Energy saving with green roofs, including water retention and heat attenuation

Daniel Szlivka, PhD student, Óbuda University, Budapest, Hungary

1. Introduction

Throughout the world the population density of cities is higher and higher, therefore natural green surfaces are vanishing. Unlike western-european tendencies, in Hungary, local governments are interested in building in all empty areas by financial reasons, making additional loss of green space. Contrarily their aim should be not only to restore existing parks but to create new green islands inside the city or town in the place of knocked down buildings. For example, in Budapest green area per citizen is 6.2 m^2, which means an average value in Europe, but considering the size of the city, it is much less than needed. If we look at the downtown, this value is more frightening, because between 1990 and 2009 there was a decrease of 3.6%, and today one citizen has 0.6 m^2 of green area in the downtown. Between these circumstances ecologic value of green roofs is increasing, therefore we should consider this topic on its right place. This is the only economical possibility to reverse the decreasing tendency of natural green. It is essential to focus on the principle used by Le Corbusier, which declares that green area occupied by buildings should be returned to the nature. Furthermore, the purpose is not only aesthetic and recreational, it has even economical and ecological advantages.

Extreme weather conditions will occur more often in the following years according to forecasts, putting a heavy burden on urban channel systems. Green roofing can be beneficial in this aspect as well, by retaining rain water, evaporating it back to the nature by vegetation and, in addition, the water run-off is delayed relieving the channel system.

Green roofs have additional advantages, such as heat attenuation and insulation, which helps to optimize heat household of buildings. In hot summer conditions green top layer avoids critical heat-up of inside space, during cold winter it is serving as an insulation layer, therefore heat loss will decrease.

In the following we are going to discuss principles and instruments, which are needed for green roofs for safety and economical operation.

2. Green roof types

We talk about green roof, if the top layer of general structure is a kind of growing medium. Both flat and sloped roofs can be green, but in general they are created on flat roofs, therefore in this article we deal only with this type. To make a flat roof green, some preconditions have to be fulfilled, such as appropriate waterproof insulation and carrying capacity for the additional burden.

Basically we make difference between two types of green roofs depending on the thickness of the substrate and the used types of plants. In case of extensive green roof we talk about a close-to-nature vegetation form, where there is a rather thin layer of growing medium with the width of 6-15 cm and the maximum weight of 150 kg/m^2. This type is practically self-supporting, its vegetation is able to adapt to extreme conditions having a good deal of regeneration ability. Therefore it does not need irrigation, but one should carefully choose the proper water retention layer to ensure supply for plants.

Intensive green roof differs from the other type by the volume of substrate, which is 20-50 cm (even 80-100 cm possible) and can be used as roof garden. There is a much wider range of plants used, even trees. Hence they require more attendance in maintenance and irrigation.

3. Green roof layers

Green roof layers have to fulfil several special requirements, such as protection of waterproof layers (e.g. from root piercing), nourishing plants (water retention), or proper weight load for the insulation layers.

Top layer, which is visually characteristic is growing medium itself, the substrate with plants. Between two different layers there is always some kind of separation membrane, which must be chemically neutral to avoid undesired reactions between chemically incompatible materials or avoid mixing of granulous layers. One of the most important layers in the aspect of water household is the retention and lead-off layer (drainage layer). Its task is to lead the redundant water off the roof and hold the necessary amount back for the plants. In the following we shall see what kind of drainage layers are used for green roofs.

This layer mainly consists of inorganic materials, such as lava, tufa, swelling clay and slate, smashed brick or tile, which are bulk density materials. Other artificial materials are used for retaining water. These are different kinds and forms of plastic plates.

3.1. Granular drainage layers

Gradient and green roof types	thickness	particle size
Extensive green roof, gradient min. 2%	3 cm	2-8 mm
Extensive green roof, without gradient	5 cm	2-12 mm
Intensive green roof, gradient min. 2%	10 cm	4-12 mm
Intensive green roof, without gradient	13 cm	4-16 mm

Table 1. Thickness and particle sizes of bulk density retention layers [FLL 2002, 7.2.1.]

We can produce granular materials for drainage layer from natural and burnt minerals as well as recycled minerals. Natural materials are gravel, smashed stone and sandy gravel, which have poor water retaining ability. Much better have lava and tufa, which are able to store water in the amount of 50% of their own weight. Burnt minerals are expanded clay gravel and slate, which can be formed in two different shapes, such as balls and edgy pieces. The latter has more water capacity but requires thicker protection layer (300 g/m^2) underneath to avoid damaging waterproof layer. Using recycled materials is an important aspect of green roofs considering environment conscious building tendency. We have to emphasize the use of these materials, which are smashed bricks or tiles and industrial cinder. These have rather high water capacity, while other recycled materials as foam glass made of waste glass is useful to increase heat insulating ability, but has almost zero water capacity.

Thickness of granular drainage materials on green roofs depends on gradient of the roof and varies between 3 and 15 cm.

3.2. Plastic plate drainage layers

Thikness of plate drainage layers made of different kinds of plastic is determined by the producer, furthermore their material has no water capacity, they are able to store water by their form. One type is form-foamed expanded PS, which has a thickness of 6-18 cm, therefore can be calculated into thermal insulation. The other type includes form-pressed plastic plates, which are available with 2-6 cm sizes. They can be filled up with granular materials to increase water retention. These plates are also useful for protecting waterproof layers, therefore they are usually used on extensive roofs with waterproof membrane on the top of thermal insulation.

In addition, there are several types of foam matresses existing made of PU or PE. PE has poor water capacity, it is used only for additional mechanical protection, while PU foam is able to store 60 V/V% water, which makes it widely useful both on extensive and intensive green roofs.

4. Water retention of green roofs

Nowadays there is real possibility to return occupied areas back to the nature by creating green roofs on the top of the buildings as international practice shows. Great number of existing and newly constructed flat roofs in cities can be turned into ecologically active surfaces. These have two decisive properties, one is water retention, the other is run-off delay. Even in case of small volume of substrate substantial amount of rain water can be retained, which provides great ecological advantage.

Layer thickness	Roof grad. <= 15°	Roof grad. > 15°
> 50 cm	C = 0,1	-
25-50 cm	C = 0,2	-
15-25 cm	C = 0,3	-
10-15 cm	C = 0,4	C = 0,5
6-10 cm	C = 0,5	C = 0,6
4-6 cm	C = 0,6	C = 0,7
2-4 cm	C = 0,7	C = 0,8

Table 2. Run-off coefficient (C) of green roofs depending on thickness [FLL 2002, 6.3.4.]

Rate of retention can be defined by run-off coefficient. This value shows the rate of run-off water compared to the amount of rain water. Table 2. shows that green roofs have to lead off only a small part of the rain water. Data of this table apply to the whole structure with an average rain intensity of 300 l/(s×ha).

„The yearly water retention much more depends on layer thickness than other properties or types of layers. Nevertheless water capacity and lead-off properties must be considered of each layer. Differences in thickness counts mainly in the hot summer period, they are more balanced in cool temperatur, and are almost irrelevant under winter conditions." [FLL 2002, 6.3.5.1.]

Apparently green roofs have beneficial effects on urban environment by holding back a remarkable amount of rain water from entering the channel system, moreover that part of the water, which run off in the end, will be delayed, therefore the peakload of channels is decreased. This is especially important at short periodic, but large intensity rainfall, and advantageous is if the green roof is not saturated, so that it can pick up water. This phenomenon is shown on Figure 1.

Green roof investment can cover other beneficial results. In a number of European countries for building green roofs the government provides channel fee allowance to compensate construction costs, motivating additional green investments.

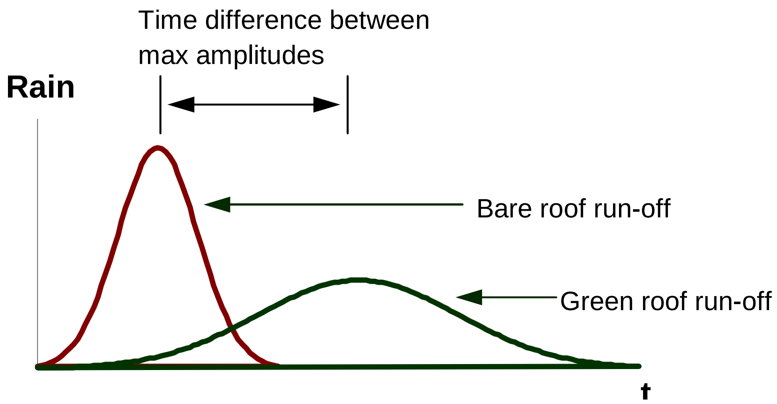

Figure 1. Run-off delay of green roof in contrast of bare roof, in case of short period of rainfall

5. Experimental results

5.1. Besides these beneficial effects of green roofs, it has to be confirmed why it is worth to create such a green layer on the top of our flat roofs, even though they have extra costs. Financial calculations show that extensive green roofs can clear their costs in a very short period of time, because they have minimal extra cost compared to gravel roofs. That is because thickness of substrate is only 5-10 cm and there is no need of additional maintenance.

A german calculation has been made for the case of Berlin. It states that 25% of the area of the city could be covered by green roofs. This way compared to gravel roofs less rain water could get into the channel system by 535 m^3 / ha, which means a substantial amount itself. In addition majority of this amount arise during the summer period, when it has a cooling effect on buildings. It was calculated that if half of the roofs in Berlin were green roof, difference in cooling energy would be 159 kWh/m^2 in a year, due to the evaporation. More than half of this value would arise in summer, when there is much need for it.

5.2. Another calculation which has been made by measurment results of the author, shows that a good deal of heat loss can be saved by putting a green top layer on an existing flat roof. The experimental roof was on a nursery school, with 10 cm of thermal insulation and waterproof membranes on the top. Temperature values has been measured during a whole year period on the surface of each layer on both green roof and flat roof. The results show that the heat loss of green roof (15 cm of substrate) is much less than that of the flat roof, and still less if the 10 cm of thermal insulation is completed with additional 10 cm, creating a duo roof. Heat loss results are shown in Table 3.

Roof types	Summer heat loss (W/m^2)	Winter heat loss (W/m^2)
Bare flat roof (10 cm therm. insul.)	-11.1	12.9
Duo roof (2×10 cm therm. insul.)	-7.38	8.61
Extensive green roof (10 cm therm. insul. + 15 cm substrate)	-1.85	7.40

Table 3. Heat loss values at bare roof, duo roof and green roof

5.3. The author have made another measurment without any calculation on a roof which is covered half extensive growing medium (15 cm), half concrete plate pavement. It has been performed in February 2012, in winter conditions. The green part of the roof was covered by snow, the terrace pavement was absolutely dry. The inside rooms of the building under the two parts of the roof had the same conditions of temperature (24°C of air temp.) and heating. Temperatures of inner ceiling surfaces had been measured, and there was 3,5 °C difference. While under the green roof, ceiling has 21,4 °C surface temperatur, the other part was only 18 °C. This simple example shows, how much heat loss can be avoided by additional 15 cm of growing medium on the rooftop.

6. Conclusion

These calculation and measurments definitely show economical advantages of green roofs in contrast of gravel or bare flat roofs. One can see that governments can save cost on long-term by supporting greening investments. Creating extensive green roofs appears to be a good solution considering the changing weather conditions with more infrequent and intensive rainfalls. It has both ecological and economical benefits beyond aesthetical values.

7. References

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