# Introduction to the Green Roof Research

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**Abstract.** Green roof is one of the best answers to the global climate change problems in urban areas with the possibility to reduce urban heat islands. It can reduce the temperature maximum and daily variance of temperatures, which has the positive effect on durability of the waterproof membrane. Retention of the rainwater enables the possibility for evapotranspiration. In this paper, the experimental measurement of various extensive green roof fragments is described with their possibilities and limitations. Temperature and water retention regime of the fragments are monitored as well. Temperature measurement results during autumn, winter and spring days are stated. The result is that daily temperature variance is reduced by use of green roof.

**Keywords:** Green roof · Temperature · Experimental · Measurement · Summer · Overheating

## 1 Introduction

Use of the green roof is not a new idea. Hanging gardens of Babylon are considered as the first use of green roof, dating back to around 600 years B.C. Riding school building has the oldest green roof in the former Czechoslovakia constructed in 1911. In 2005 most of the green roof layers were replaced by the new ones, but the waterproof membrane remained original. In Slovakia, terraces of the Nitra castle are one of the oldest example of green roofs.

Benefits of green roofs are for example: reducing the urban heat island intensity, reducing the summer overheating of interiors, rainwater retention and evapotranspiration, dust particles collection, fire safety, different architectural and aesthetic aspects etc.

Research in the green roofs area in Slovakia is limited to the experimental roof in Kosice [1]. Similar research is conducting in the Czechs UCEEB with more types of green roofs [2]. Measurements worldwide [3–9] in this area is compared to the simulations, where the modelling parameters of the layers are crucial [10] so as the boundary conditions [11, 12]. With its new measuring platform of green roofs University of Zilina was added to the international effort to mitigate the climate change. In this paper methodology, results of comparison one of the green roof fragment and flat roof without vegetation was described. Also the planned and possible outcomes in future are mentioned.


P. Akimov and N. Vatin (Eds.): RSP 2021, LNCE 189, pp. 108–115, 2022.
https://doi.org/10.1007/978-3-030-86001-1_13

## 2 Methods

In the year 2019 one of the flat roofs in the University of Zilina campus was completely reconstructed. Whole structure up to the load carrying concrete slab was removed. During the reconstruction temperature/humidity sensors were incorporated within the roof structure in two places (Fig. 1).

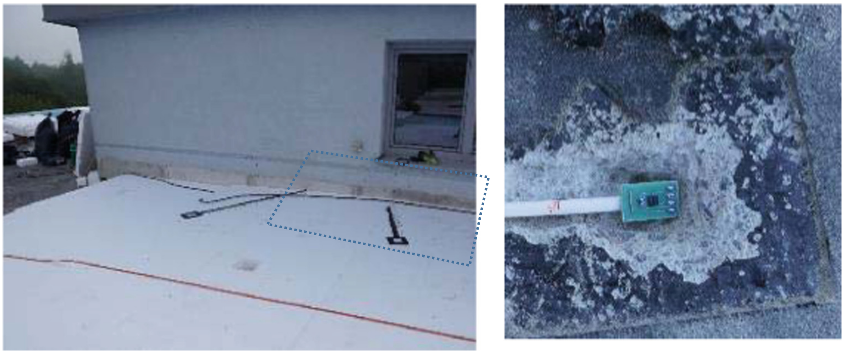

**Fig. 1.** Setting up sensors within the roof composition. On left side are sensors for the composition without vegetation, right side where green roof will be. Right picture: Sensirion SHT21 sensor on the top of the concrete slab.

**Fig. 2.** View of different green roof compositions: upper row for measuring the rainwater retention, bottom row for measuring the temperatures.

Calibration measurement was made between these two places, which showed matching courses with slight differences caused by the shading of the higher part of the building showed also in Fig. 1. During the year 2020, four different green roof compositions were constructed. Each composition is made twice, one is for monitoring the temperatures, because it is placed on the original waterproof membrane. The second one is slightly elevated with additional pitched layer to increase the angle and add the possibility to use the tipping bucket rain gauge for measuring the amount of rainwater. Complex view on both segments is shown in Fig. 2.

The differences between the individual compositions are up to the manufacturers of the compositions: they differ from each other by use of mineral wool for water retention and filtration or use of different drainage layer. All compositions are commercially available.

Except the composition S1, which is analyzed in this paper, sensors are placed only within the vegetation layers (Fig. 3). Used are the PT100 sensors and sheathed thermocouples with capability of immersion into the water or for usage in humid environment. Recording time interval is one minute. As it was stated before, also monitoring of the outdoor climate is important. There is a weather station on site, on the roof of another building within the campus [12–14].

Another pictures from the construction of the green roofs are in Figs. 4, 5 and 6.

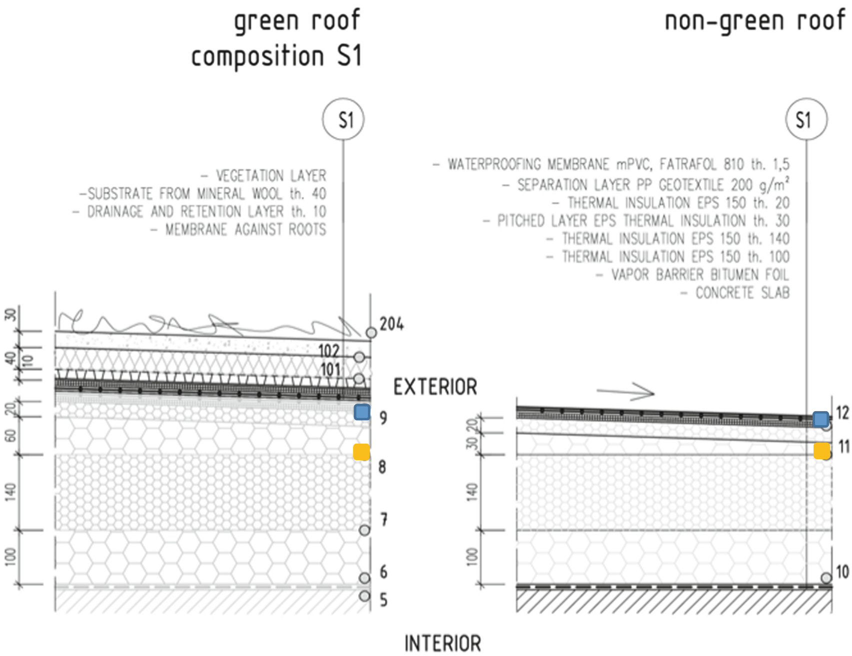


**Fig. 3.** Sketch of the compared compositions with marked sensors positions. Colored are positions which are compared in the results graphs: under the waterproof membrane and between layers of thermal insulation. Regular flat roof ending with mechanically attached membrane is named non-green roof.

**Fig. 4.** Construction of the elevated compositions for rainwater retention measurement.

**Fig. 5.** Using of special boards from recycled waste and with already pre-grown vegetation. Right: drainage and retention layer.

**Fig. 6.** All fragments are covered by the snow. Right: Powder snow on the vegetation.

## 3 Results

Regular flat roof with top layer, mechanically attached membrane is named in the results courses as non-green roof. Figures 7, 8, 9 and 10 show the selected daily temperature courses in the roof composition 1 compared to the non-green roof. Compared are the temperatures on the waterproof membrane and between the thermal insulation layers.

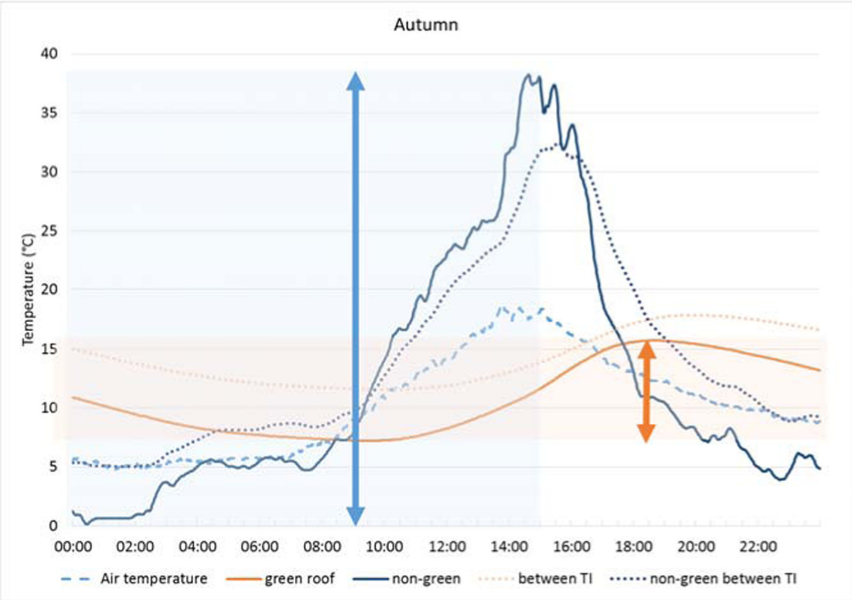


**Fig. 7.** Temperature course for 9th of October 2020. Daily variance for green roof 5 °C, non-green roof 33 °C.

## 4 Discussion

Figure 7 shows the daily course for the sunny autumn day (9th October 2020). The temperature variance is much lower for the green roof. Benefits of the green roof can be clearly seen. Daily variations affects the durability of membrane. Green roof also protects the membrane against UV radiation. There is also time shift in the temperature peaks, which is not such significant nowadays with highly insulated structures [15]. Night radiative cooling can be seen, which overcooled the surface of the non-green roof by around 5 °C.

In Fig. 8 and 9 there are two winter periods, which differ from each other with the snow on the roof. Powder snow has very good thermal conductance coefficient [16], so by the non-green roof it creates relatively good insulating layer (Fig. 9). Snow also serves as the protective layer against the long-wave radiation from the cold sky during the night.

The surface is therefore not overcooled as in the case without snow (Fig. 8), where the non-green roof surface is much cooler than the outdoor air.

The night radiation effect in Fig. 8 is above 5 °C. Daily variance of temperature is as high as in spring. Also in winter, when there is no snow on the roof the temperature variance can be very high. In this case, the non-green roof waterproof membrane is much colder than the outdoor air. But when there is snow, the courses are opposite.

Figure 10 shows the sunny spring day course of 1st April 2020. A moderate night radiative cooling can be observed. Daily temperature variances are very different from each other. The temperature of membrane by the non-green roof rises very quickly, but

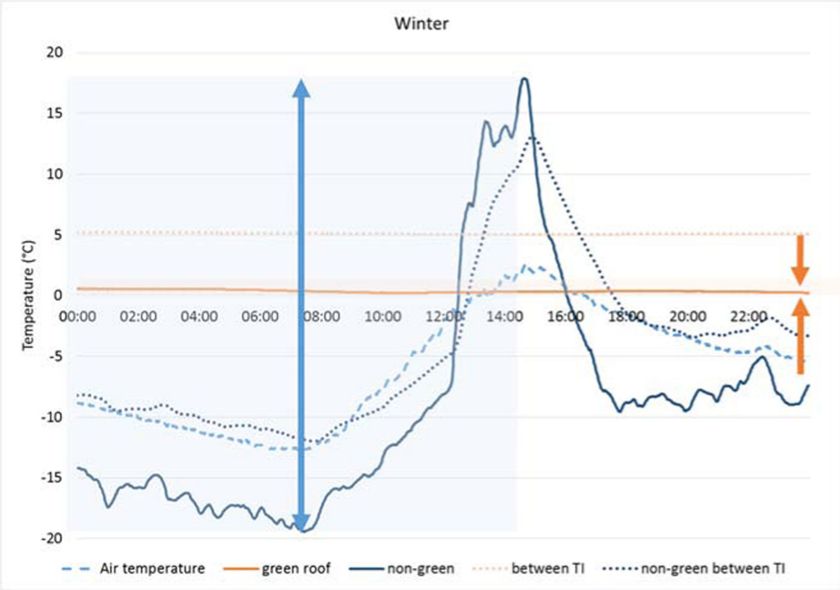


**Fig. 8.** Temperature course for 1st of February 2021. Daily variance for green roof 1 °C, non-green roof 36 °C. Roof is without snow.

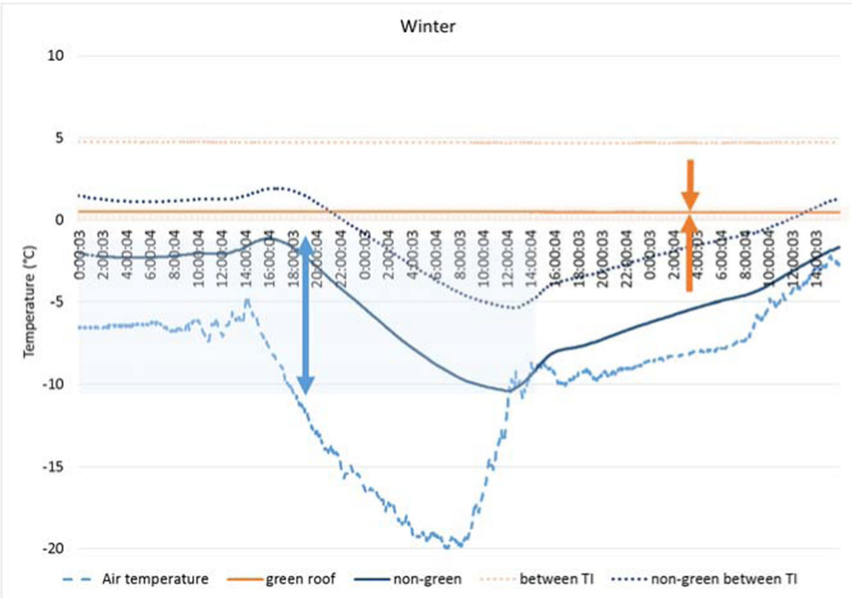


**Fig. 9.** Temperature course for 17th–19th of January 2021. Daily variance for green roof 1 °C, non-green roof 9 °C. Roof is fully covered with powder snow of thickness 150 mm.

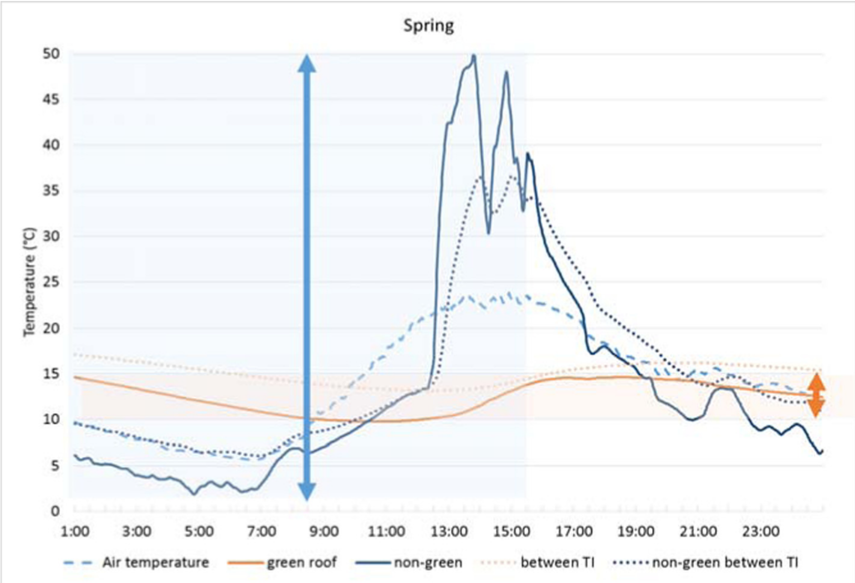


**Fig. 10.** Temperature course for 1st of April 2021. Daily variance for green roof 6 °C, non-green roof 48 °C.

it is highly influenced by the direct solar radiation. Passing cloud causes the difference on the surface temperature up to 20 °C within few minutes.

## 5 Conclusion

In this paper the creation of the experimental setup for measuring the properties of extensive green roof was briefly described. Autumn, winter with or without the snow and spring were compared to each other in the area of non-green/green roof.

Results show a clear benefit of the green roof against the nearby position without the green roof system. Waterproofing membrane is protected against UV radiation, temperature variances are very low, during winter almost constant. This is due to the higher thermal capacity compared to the flat roof with EPS. This also minimize the radiation overcooling in the night.

The measurements are constantly running and prepared for the summer season and the rainwater retention. Fourth composition is not completed due to the lack of pre-grown vegetation roll last year. In the future, water regime of each composition will be monitored. Radiation potential and temperature above the surfaces of individual compositions will be compared during the next part of research as well.

**Acknowledgment.** The research is supported by the grant project VEGA No. 1/0673/20, the UNIZA Grant scheme No. 8013 and Knauf Insulation.

## References

1. Vertal, M., et al.: Experimentálna vegetačná strecha s biodiverzným potenciálom (in Slovak). Strechy Fasády Izolace, 11–12 (2020)
2. https://www.uceeb.cz/aktuality/testujeme-zelene-strechy. Last accessed 21 Nov 2020
3. Besir, AB., Cuce, E.: Green roofs and facades: a comprehensive review. Renew. Sustain. Energy Rev. (2018)
4. Peterkova, J., et al.: The influence of green walls on interior climate conditions and human health. In: MATEC Web of Conferences, vol. 282 (2019)
5. Zhang, S., Lin, Z., Zhang, S., Ge, D.: Stormwater retention and detention performance of green roofs with different substrates: observational data and hydrological simulations. J. Environ. Manag. 291 (2021)
6. Smalls-Mantey, L., Montalto, F.: The seasonal microclimate trends of a large scale extensive green roof, Build. Environ. 197 (2021)
7. Vera, S., et al.: Influence of vegetation, substrate, and thermal insulation of an extensive vegetated roof on the thermal performance of retail stores in semiarid and marine climates. Energy Build. **146**, 312–321 (2017)
8. Hernandez, A., et al.: Test box experiment and simulations of a green-roof: thermal and energy performance of a residential building standard for Mexico. Energy Build. 209 (2020)
9. Ascione, F., et al.: Green roofs in European climates. Are effective solutions for the energy savings in air-conditioning? Appl. Energy 104 (2013)
10. Vertal, M., et al.: Hygrothermal initial condition for simulation process of green building construction. Energy Build. 167 (2018)
11. Katunsky, D., et al.: Experimentally measured boundary and initial conditions for simulations. Adv. Mater. Res. 1041 (2014)
12. Staffenova, D., et al.: Climate data processing for needs of energy analysis. Adv. Mater. Res. 1041 (2014)
13. Jurasova, D.: Analysis of long-term measured exterior air temperature in Zilina. Civil Environ. Eng. **14**, 124–131 (2018)
14. Juras, P., Jurasova, D.: Outdoor climate change analysis in university campus: case study with heat-air-moisture simulation. Civil Environ. Eng. 16 (2020)
15. Ponechal, R., Staffenova, D.: Impact of external wall insulation thickness on internal surface temperature behavior. In: Matec Web of Conferences, vol. 117 (2017)
16. STN 73 0540:2019: Thermal protection of buildings. Thermal performance of buildings and components (in Slovak)