Utilization of roof garden installation to reduce rainwater runoff in urban residential

IOP Conf. Series: Materials Science and Engineering **852** (2020) 012029 doi:10.1088/1757-899X/852/1/012029

Utilization of roof garden installation to reduce rainwater runoff in urban residential

Endah Lestari[1]* Muhammad Sofyan[2] Buddy Pamuji[3]

[1]Civil Engineering Department, Faculty of Engineering
Sekolah Tinggi Teknik-PLN Jakarta, Indonesia
[2] Civil Engineering Department, Faculty of Engineering
Sekolah Tinggi Teknik-PLN Jakarta, Indonesia
[3] Architect, Matlom Aera Persada, PT

*endahlestari@sttpln.ac.id

Abstract. The role of natural resources is very important in fulfilling human life dan must be managed in non-destructive ways. The discoveries of technology utilized, and managed natural resources is very important and more beneficial in the future. The water resources are one of natural resources can be managed. The rainwater runoff caused a significant problem for many cities due to lack of catchment area. Roof garden becoming potential solutions in controlling the volume of rainwater runoff. Several studies, rooftop garden have not been fully implemented in developing countries due to high construction and long-term maintenance costs. The roof shape can affect to the construction and installation of a roof garden. The research is a roof garden type that can be adapted to the most used roof on the area. The method is to design, build and install the roof garden on sloping shape roofs type. By watering the roof garden, we get the result of minimum runoff according to soil condition. The water maximum infiltrated to soil and the percentage of runoff that occurs is 22% from total water. The conclusion of this research is the roof garden influences the surface runoff; this cause positive impact on reducing rainwater runoff.

1. Introduction

Managing natural resources is very important to develop environmentally sustainable. One of natural resources that can be manage is water resources. The management of water resources is controlling the destructive force of stormwater. The stormwater runoff which flows into the city canals and caused a significant problem in urban area due to lack of catchment area such as flooding and inundation. Storm water produce surface runoff can be control and properly managed in environmentally.

As we know that vegetation has been identified as an important component of a strategy to reduce greenhouse gas emissions and through evapotranspiration process can accelerate the cooling of leaf surface which can reduce air temperature. Vegetation as an urban ecosystem balancer which are hydrological system, climatology, biodiversity or other ecological systems to improve the quality of the environment. How to improve urban environment quality is to increase the availability and effectiveness of Green Open Space (GOS) in urban areas. The limitation of land especially in urban areas, new adaptation strategy is by placing vegetation on the roof top of the buildings are the most innovative and attractive solution. Roof garden is an imitation of the GOS system in capturing rainwater during rainy season. Based on these roof garden becoming the potential solutions to solve problem in controlling and reducing the volume of rainwater runoff. Water that falls on the roof can be absorbed into pore spaces in the substrate or can be taken up by absorbent materials in the substrate. It can also be taken up by the plants and either stored in plant tissues or transpired back into the atmosphere. Some water may lodge on plant surfaces and subsequently evaporate (Nagase, A, 2012). Regards to this issue, the study is aimed to design and build an application of roof garden which adapted to any kind of sloping roof to minimized rainwater runoff on urban residential building.

2. Literature Review

2.1. Roof Garden

Roof garden is a Green Open Space created by adding a layer of plants on the roof system. A roof garden are gardens meant for people to directly enjoy and interact with. They are often modeled after the traditional on-the-ground garden but on the roof (Donnell-Kilmer, 2012). The construction of the roof garden system from top to bottom layer are (1) Plants, usually selected plants for certain application, (2) Irrigation and control system, (3) Planting media/soil, (4) Filter, (5) Drainage layer, (6) Water proof membrane coating, (7) Roof structure. One of the challenges is understanding the process of building the garden and the components of a rooftop garden. In figure 1 shown a typical rooftop garden in cross section.

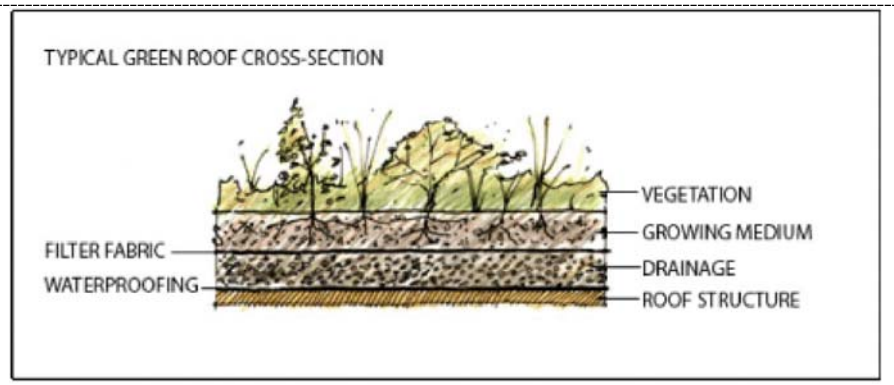

Figure 1. Typical Rooftop garden in cross section

There are some different designs between making plants on the ground and making plants on the roof. The entire rooftop assembly, plants and planting media is considered a part of the dead load of the structure. Excess water, rainwater and people who visiting the roof garden considered a part of live load of the structure (Luckett, K, 2009). There are specific construction requirements in making a roof garden, as follows:

- Roof and Structure Protection, there must be a long-term waterproof coating or membrane to prevent damage and the possibility of reconstruction at high cost.
- Load Bearing Capacity, verifying the maximum load bearing capacity that can be borne by the existing structure. This depends on the weight of the roof garden and the material used, prefer plastic, fiberglass, or foam planting.
- Drainage, the right size is needed for roof garden. Some modifications made to facilitate access to the roof drains, easy to clean up to avoid roof damage.
- Climate consideration,
- Roof Slope, the recommended roof slope is above 10° and not more than 45°. Roofs with a slope less than 2° will caused water pools and caused damage to the roof such as leaking. Roof models in residential buildings are very crucial for roof garden installation. Harvested rainwater quality based on roofing slope and rough-ness is important for local administrations and town planners in redesigning buildings and towns from the viewpoint of sustainable rainwater management (Norman, M, 2019).

2.2. Beneficial of Roof Garden

Creating a rooftop garden produces many benefits, both at the macro-level throughout the city and in micro-building residential environments (Donnell-Kilmer, 2012). Green roof systems save a large portion of annual rainfall and release it into the atmosphere with a transpiration system. Some benefits are follows:

- Runoff reduction, roof garden is one of Stormwater management system to reduce stormwater runoff from roof gutter not directly into the rivers body or city drainage.
- Urban Heat Island Effects, vegetation on the roof as a cooler by release the water through evapotranspiration. Green roofs have been recognized as a great means of removing heat from the air through evapotranspiration of the plants, which leads to a reduction of the temperatures of the roof surface and the surrounding air (Kasera, S, 2012).
- Water Quality, the vegetation, planting media, and waterproof sheet on green roof acting as a filter and absorb the contaminants of rainwater from the building roof. The quality of excess water from the garden is better than before thru roof garden.
- Building Insulation, roof garden as an extra layer on the roof covered from the solar thermal and cooling the inside building.

As a revived ancient system, green roofing systems were originally intended to restore environment and protect roof membranes, but as the green roofing technologies flourished scientific research began to find a number of versatility benefits, that include flexibility and simplicity in design, lightweight components of the system, effective storm water management (Korol, E, 2016).

3. Research Method

3.1. The experimental design

The research was conducted at residential house in Central Jakarta. The site is located on a second-floor roof with 2 type of roof models, flat roof and sloping roof. The vegetation roof applied with type of the roof is 30° sloping roof with clay tile roof covered. The size of green roof media is 1 m x 1 m with 4 inches planting media connecting the building's gutter and downpipes. Figure 2 and 3 below are the design and cross section of green roof media.

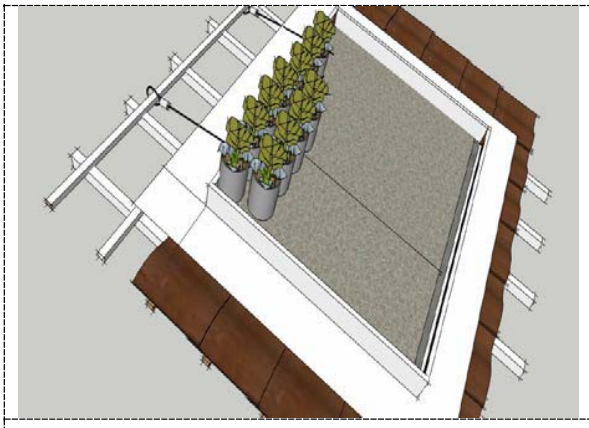

Figure 2. Design of Green Roof Media

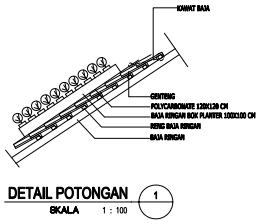

Figure 3. Cross section of green roof media

3.2. Data analysis

The rain data used with records from 15 years from January 2004 to December 2018, for the hydrological analysis of the Sunter watershed using 5 (five) rain stations namely Cibinong, Cawang, Pulogadung, Sunter Kodamar and Sunter III Rawa Badak. From the maximum rainfall data above obtained a calculation of the average rainfall at this area is 11.5 mm/hour with average rain duration is 2 hours per 1-time rain. Maximum Rainfall Sunter watershed showed in table 1.

Table 1. Maximum Rainfall Sunter Watershed Table.

Year	Rainfall (mm)
2004	65.592
2005	105.746
2006	52.993
2007	73.299
2008	92.619
2009	43.923
2010	43.319
2011	72.264
2012	53.394
2013	59.966
2014	59.836
2015	88.906
2016	75.715
2017	74.426
2018	76.776

4. Result and Discussion

4.1. Runoff Discharge Calculation

The focus of this research is that the construction of a roof garden can reduce/minimalized rainwater runoff, thereby reducing the amount of runoff flowing into the city drainage channel. In this study the amount of runoff obtained after the construction of the roof garden at the house. Since roof cover in all surface area in the cities, they operate the main role in the urban stormwater runoff (Ugai T, 2015).
The average volume of the water captured by a roof can be estimated by the following equation:

$$V = \alpha . I . A . T \quad (1)$$

V potential volume of water catchment
α RC (Runoff Coefficient)
I local precipitation, m/hour
A catchment area, m²
T rain duration, hour

Runoff coefficient measures the percentage of water that drains off. The higher the coefficient, the greater the amount of water will run off. A runoff coefficient of 0.40, for example, means that 40% of the water that falls on the material will run of, while 60% will be absorbed. In this study the value of C (Runoff coefficient) values recommended by SNI 03-2415-1991. The runoff coefficient of concrete and clay tile roof is 0.95. Runoff coefficient for green roof is 0.30 assuming a minimum thickness of planting media is 4-8 inches (discoverdesign.org). Figures 4 showed 2nd Floor Roof Plan.

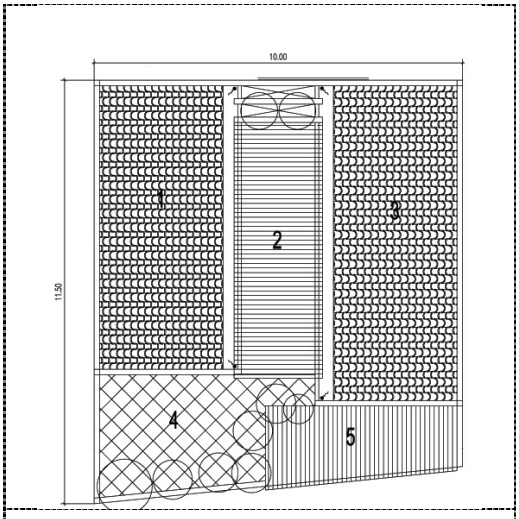

Figure 4. 2nd Floor Roof Plan

Catchment area calculation of residential building = 95 m².

V = 0,95 . 0,012 . 95. 2
V = 2,166 m³ (in 1-time rain)

All the roofing area is full covered by vegetation. The calculation of runoff volume produced on the roof with full covered of vegetation is:

$V = 0{,}30 \cdot 0{,}012 \cdot 95 \cdot 2$

$V = 0{,}684\ m^3$ (in 1-time rain)

4.2. Residential Roof Garden Model

The roof garden model on study location made from an impervious hard plastic base (polycarbonate). The construction of roof garden model is, polycarbonate, waterproof membrane, geotextile membrane, planting media and vegetation. The model was vegetated with three kinds of plants, Walisongo Varigata, Sabrina Mini, and Lantana Kuning. Planting media is mixed of grain, red soil and cocopeat. Cocopeat is a type of growing media made from coconut fiber. Figure 5 and 6 showed roof garden model at study location.

Figure 5. Roof garden model applied on sloping roof

Figure 6. Roof garden model applied on flat roof

The percentage of runoff volume after green roof applied is 31,58% of total runoff volume before green roof applied. The amount of water infiltrated to green roof application is 1,482 m^3, it's around 68,42% of total runoff volume. From the results of the calculation analysis, the process of green roof media can reduce rainwater runoff almost 70%.

Most of the water will go through a process of evapotranspiration and the excess will be stored by planting media. Green roof application as a sustainable concept of stormwater management to facing a climate change which are caused flooding, drought and lack of clean water. The green roof media need low maintenance and properly irrigation system, this could affect to provides protection and roof structure. Roof garden could be applied on both type of roof, sloping and flat roof.

For further research should be reviewed the type of vegetation used for green roof application such as the effects of plant species, diversity, plant structure, soil media thickness uptake to falling rainwater and can be classified which types can absorb rainwater optimally. It should be further research for how to maintenance of the roof garden especially at sloping roof model and need an automatic watering system for roof garden special on dry season.

5. References

[1] Nagase, A; Dunnet, N, 2012. Amount of Water Runoff from Different Vegetation Types on Extensive Green Roofs: Effects of Plant Species, Diversity and Plant Structure. *Landscape and Urban Planning 104*. 2012, 356-363.

[2] Donnell-Kilmer, N, Rooftop Gardens A Green Solution to Los Angeles' Urban Problems. *Journal Article*. 2012, pp. 77.

[3] Luckett, K, Green Roof Construction and Maintenance. U.S.A: The McGraw-Hill Companies, Inc. 2009.

[4] Norman, M; Shafri, H; Mansor, Shattri; Yusuf, B. 2019. Review of Remote Sensing and Geospatial Technologies in Estimating Rooftop Rainwater Harvesting (RRWH) Quality. *International Soil and Water Conservation Research 7*. 2019, 266-274.

[5] Kasera, S; Nayyar, A; Sharma, D. 2012. The Energy Cunsumption Performance of Roof Garden. *International Journal of Scientific & Engineering Research*. Volume 3, Issue 7.

[6] Korol, E; Shushunova, N, 2016. Benefits of A Modular Green Roof Technology. *Procedia Engineering 161*. 2016, 1820-1826.

[7] Gibler, M. R, 2015. Comprehensive Benefits of Green Roofs. World Environmental and Water Resources Congress 2015, 2244-2251.

[8] McRae, Anderson. 2013. *Design and Development of a Roof Garden.* USA: McCarenDesigns, Inc.

[9] Meder, Amanda, 2010, http://bebasbanjir2025.wordpress.com/teknologipengendalian-banjir/rain-gardens/

[10] Ugai, Takao, Evaluation of Sustainable Roof from Various Aspects and Benefits of Agriculture Roofing in Urban Core. *Procedia - Social and Behavioral Sciences*. 2016, 216, 850-860