilitation of some flat roofs we observe that there was no system for collecting and evacuating the vapours (diffusion layer) from the flat roofs structure. To determine what effect the lack of collection and evacuation system of vapour from flat roofs structure has a series of accelerated simulation, with WUFI program, on two types of flat roof structure, were performed.

Key words: flat roof; envelope; diffusion layer; rehabilitated flat roof.

1. Introduction

Roofs are construction elements that close the building at the upper part, in order to protect against the bad weather – rain and snow, wind, sun,

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temperature variations, etc. The roof can be designed to provide useful areas located over the roof covering (terrace arranged for household jobs, solarium, garden, restaurant) or below it (mansard, attic).

Roofs of civil and industrial buildings with slopes under 7^o are called *flat roofs* and with slopes more than 7^o are called *slope roofs*.

For roofs classification may be adopted different criteria: the slope used, roof shape, hygrotermic behavior, type of roof framing or cover.

Depending on the slope, roofs can be

a) pitch roof, with big slope (21%...50%) or with medium slope (8%... 20%);

b) flat (terraces), uncirculated with slope 2%...7% or circulated with a slope of 1.5%...4%.

Depending on the flow of heat, flat roofs are called *hot roofs* because roof covering is subjected to direct flow of heat, and slope roofs are considered *cold*, being isolated by the air contained in the attic.

Roofs in general, over heated rooms can be grouped in

a) roofing which include layers of ventilated air (compact flat roof and aerate by the diffusion vapour layers);

b) roof comprising a layer of ventilated air (flat roofs with air channels or roofs with technical or used attic).

2. Short History of Flat Roofs in Romania

The main applied thermal insulation solutions to residential buildings in Romania until 1985 were.

2.1. Flat Roofs

This coating system has been predominantly used at apartment's blocks. Ordinarily, were used flat roofs with a compact structure without ventilated air layer, insulating layer being disposed either directly onto the slab of the last level or on a layer of concrete slope.

In the period 1955...1985 have been apply the following solutions for flat roofs:

a) The solution amployed in the years 1955...1965 with the "hydrophobic powder", material that would claim to achieve both thermal insulation and the hydrofuge insulation. The material was not appropriate. The situation could be fixed by applying a bituminous waterproofing, but in time were lost through humidity and the poor insulation properties of hydrophobic powder, so this type of existing flat roofs are very poorly insulated.

b) The solution with concrete slope above which is located a layer of thin insulation from: polystyrene, AAC or slabs of semi-rigid mineral wool with density of 350 kg/m^3 (produced before the introduction of technology Hartmann upon which are now manufactured the mineral wool plates G100).

c) The solution with filled bulk thermal insulation, with variable thickness, quite amployed, using materials such as: granulated slag or expanded, granulite, scoria s.o.

d) The solution without concrete slope, with AAC-GBN-T plates or GBN 35 arranged in steps.

e) The solution with slag and fly ash filled – material that is inappropriate in terms of thermo characteristics and moisture behavior. To this solution are placed, over the thermal insulation filling, AAC plates, with distances between them to create the necessary aeration channels necessary for water vapour evacuation from the layer of ash or slag.

With solutions listed above were obtained in the current field following values: R = 1.00...1.30 m^2.K/W, but averages value R' much lower because, first some insulating materials were used improper (as thickness, quality, density and moisture) and on the other hand, by the contour, at connection with the outer walls, in the attic or cornice area, existing significant linear heat losses. This area presents a high risk of condensation, the minimum temperature on the inner surface is very low (5°...6°C).

2.2. Thermo Technics Characteristics of Perimeter Structural Components Used During 1950 ... 1990

The tables give the thickness, thermal conductivity and thermal resistances $R_{sj} = d_j/\lambda_j$ of the layers that enter in the composition of the construction elements, except insulating layer.

For each solution is presented, also, the unidirectional total thermal resistance, $\overline{R}$, for all layers, except insulation layer (which may vary), plus superficial thermal resistances

$$\overline{R} = R_{si} + R_{se} + \sum \frac{d_j}{\lambda_j}, \text{ [m}^2\text{.K/W].}$$

2.3. Flat Roofs Systems

The characteristics of these systems are indicated in Table 1.

Table 1
Characteristics of Flat Roofs Systems

No. Crt.	Composition (layers)	Thickness, d_i m	Conductivity, λ_i W/(m.K)	d_i/λ_i m^2.K/W
1	Protection layer (gravel)	0.04	0.70	0.057
	Bitumen waterproofing	0.01	0.17	0.059
	Mortar cement blanket (2...4 cm)	0.025	0.93	0.027
	Thermal insulation	–	–	–
	Vapour barrier	0.002	0.17	0.012
	Slope concrete ($d_{med.}$ = = 10...16 cm)	0.10	1.62	0.062
	Reinforced concrete slab (*d* = 8...18 cm)	0.10	1.74	0.057
	Ceiling plaster (1...2 cm)	0.01	0.93	0.011
	$\overline{R}$	–	–	0.452
2	Protection layer (gravel)	0.04	0.70	0.057
	Bitumen waterproofing	0.01	0.17	0.059
	Mortar cement blanket (3...5 cm)	0.035	0.93	0.038
	Thermal insulating fill	–	–	–
	Vapour barrier	0.002	0.17	0.012
	Reinforced concrete slab (*d* = 8...14 cm)	0.10	1.74	0.057

It results that α_i = 8 W/(m^2.K); α_e = 24 W/(m^2.K); R_{si} + R_{se} = 0,167 m^{2}K/W.

3. Flat Roof Structure and Materials Used for Simulation

3.1. Flat Roof Structure from Galați

The flat roof structure from Galati, Romania is represented in Fig. 1.

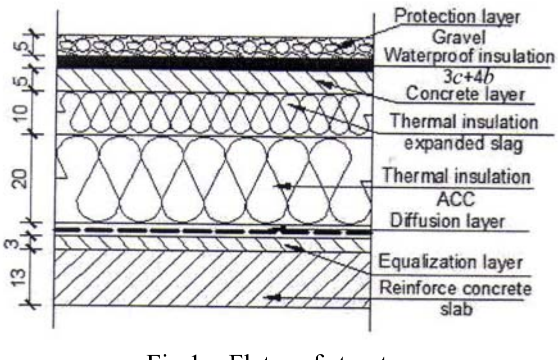

Fig.1 – Flat roof structure.

Table 2

Picture Taken from Site

 Flat roof structure	 Degraded waterproof
 Degraded waterproof	 Waterproof elements extracted from flat roof structure
 Degraded waterproof	 Degraded waterproof

3.2. Rehabilitated Flat Roof Structure from Iaşi and Galaţi (Fig.2)

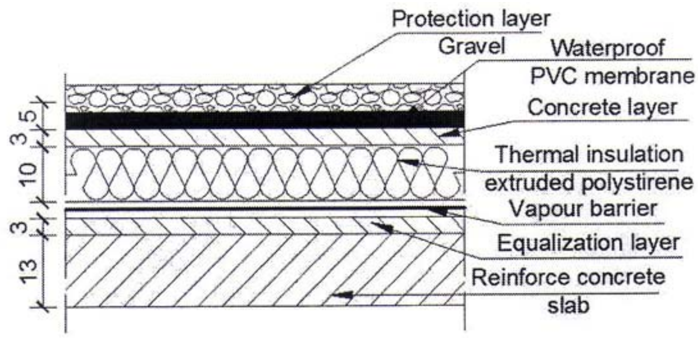

Fig. 2 – Flat roof structure from Galaţi.

3.3. Properties of the Material Founded in Flat Roof Structure

These properties are indicated in Table 3.

Table 3
Characteristics for Materials Found in Old Flat Roofs Structure

Material	Bulk density ρ kg/m^3	Porosity m^3/m^3	Specific heat capacity dry J/kg.K	Thermal conductivity dry λ W/m.K	Water vapour diffusion resistance factor	Thermal assimilation coefficient s W(m^2.K)
Reinforce concrete	2,400	0.18	840	1.62	21.3	15.36
Equalization layer	1,800	0.30	840	0.93	7.1	10.08
Expanded slag	900	0.60	840	4.11	3.1	4.11
ACC	550	0.77	840	0.22	3.5	2.71
Bitumen cloth	600	0.001	1,460	0.17	1,000	3.29
Gravel	1,800	0.30	840	0.70	2.4	8.74

4. Climatic Data for Krakow (Poland)

Krakow has an oceanic climate (Cfb) according to the Köppen climate classification system, one of the eastern most localities in Europe to do so (East of Tarnów, and north of Kielce the January mean dips below −3°C (27°F) and thus becomes continental (Dfb) in nature). The city features a temperate climate.

Average temperatures in summer range from 18°C to 19.6°C and in winter from −2.1°C to 0°C. The average annual temperature is 8.9°C.

In summer temperatures often exceed 25°C, and sometimes even 30°C, while winter drops to −5°C at night and about 0°C at day; during very cold nights the temperature drops to −15°C. In winter reaches to –20°C.

4.1. Climatic Data for Krokow from WUFI

Outdoor and indoor climate conditions are represented in Fig. 3.

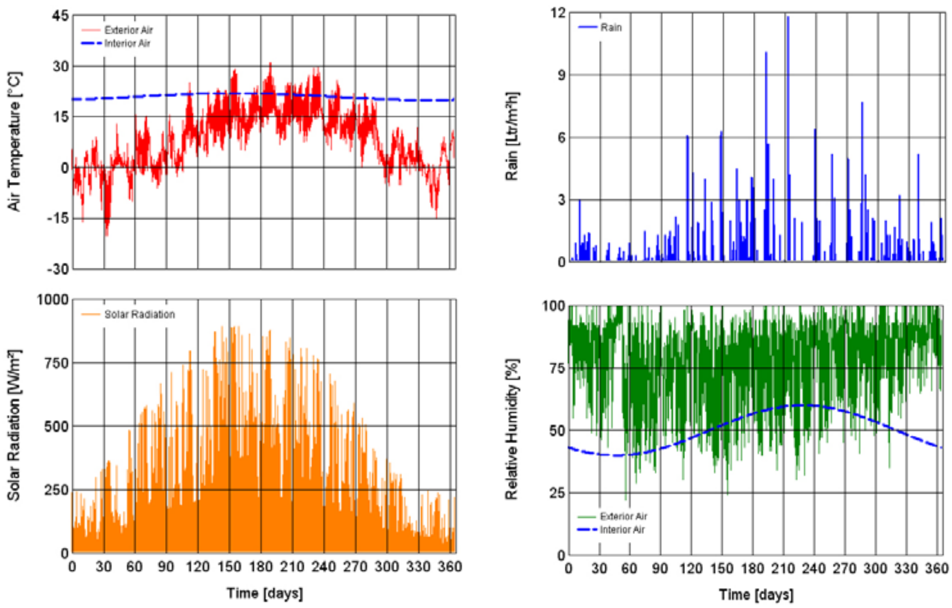

Fig. 3 – Outdoor and indoor air temperature, relative humidity, rainfall and solar radiation.

5. Results from Wufi 1D

5.1. Flat Roof Structure from Galați

The total water content is represented in Fig.4.

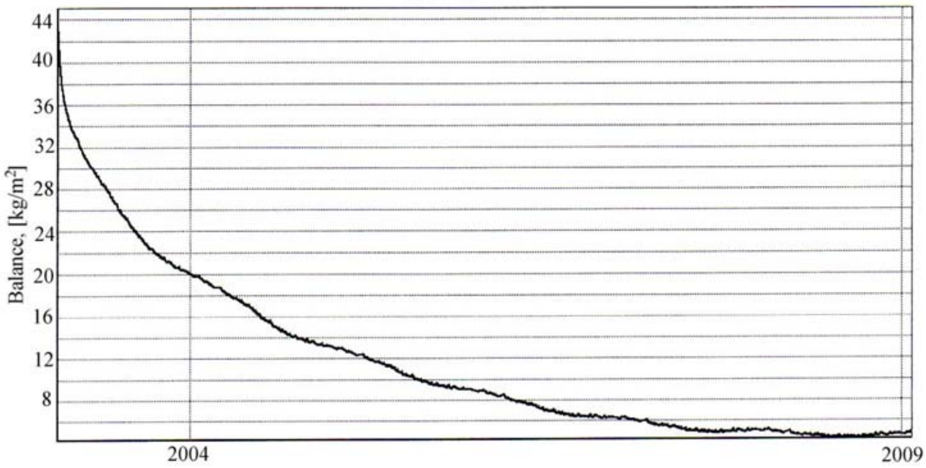

Fig. 4 – Total water content.

a) *Water content in structure layers*

This water content is represented in Figs. 5,…,7.

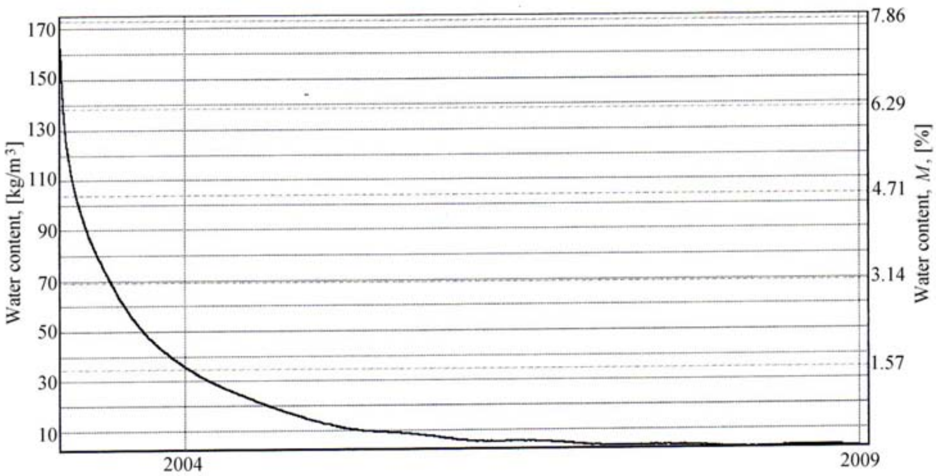

Fig. 5 – Water content in RC slab.

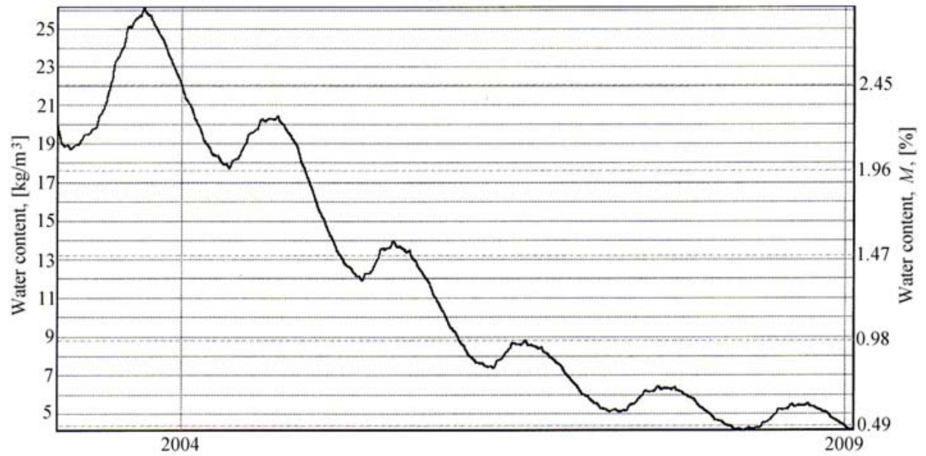

Fig. 6 – Water content in expanded slag insulation.

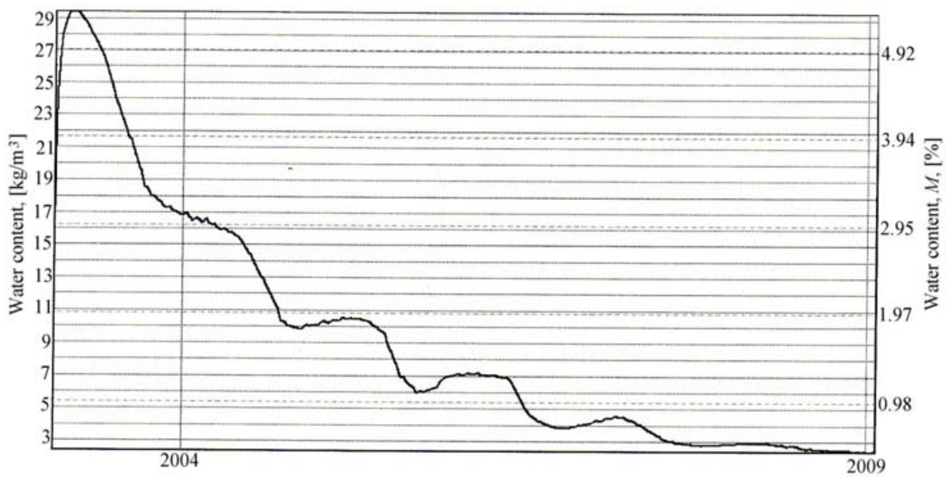

Fig. 7 – Water content in ACC insulation.

b) *Relative humidity in structure layers*

The relative humidity in structure layers is represented in Figs. 8,…,10.

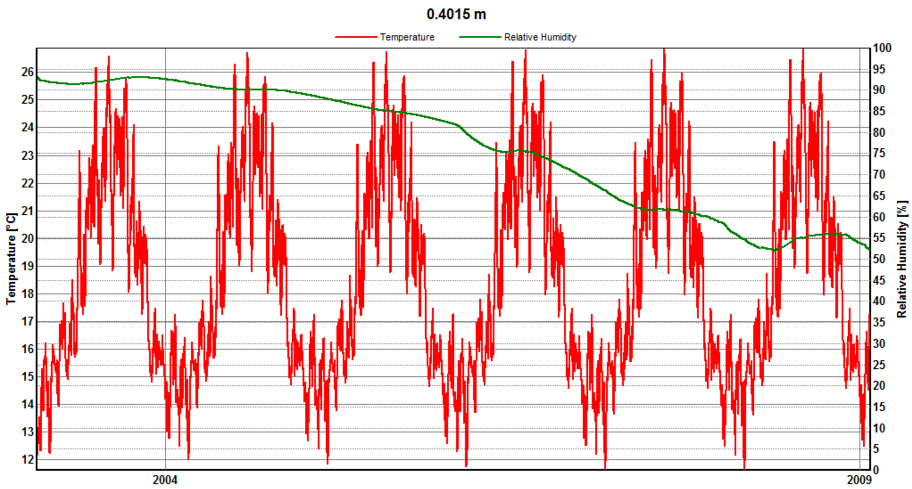

Fig. 8 – Relative humidity in RC slab.

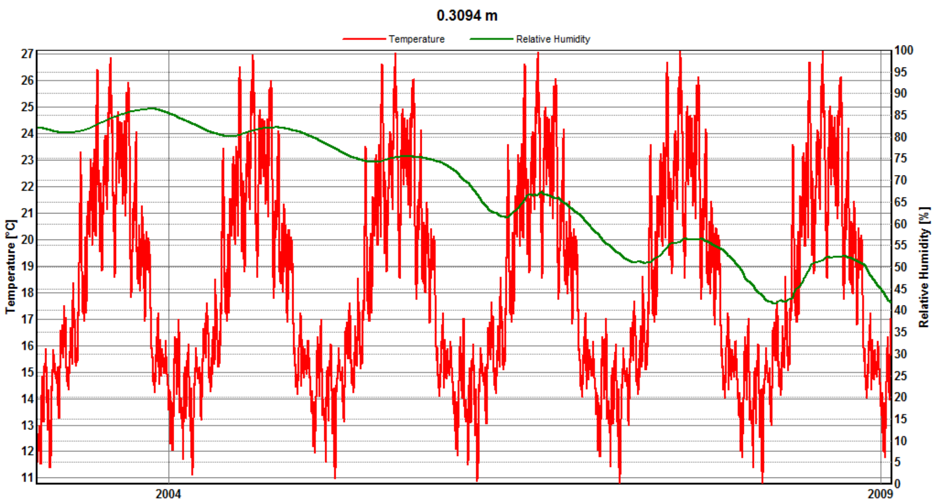

Fig. 9 – Relative humidity in expanded slag insulation.

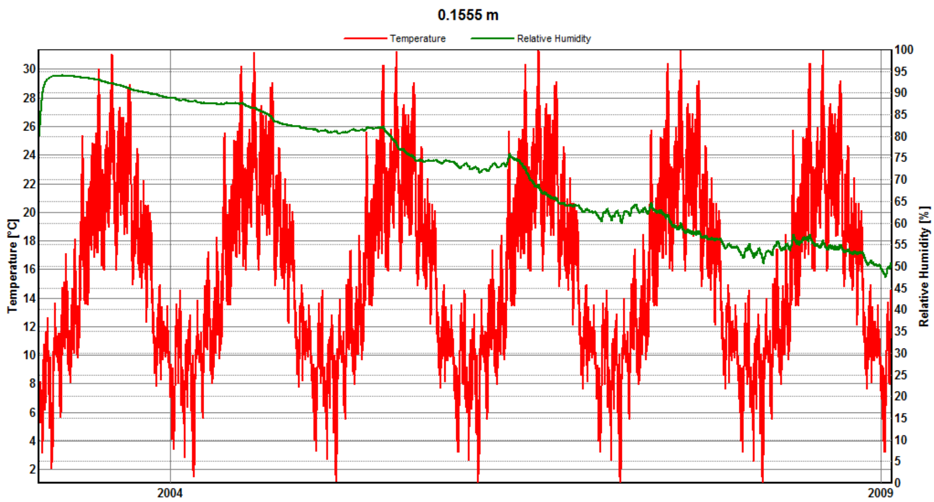

Fig. 10 – Relative humidity in ACC insulation.

5.2. Rehabilitated Flat Roof Structure

The total water content is represented in Fig. 11.

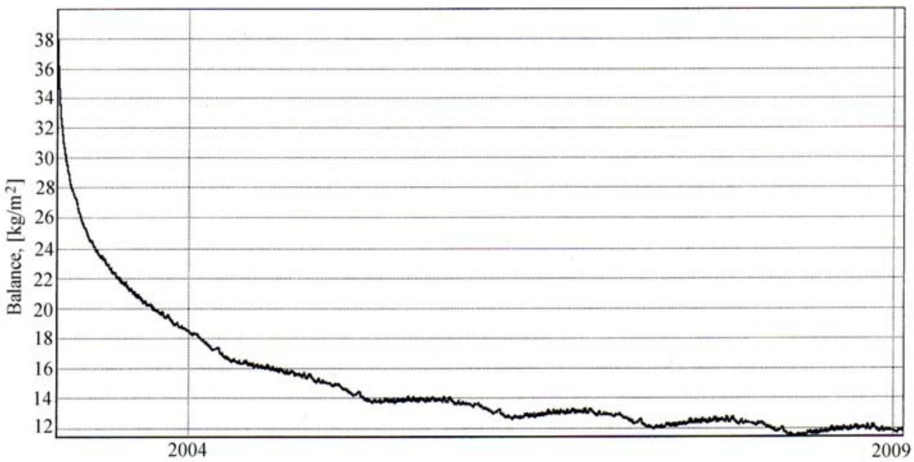

Fig. 11 – Total water content.

a) *Water content in structure layers*

The water in structure layers is represented in Figs. 12 and 13.

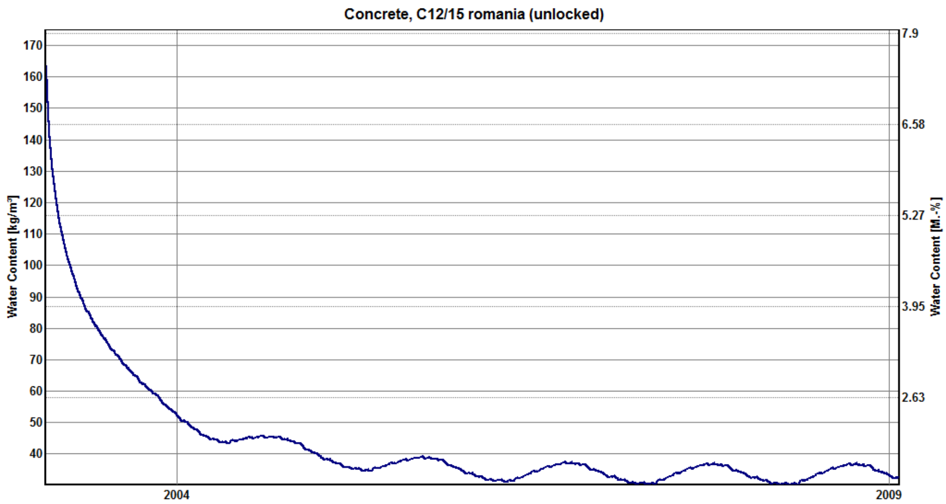

Fig. 12 – Water content in RC slab.

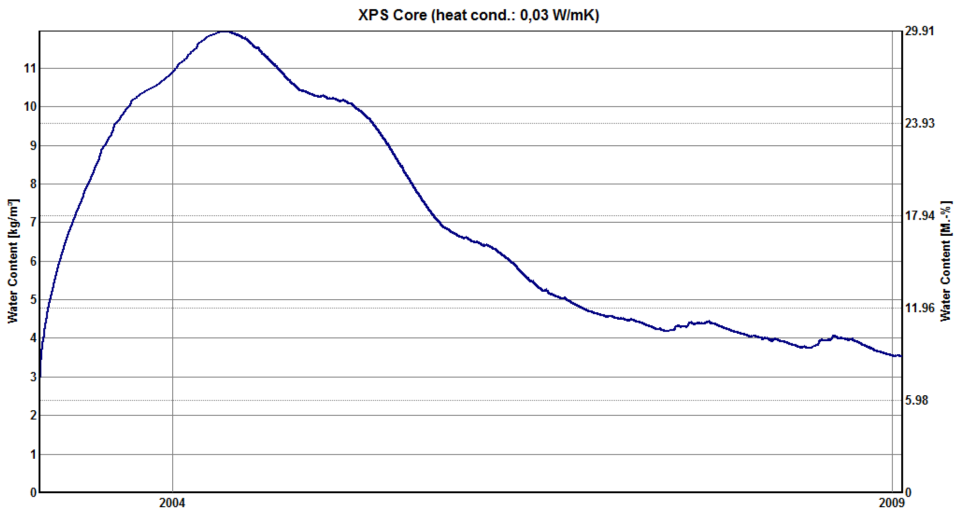

Fig. 13 – Water content in XPS insulation.

b) *Relative humidity in structure layers*

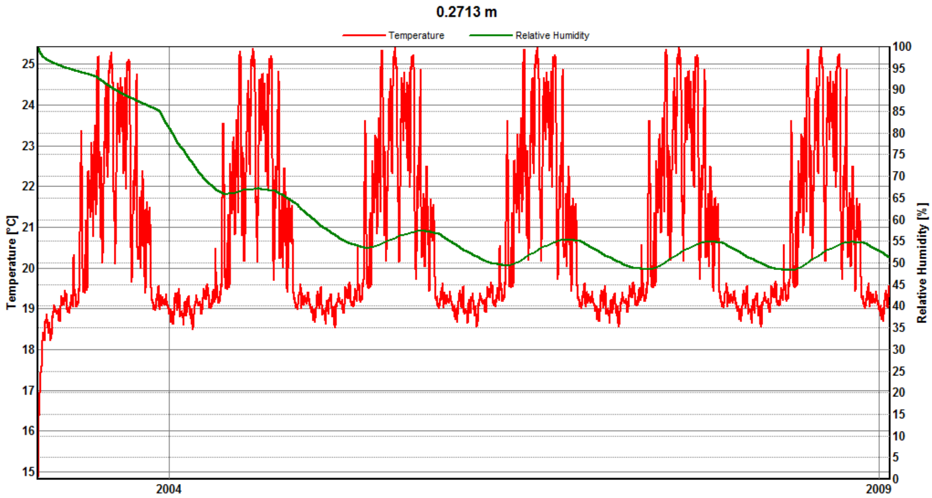

Fig. 14 – Relative humidity in RC slab.

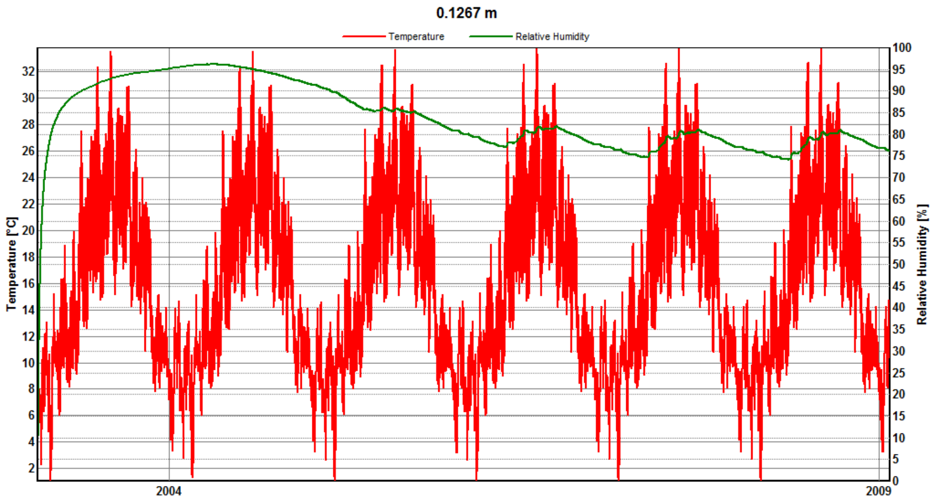

Fig. 15 – Relative humidity in XPS core.

6. Conclusions

After analysing the obtained results from the accelerated simulation we can observe that the amount of water from the whole structure as well as from the component layers is higher for the rehabilitated structure. Absence of the collecting and disposal system for water vapour leads to accumulation, in the flat roof structure, of a quantity of water and humidity that could compromise the durability of the entire system.

Greater quantity of water and moisture from the rehabilitated structure are due to superior materials properties that make flat roof structure to be more compact than the existing one.

In Romania climatic conditions, that are similar to those used for accelerated simulation (Krakow/Poland), it requires the use of collection and disposal system for water vapour to increase the durability of roof terrace structures.

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IMPORTANŢA SISTEMULUI DE COLECTARE ŞI ELIMINARE A VAPORILOR DE APĂ DIN STRUCTURA UNUI ACOPERIŞ TERASĂ

(Rezumat)

O pondere importantă în cadrul acoperişurilor o ocupă acoperişurile terasă. Acestea trebuie să satisfacă cerinţe de rezistenţă la acţiuni mecanice, de izolare termică, hidrofugă şi acustică, de rezistenţă la foc, durabilitate şi estetică. În urma vizitelor efectuate pe şantier la reabilitarea unor acoperişuri terasă s-a constatat lipsa sistemului de colectare şi evacuare a vaporilor de apă din structura acoperişurilor terasă. Pentru a stabili ce efect are lipsa acestui sistem s-au realizat o serie de încercări accelerate cu ajutorul programului de calcul WUFI 1D.

În condiţiile climatice ale României, care sunt asemănătoare cu cele folosite la simulările accelerate (Cracovia/Polonia), se impune folosirea sistemului de colectare şi eliminare a vaporilor de apă pentru creşterea durabilităţii structurilor de acoperiş terasă.