International Journal of Control and Automation
Vol. 9, No. 8 (2016), pp.59-68
http//dx.doi.org/10.14257/ijca.2016.9.8.07

A Field Study to Evaluate Runoff Quantity from Blue Roof and Green Blue Roof in an Urban Area

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Abstract

This study evaluated performance for runoff management of the Blue roof and Green blue roof comparing monitoring data measured at two low impact development (LID) facilities and control roof in Seoul metropolitan area. From the results these two roofs proved as suitable stormwater management practices in urban areas. For this purposes, Blue roof and Green-blue roof were installed at Seoul City Hall Annex Seosomun and Cheong-un middle school respectively. The data used for this study were collected during the actual storm events of more than 30 mm/hr and 60 mm/hr rainfall intensity in July and September 2014 at green blue roof and blue roof. During different actual storm events, rainfall runoff outflow was measured from blue roof was 0.45 l/s as compared to common roof where outflow was 1.55 l/s. While on the other hand, the outflow from green blue roof was 0.1 l/s to as compared to control roof where the runoff outflow was 0.3 l/s. Results also indicated the peak flow reduction in both types of roofs. From the results, it was found that Green blue roof is capable of handling effectively long duration rain events than blue roof. However, the blue roof is inexpensive than green blue roof and suitable option for retrofitting in urban areas. These results also revealed that Blue roof and Green blue roof could be applied to urban buildings as the suitable management practices for rainfall runoff management in urban areas. At the end, from theoretical analysis some suggestions are also made which could be apply for the more safe sustainable drainage system of an urban area.

Keywords*: Low impact development (LID), green-blue roof, blue roof, rainfall runoff, rainwater management*

1. Introduction

The population in urban areas is increasing worldwide. At present, about 50% of the global population lives in urban areas, which is almost 2.8% of the total land of our planet [1]. Due to urbanization, the natural surface areas are changed into impermeable areas (*i.e*. roads, buildings, roofs *etc*.). Due to the effect of this infiltration decreases and surface runoff increases which causes flooding and heat island phenomena in urban areas [2]. In the developed countries, the urban roofs areas account for almost 40 to 50 % of the impermeable surface areas [3]. Stormwater runoff from the urban roofs makes a momentous contribution to sewage water and demands more attention to handle safely.

ISSN: 2005-4297 IJCA

Recently, Low impact development (LID), a new green stormwater approach has been acquiring more attention [4].

Conventional roofs have impervious surfaces and creates a large amount of runoff that causing the flash flooding in the urban areas. To avoid these adverse effects, green-roofs and blue roofs have become relatively common LID practices over the last 20 years in many countries such as Germany, Sweden, USA, UK, Japan and Singapore. Blue roofs are very effective for retrofitting options for the stormwater management in developed urban areas. Due to their tremendous results in the stormwater management, blue roof are applying in the pilot projects [5]. Green roofs are very effective LID practices and have many positive effects in the urban area which includes, to retain and detain a large amount of storm water for long duration [6], reduce urban heat waves [7], reduction in the building energy consumption by cooling effect [8]. Green-blue roof is a new innovative design which also has the same concept as the green roof but in these type of roofs an additional storages is available below the soil layers which can store more water. Like many other urban cities in the world, the capital of Korea, Seoul also facing the stormwater management problems. To overcome all these adverse effect, different LID practices were installed at different location.

Blue roof and Green-blue roof were installed at Seoul City Hall Annex Seosomun and Cheong-un middle school respectively in Seoul metropolitan, Republic of Korea. The different storm events were monitored and data is analyzed from for the rainfall runoff management. The results from these two roofs indicated that these two roofs are the suitable LID practices for the rainfall runoff management in the urban areas. The results also revealed that green blue roof performance for the rainfall runoff control and delay is more effective than the blue roof.

2. Materials and Methods

2.1. Roof Types

There are different types of roofs using around the world. The roof type is depends upon the different factors *i.e.* geographical location, climatic conditions and available material for the construction of roofs *etc*. Roofs can be categories as follows.

2.1.1. Common or Traditional Roofs

Flat roofs are the traditional roofs which are almost have flat surface and have a slope up to 10^{o} for the drainage [9]. Flat roofs exist all over the world and different materials is used for the construction of flat roofs with respect to area. Commonly flat roofs are simply built of masonry or concrete. In the urban areas, these impervious roof surfaces makes a more rain runoff that causes flash flooding problems. There are different types of roof as shown in Figure 1.

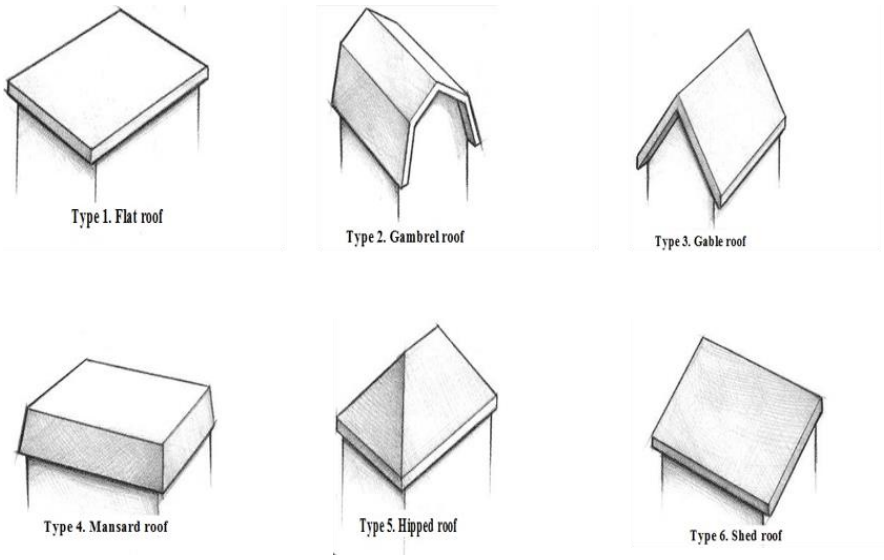

Figure 1. Different Types of Roof

2.1.2. Blue Roof

Blue roof are non-vegetated source control that retain the stormwater. Weirs use at the roof drain inlets which can create the temporary ponding and slowly release of the rainwater. The main focus in the blue roof is the collection of rainwater by catchment in an area. Light colored roofing material is mostly used because these will also good for the cooling of rooftop. Blue roof are less costly than the green roofs and it can reduce the runoff in an area.

2.1.3. Green Roof and Green Blue Roof

Green roofs or living roofs are the roof of the building that are covered with the vegetation and soil medium, planted over the water proofing membrane. These roofs are mainly use for use the stormwater management in urban areas. These roofs can absorb and retain a large amount of water. Moreover, these roofs provide the sustainability benefits such as the absorbing the noise pollution, reducing the urban heat island phenomena and creating the living environment for birds and also improve the quality of life in an area [10].

Green blue roofs has the same principle as the green roof for the stormwater management but the green blue roof has one more storage layer below the soil media. In this way, the green blue roof can store a large amount of rainwater and can work more efficiently to avoid flooding in an urban area.

2.2. Location of the Roofs

Blue roof and green blue roof were installed in the highly developed city of the Korea, Seoul. Figure 2, shows the location of the blue roof and green roof in Seoul metropolitan. These roof were installed for the rainwater runoff control.

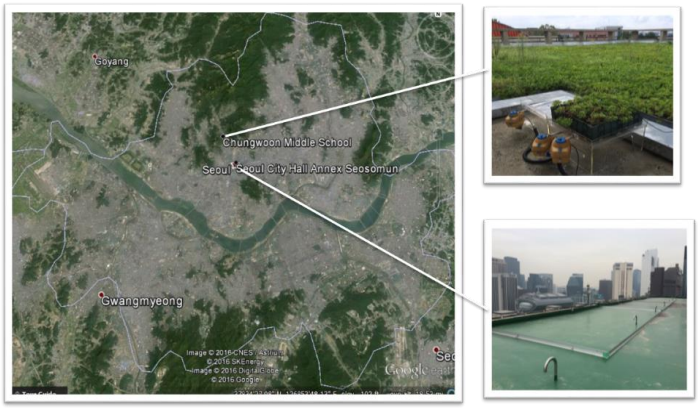

Figure 2. Location of Green Blue Roof and Blue Roof in Seoul

2.3. Blue Roof Design

Blue roof are non-vegetated source control that use to detain and retain the stormwater. Blue roof was installed on the roof of Seoul City Hall Annex Seosomun, Korea and has catchment area is $50m^2$x 2 points. From these two catchments areas, one is the common roof that is temporary storage where the all water is the surface runoff. The second is the blue roof where water can retain and pass slowly through the orifices which helps to retain and detain the rainwater and also reduces the chances of flash flooding in urban areas. In this roof, water gauge, flowmeter and rain gauge were installed. In order to analyze the rainfall runoff from these two roof the data for the different storm events of September 2014 were collected. The detail of the blue roof as shows below (Figure 3). Table 1, shows different characteristics of the blue roof.

Table 1. Blue Roof Detail

Division	Catchment Area	Reservoir fence height	Maximum storage capacity	Spill form	Instruments
Common roof	50 m^2 (10x5)	0.14m	6.7m^3	Surface runoff	Water gauge 1 Flowmeter 1
Blue roof	50 m^2 (10x5)	0.14m	6.97 m^3	Orifices	Water gauge 1 Flowmeter 1

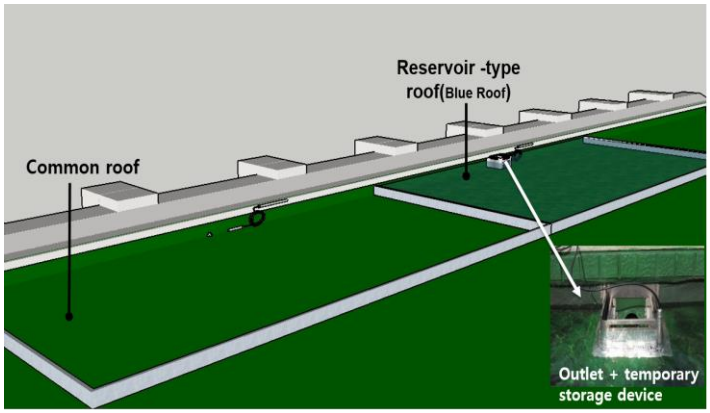

Figure 3. Detail Image of Blue Roof Seoul City Hall Annex Seosomun

2.4. Green Blue Roof Setup

Green blue roof is a new innovative design of roof and it was installed on the roof of Cheong-un middle school building, Seoul, republic of Korea. The total catchment area of the green-blue roof is 285 m^2. The roof systems were designed in several 0.5 × 0.5 × 0.2 m assemblies as shown in Figure 4. Green blue roof assembly is made of plastic that consisted of vegetation and storage layers. This roof have some orifices from where water can enter into storage layer. We analyzed the data of actual storms from the Control roof (no soil and vegetation) and green roof which are shown in Figure 4. This site include the weather station, which records temperature, relative humidity, wind speed, and rainfall. Two tipping bucket flow meter, water gauge and moisture gauge were also installed in the blue green roof. Green blue roof works same as the green roof as to control rainfall runoff and to maintain the natural environment in an area. In order to analyze the rainfall runoff from the green blue roof the data of rainfall event in July 2014 were collected.

Figure 5, represents the green blue roof layers. Green blue roof consists of the plants which grows on the top of the soil. This roof have extra storage layer under the soil layer where more rainwater can store.

Figure 4. Green Blue Roof Cheong-un Middle School

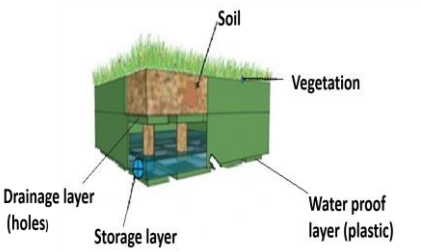

Figure 5. Overview of Green Blue Roof

3. Results and Discussion

Rainwater can be manage on the roof and at the ground in many different ways. This can be explain in the different scenarios. Rainwater could be manage by using the blue roof, green roof and green blue roof but it is possible in the case of flat roof. As there are many different types of the roofs in an area, so we should select our roof system with respect to our requirement. Roof rainwater management can be manage by the following ways is shown in Table 2. Rainwater could be management on the roof, as well as on the ground surface by using the innovative LID approach. This also explained in different scenarios as below.

Table 2. Comparison of Rainfall Runoff Management by Different Approaches

Traditional Stormwater Management	**LID Approach**	**New Innovative LID Approach**
Concept: No collection nor retention of rainfall runoff on the roof	Concept: Collection and retention of rainfall runoff by using LID practices on the roof	Concept: Collection and retention of rainfall runoff on the roof as well as on the ground
Main rainfall runoff flow directly into sewer system	Rainfall Runoff first collecting on the roof and extra goes into sewer system	Rainfall runoff management on the roof as well as on the ground. Try to utilize all the rainfall runoff by using Suitable combination of LID facilities
No LID facilities on the roof	Rainfall runoff is retain and detain by using green roof, green blue roof and Blue roof	On the first retain and detain by green roof, green blue roof and Blue roof and then on ground also use the suitable LID facilities (*i.e*. rain garden, permeable infiltration trench and rain barrel)
From real data, it also proved that this approach is not suitable for Rainfall runoff management	From actual storm data analysis, this approach prove as the suitable approach for the stormwater management	This is the new conceptual design that have no actual data now. But from theoretical analysis this approach is proved as the more effective and efficient for the rainfall runoff management
Not suitable practices for the rainfall runoff management	This approach have limited advantage for the rainfall runoff management	This the suitable approach for rainfall runoff Management in urban areas
The construction cost is low but have no benefits for the rainfall runoff management	The construction cost is high but have many benefits for the stormwater management	Initial construction cost is little high but have more cost benefits analysis form all the former practices. It is also best suitable practices for the rainfall runoff management

3.1. Scenario 1 Rainwater Runoff Control on the Roofs in Case of Flat Roofs

3.1.1. From Real Data

In case of flat roof of the building. Blue roof, green roof and green blue roof can easily be apply on the building top for the stormwater management. In this case, green blue roof and blue roofs were installed in Seoul. The water is only considered at the roof top and

managed on the roof. Data is analyzed from these roofs and the results indicated that the both roof retain the large amount of rainwater and reduces outflows.

3.1.2. Blue Roof Results

As shown in Figure 6, in blue roof the rainfall runoff is less as compared to the common roof (without blue roof). The storm with maximum 90 mm/hr rainfall intensity that was occurred between 22/7/2014 – 25/7/2014 analyzed on the common roof (without) and blue roof. From the analysis, results indicated that the rainwater outflow form the blue roof and common roof is 0.45 l/s and 1.55 l/s respectively (Figure 6). Peak flow of blue roof also reduced as compared to common roof. Through these results, it is proved that the blue roof can control and delay rainfall runoff.

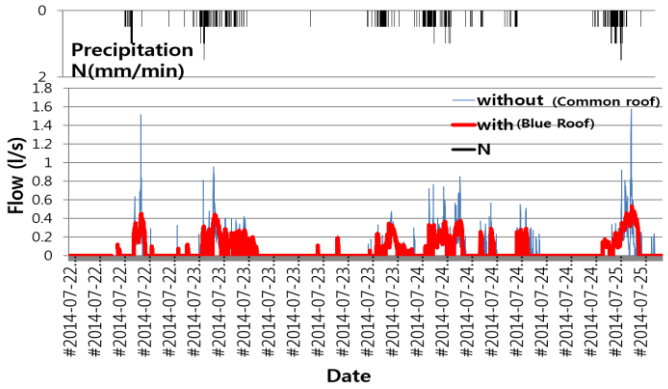

Figure 6. Variation of the Rainwater Outflows from the Common Roof and Blue Roof during Rainfall Event

3.1.3. Green Blue Roof Results

Rainfall outflow and peak flow reduction between green blue roof and control roof were monitored in a real storm event of September 3, 2014, when the maximum rainfall intensity was 60 mm/hr. Results indicated that rainfall runoff outflows from the green blue roof and control roof were 0.1 l/s and 0.3 l/s respectively (Figure 7). Due to soil media and storage layer to collect the water in the green blue roof, and the water outflow from green blue roof is observed after few hour. Green blue roof reduced the outflow and peak flow which are very helpful for sustainable urban design. Green blue roof reduced the rainfall runoff by retaining the water in soil media and storage layer.

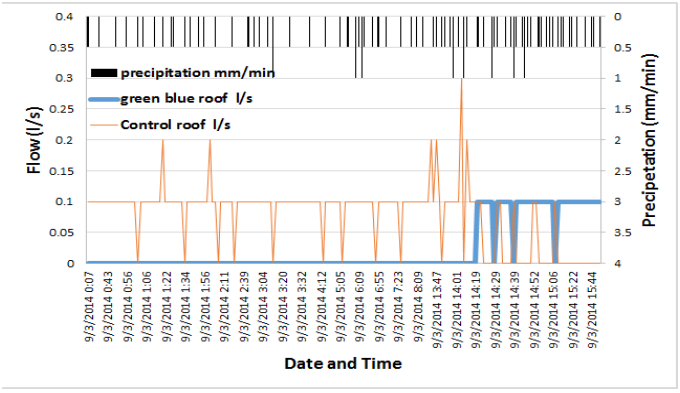

Figure 7. Variation of the Rainwater Outflows from the Control Roof and Green Blue Roof during Rainfall Event

3.2. Scenario 2 Rainwater Runoff Management on the Roofs as well as on the Ground

In this case, some assumption are made for the rainwater water runoff management from the different type of the roof. In Korea, the average rainfall per month is approximately 5.0 inch [11]. Roof rainwater could be mange on the roof as well as on the ground as explained in scenario 2.

There are many other types of the roofs as shown in Figure 1. In Figure 1, the roof types are explained well and also different roof types are shown. Roof types are explained below for the rainfall runoff management

3.2.1. Roof Type 1 and Type 4

For the roof type 1 and 4 which are flat and mansard roof types. In this type of roof, for the stormwater management LID facilities (*i.e*. blue roof, green blue roof and green roof) can be installed easily. The rainwater could be collected first at the roof and then surplus rainwater can be diverted towards rain garden and permeable infiltration trench. In this new innovative LID approach the main purpose is to utilize all the rainwater at the roof as well as on the ground without wasting it into the sewer system. These roof types are commonly found and the rainwater can easily handle in these types of roofs.

3.2.2. Roof Type 3 and Type 6

Green roof and blue roof can be installed in case of roof type 3 and 6, but it requires a special design for the construction. Repair and maintenance cost will be high as compared to roof type 1 and 4. Rainwater runoff could be collected and stored on roof as well as in rain barrel and other nearby LID facilities.

3.2.3. Roof Type 2 and Type 5

In these type of roof, blue roofs and green blue roofs cannot install due to their shape. In this case, the rain fall runoff could be collected from the roof top with the help of pipe and diverted towards the rain garden, infiltration permeable trench and store water into storage tank near that building area. Nowadays, the most important thing is to design a new innovative facility which can have multiple benefits with less economy. In this scenario, the main focus was on the management and utilization of all the roof rainfall runoff. For this purpose, we have indicated the new idea in which the rainwater could be managed by using the blue roofs, green roofs, and green blue roofs on the roof and extra water could be managed in nearby rain garden, infiltration permeable trench or store into storage tank. In this way, the rainwater could be mange more suitable and sustainable way in an urban areas. The main purpose to install the different LID facilities nearby building is to cutoff roof runoff from sewer system. By cutoff rooftop water from the sewer system will helpful to reduce flooding in urban areas.

4. Conclusion

For green blue roof the data of rainfall event with maximum 60 mm/hr of rainfall intensity, results indicated the outflow reduction from green blue roof was 0.1 l/s as compared to control roof where the runoff outflow was 0.3 l/s. This was the small storm event so that the outflow from the green blue was started few hours later as compared to control roof because the first water stored in the soil and storage layer and then will become outflow. Green blue roof can handle big storm event more effectively as compared to blue roof.

The data for the rainfall event from with the maximum 90 mm/hr rainfall intensity at blue roof, outflow from the blue roof was 0.45 l/s as compared to common roof where the

outflow was 1.55 l/s. The outflow amount of blue roof was very less as compared to the common roof because first the water is collected in the blue roof and then gradually outflow from the offices. This process also help to delay and slow release of water to sewer system which avoid the flooding. Blue roof is cost effective and suitable options for retrofitting. It can easily handle the small storm events and avoid flash flooding in urban areas.

These two practices were the rainfall runoff management on the roof that we can easily apply in case of flat roofs. However, there are so many roof types and the suitable combination of LID practices could be applied for the stormwater management in an urban area. The main purpose in the second scenario was prohibit the roof rainwater into sewage system. It could be connected to suitable LID facilities on the ground such storage tank, rain garden, and permeable infiltration tank *etc*. For the sustainable and sustainable stormwater management approach it is necessary to handle and to utilize the rainwater runoff on the roof as well as on ground by using different LID facilities. By using the new innovative LID approach that was discussed above the rainwater from the roof could be handle in a more efficient way.

Acknowledgements

This work is supported by the Korea Agency for Infrastructure Technology Advancement (KAIA) grant funded by the Ministry of Land, Infrastructure and Transport (Grant 1615007273).

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