Monitoring of the Green Roofs Installation in Brno-City District, Czech Republic

Tatiana Rebrova [1], David Beckovsky [1], Petr Selnik [1]

[1] Brno University of Technology, Faculty of Civil Engineering, Veveří 331/95, Brno,

176712@vutbr.cz

Abstract. In spite of the rapidly growing interest to the green roofs, there is insufficient information about their local quantities and areas in Czech Republic as well as in Central Europe. There is a lack of technical information that leads to the further development, application and environmental contribution of green roofs under local climatic conditions. The purpose of the research is to follow the tendency of how the process of green roofs' popularization is performed in the Czech Republic and to determine basic parameters of the installed green roofs. These parameters include total quantity, area and the most common roof vegetation type (extensive or intensive); how many green roofs were installed over the last years and as a result, how the proportion of the green roofs to the conventional ones is changing. For initial evaluation Brno-City District was chosen as the next stage of university environmental project EnviHUT following the genesis of green roofs under local weather conditions.

1. Introduction

The application of green roofs is currently the subject of numerous supportive financial projects aimed at enhancing the environmental value of urban areas and agglomerations. In general, this benefit could be evaluated positively. However, it is necessary to draw up a local study of the green roof development for more accurate and targeted assessments of this construction on the environment and sustainable construction respecting national and European level of benefits.

According to the evaluation of green roof market provided from 2014 by European Federation of Green Roofs & Walls Germany [1] has a leading position between European countries total areas and yearly increasing rate of green roofs were investigated for (Table 1).

This article follows mentioned concept to study the installation of individual vegetative types of green roofs considering the most relevant parameters selected by authors to prove qualitative and quantitative efficiency evaluation in terms of strategic developing funds. The green roof structures have been supported in the Czech Republic since 2017 in two different levels:

- nationally by the New Green Savings program (translated from „Nová Zelená úsporám"; official original title of the program);
- locally by the local authority initiative.

The New Green Savings program is the most important way of green infrastructure support with a benefit to a maximum amount of 500 CZK per 1 m^2, i.e. 18,52 EUR (average exchange rate related to February 2017). The real impact on the Czech construction industry market and development will need to be determined in view of already existing green roofs. The monitoring of the current state of

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green roof applications in selected city districts of Brno with regard to the historical development from 2003 to the beginning of 2017 is also required for present and future market research and its dependence on two previously mentioned supportive variants.

Table 1. Results of the green roof market evaluation, [1]

Target country	Green Roof Stock total m^2 (2014)	Green Roofs new/year m^2	Ratio extensive %	Ratio intensive %	Yearly sales figures €
Austria	4.500.000	500.000	73%	27%	27.350.000
Germany	86.000.000	8.000.000	85%	15%	254.000.000
Hungary	1.250.000	100.000	35%	65%	5.662.500
Scandinavia (S, N, DK)		600.000	85%	15%	16.050.000
Switzerland		1.800.000	95%	5%	51.300.000
UK	3.700.000	250.000	80%	20%	28.000.000
	95.450.000	11.250.000			382.362.500

This topic was consulted by the authors with representatives of the Ministry of the Environment at the Construction trade show 2017 in Brno. The questioned representative described the hesitant approach of the building owner to ask to subsidize the green roof construction and their doubts about possible fulfilment of the all obligatory conditions. The amount of benefit in the case of a smaller roof is likely to be partially deterred by the administrative process. This assumption will have to be validated in the following years on the basis of input data from local studies taking into account the urban development support and on the basis of the statistical data of the subsidy program.

The following monitoring of the current state was complemented by the type of the object in order to evaluate the behavior of the investors in the given location.

The parameters set are based on the experiences of similar thematic studies and taking into account the needs of the EnviHUT project. [2], [3].

EnviHUT is part of the external testing grounds of AdMaS Research Centre of Brno University of Technology. AdMaS research center is located on the outskirts of Brno (Czech Republic) near the university's dormitories. The experimental grounds are to be used by doctoral students of the faculty and by the employees of the research center to study green infrastructure and sustainable building structures.

The distribution of green roof types was selected according to the following sorting in connection with the EnviHUT project [4]. Green roofs can be divided into extensive, semi-intensive and intensive variants within the general consciousness. For the purposes of monitoring, the semi-intensive and intensive green roof categories were grouped together into the one group - the category of intensive roofs (because of the low distinguishing capability between these two categories in the authors' chosen methodology). The demonstration of considered categories is displayed in the Figure 1.

The smaller numerosity of intensive green roofs is dependent on more complex construction technology and consequently higher financial demands of long-term maintenance in the selected locality.

The differentiation of the extensive and intensive variations is clearly recognizable within the set methodology. The project does not address the level of vegetative development at this stage, that is also relevant aspect for a credible assessment of the annual amount of water held back before drainage. This article aims to quantify the potential of this monitored parameter within the chosen area

at the required quality level according to normatively set outflow coefficients and to the green roof areas, which were specifically determined in this study for the purposes of this calculations, as the determination of green roof area in itself is meaningless. The real qualitative aspect of the calculation has not had a clearly defined evaluation procedure to be a part of this study yet. The monitoring level of vegetation development in relation to the overall green roof retention parameters must be supported by long-term monitoring of at least dozens of roofs in the selected city districts so that the qualitative parameter can be included in the final assessment.



Figure 1. Distribution of green roof types (source: authors)

Therefore, the current study includes determination of areas of green roofs as well as calculation the amount of water held before drainage according to the found roof areas and thus the stormwater mitigation effect on the city sewer system.

2. Methodology

The process of green roof monitoring included:

2.1. Finding the green roofs on the image maps of one of the mapping service.

Generally, the choice of the mapping service depends on country the monitoring is providing in. For Brno were mainly used maps of State Administration of Land Surveying and Cadaster [5], Google Maps [6] and Mapy.cz [7]. Brno consists of 29 city districts. The area of the city was step by step scanned from the central to remote districts to find objects with green roofs. For each roof found the basic information was writing down, such as name of city district, post address, area, type of vegetation, type of the building the green roof is installed on, period of installation.

As in some cases, it was rather difficult to determine if some green space is situated on the roof or on the ground, so for more accurate specification 3D Google Maps were used for searching the buildings with installed green roofs. Therefore, the process of the monitoring can hardly be automated because of the complicated determination of the studied surface levels as the green roof or urban green space. 3D maps are accessible for Brno, but for smaller towns 3D maps sometimes does not exists. When the green roof was found the city district and post address could be determined by clicking on the building on the map.

Maps of State Administration of Land Surveying and Cadaster were used for finding out an area of the green roof with the help of the tool „area measurement“, according building post address. Mapy.cz were used for determination the period of installation as this mapping service includes archive maps from the years 2003, 2006, 2012 and 2015; also there is a hyperlink to State Administration of Land Surveying and Cadaster where the information about type of the building can be found. Type of roof vegetation was considered according to its appearance on the majority of maps of different mapping services. The vegetation was considered extensive if had yellow to red, green to red or brown color, was sparse and low. Conversely, the vegetation was considered intensive if had bright green colour, was rather lush ore there was some taller plants like bushes or small trees (Figure 2).

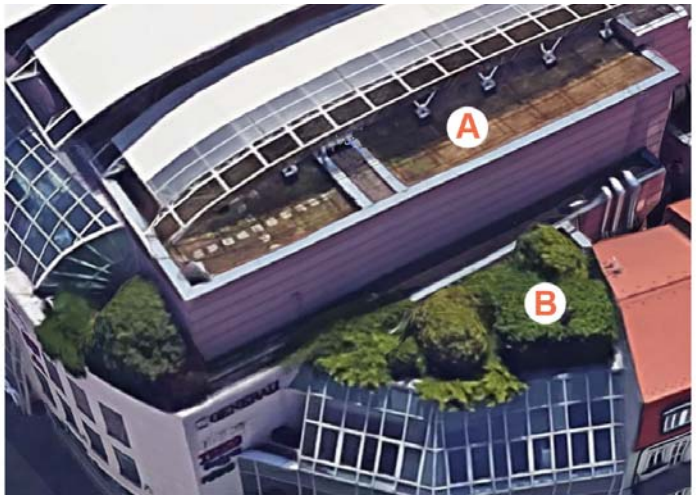


Figure 2. Examples of A) extensive green roof B) intensive green roof (source: Google Maps)

2.2 Creating the database of green roofs which included all determined characteristics.
Data can be sorted by different parameters to obtain required overview of the results. On its base the following charts were generated:

Chart 1. The rate of extensive and intensive green roofs;
Chart 2. Green roofs installation occurrence according to their size;
Chart 3. Quantity of buildings with installed green roofs in years 2003-2017.

3. Results and discussions

3.1 Green roofs monitoring.

3.1.1 The rate of extensive and intensive green roofs. The total quantity of green roofs is 233, including 180 (77%) extensive and 54 (23%) intensive ones (Figure 3). One of the roofs consists of the intensive and extensive parts, so it was included twice.

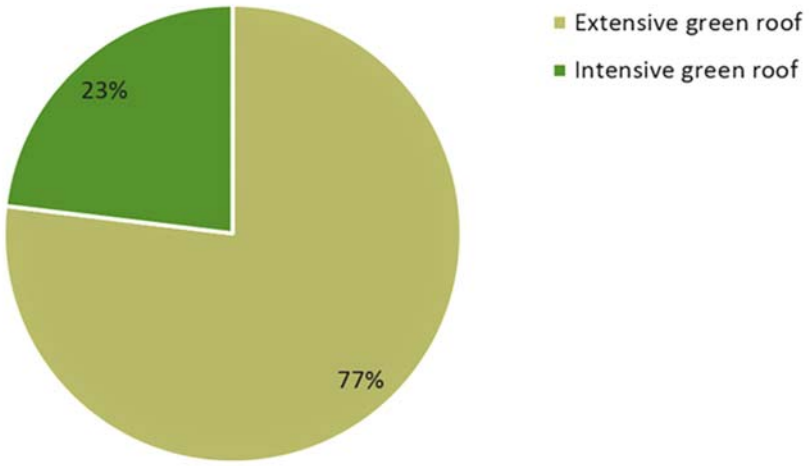


Figure 3. The rate of extensive and intensive green roofs

3.1.2 Green roofs areas.
The minimum area of the green roof is 9 m^2 (private house in Brno-Jundov), maximum is more than 18 000 m^2 (University campus Brno-Bohunice).

All the roofs were divided into three groups and seven subgroups according to their size:

1. Small: 1a <50 m^2
   1b 50-100 m^2
2. Medium: 2a 100-200 m^2
   2b 200-500 m^2
   2c 500-1000 m^2
3. Large: 3a 1000-2000 m^2
   3b > 2000 m^2

Large roofs occupy 9% of the total quantity, medium 42% and small 49%. Small green roofs are mainly installed on the private houses, large ones – on the public buildings (Figure 4).

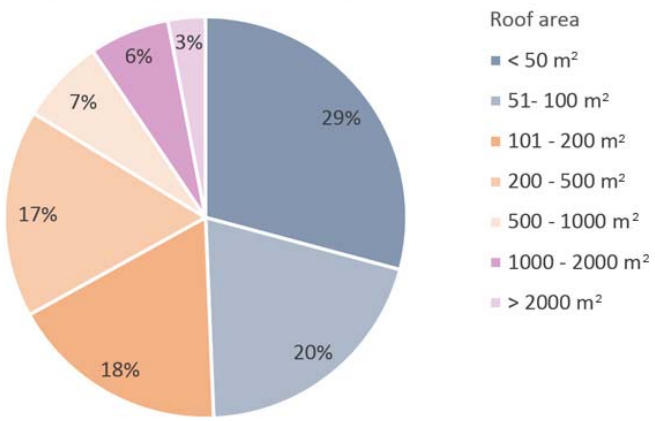


Figure 4. Green roofs installation occurrence according to their size

3.1.3 Green roofs location. The majority of the green roofs are situated in the city district Brno-Střed (central part of the city) and in the close to the center and some north city districts, conversely in some city districts Brno-Bosonohy, Brno-Řečkovice a Mokrá hora, Brno-Ivanovice, Brno-Jehnice, Brno-Ořešín, Brno-Útěchov, Brno-Chrlice there are no green roofs installed.

3.1.4 Green roofs quantity in years 2003-2017. The total quantity of the green roofs amounted to 45 in 2003, the increase to the year 2006 was 23 green roofs (68 in sum), to the year 2012 – 128 green roofs (173 in sum), to the year 2015 – 168 green roofs (213 in sum) and to the year 2017 – 188 green roofs (233 in sum). From this data it follows that the most significant green roof amount increase happened between the years 2006 and 2012 (Figure 5).

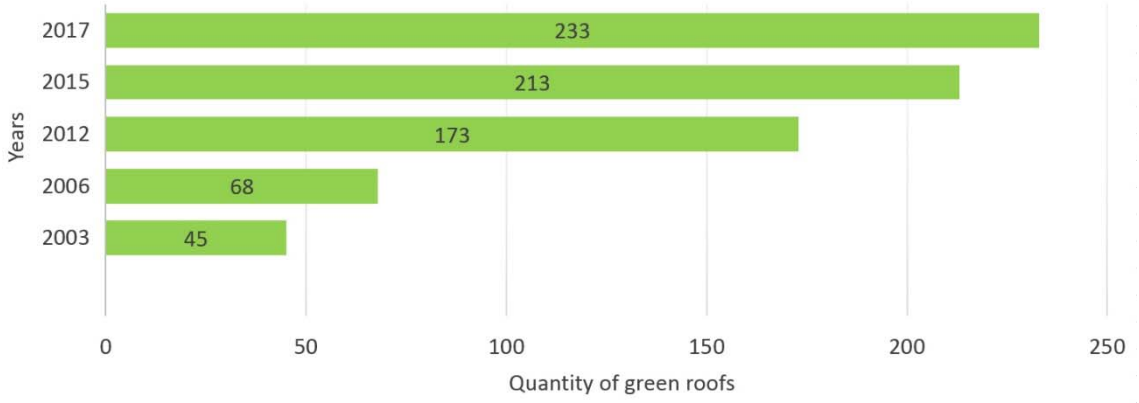


Figure 5. Quantity of buildings with installed green roofs in years 2003-2017

3.1.5 Building types green roofs are installed on.

The majority of all green roofs (36%) are installed on the private houses, and here the garages that belongs to private houses are not included. Two times more uncommon are the green roofs installed on the apartment buildings (19%) and public buildings (18%). The most unusual case for Brno is the green roof installed on a technical infrastructure facility building – the only green roof in the whole city, which finally amounts to less than 1%.

3.1.6 The rate of green roofs area to the total built-up areas and yards.

According to the performed monitoring the approximate total area of all the green roofs in Brno is 112 718 m2. As stated in the data of the Czech Statistical Office [8] the total built-up areas and yards amount to 20 983 500 m2. By this the rate of the green roofs makes 0.5% from the total built-up areas and yards in Brno.

3.2 Rainwater detention

Decree 428/2001 Coll., Appendix 16 specifies how to calculate the amount of precipitation water drained into sewer. The calculation of the water to be drained to the sewerage system amount under this decree is the basis for determining the sewage cost. For rainwater the value of the drain factor is 0.05 for vegetation areas. This is the value reported for the long-term rainfall aggregate. For rainwater detention is calculate 5% reduction for roof geometry and no green roof details. Monthly sum of precipitation characteristics [9] were used for calculate annual amount.

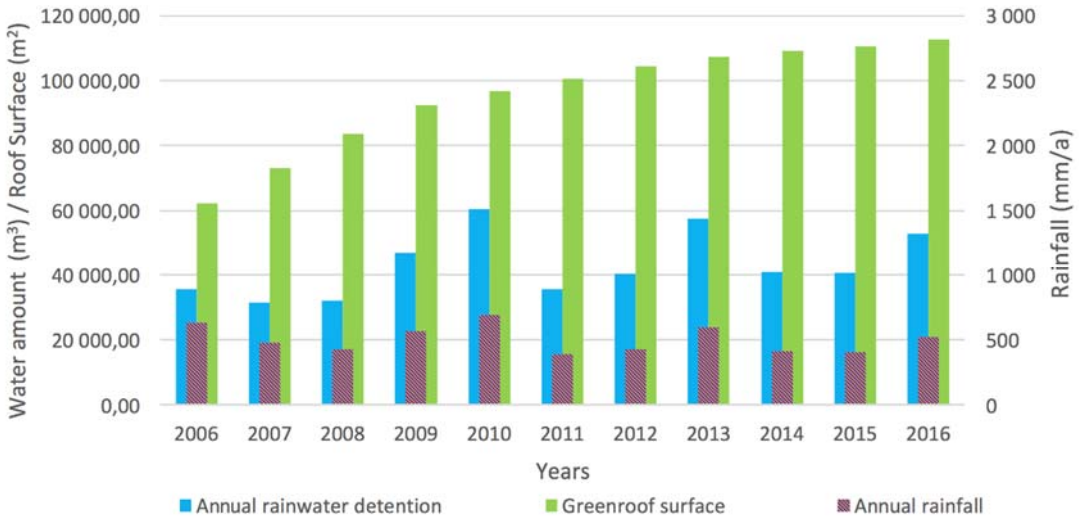


Figure 6. Annual rainwater detention with green roofs

4. Conclusions

According obtained data from web mapping services were analyzed the total quantity of green roofs. In Brno-City District increased from 45 in 2003 to 233 in 2017, and this include 77% of roofs with extensive and 23% with intensive vegetation. On the data analysis, it is possible to determine the contribution of green roofs in Brno for rainwater and stormwater management. Modern web mapping services allow to monitor several civil engineering data include green roof parameters of total quantity, area and the most common roof vegetation type (extensive or intensive); how many green roofs were installed over the last years and as a result, how the proportion of the green roofs to the conventional ones is changing. Together with the technical web portals data analysis we obtain large amount of data.

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