Conference Proceedings

ASES National Solar Conference 2017

Denver, Colorado 9 – 12 October 2017

Case Study of a Green Roof in Islamabad

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Abstract

With the increase in environmental degradation globally, people are beginning to shift towards resources and strategies such as green roofs to reduce the environmental footprint and upgrade the living environment. Green roofs provide for aesthetically pleasant environments and habitat for variety of plants, insects and birds. They are most suited to reducing indoor cooling and heating for thermal comfort in buildings. Green roofs also help to improve air quality especially in populated urban areas. One of the metropolitan areas of Pakistan, like twin cities of Islamabad-Rawalpindi, has a combined population of 5.1 million (the 3rd largest agglomeration in Pakistan). These cities have mostly concrete buildings, asphalt roads and concrete paving in their built environment, which contribute towards heat island effect and exacerbates worldwide global warming. In particular, Islamabad undergoes a cold winter and a hot and dry/humid summer. There are a myriad of benefits to installing green roofs in the urban area of Islamabad such as, reducing heating and cooling energy and heat island effect, increasing biodiversity and evapotranspiration and improving environmental air quality. This paper explores the case study of a green roof installation in the capital city of Islamabad and determines the feasibility of installing green roofs in this city. Conclusions reached in this research point out that there are far more pros than cons in integrating the tops of buildings with green roofs in the climate of Islamabad, particularly in the dominant warm/hot and dry/humid summers.

Keywords: Green Roof, air quality, heating and cooling energies, thermal comfort.

1. Introduction

A green roof is a high performance roof installed on the top of a building. It is a roof of building that is covered by vegetation typically growing in layer of a growing medium on the roof. A green roof consists of organic soil mixed with lightweight aggregate installed on a concrete roof. Grass, small and large flower plants, shrubs and small trees could be grown on a green roof. A green roof installed on a built structure can reduce heating demand in winters and cooling demand in summers; additionally it also reduces the heat island effect, storm water runoff and noise transmission. It improves environmental air quality and increases biodiversity and evapotranspiration.

Green roofs offer many benefits to an urban area. They can reduce energy demand on internal space conditioning, and hence reduces the green house gases (GHG) emissions, through direct shading of the roof, evapotranspiration and improved insulation values, by virtue of the thick layering of growing medium. If widely adopted, green roofs could reduce the urban heat island effect, which would decrease smog, problems associated with heat stress and further lower energy consumption. They could also help to improve storm water management if sufficiently implemented in an urban area. Part of the rainwater is stored in the growing medium temporarily, and will be taken up by the plants and returned to the atmosphere through evapotranspiration. Also green roofs delay rain water run-off into the sewage system, thus helping to reduce the frequency of combined sewage overflow events, which is a significant problem for many major cities in Pakistan. The plants and the growing medium can also filter out airborne pollutants washed off in the rain, thus improving the quality of the run-off. Even though green roofs represent an inexpensive adaptation strategy, technical information on their thermal performance and environmental benefits, in a Pakistani context, is not much available.

This applied research project aims to study the various benefits of this technology regarding installation and feasibility of green roofs. The objective is to identify sensitivities to climate variability and to quantify the benefits of the technology under Islamabad climatic conditions. Furthermore, this research compares the performances and thermal effects of a green roof with a typical non-insulated concrete roof on top of a building, in Islamabad. Here, a green roof would be installed on an existing structure with a typical concrete roof and another portion would remain intact as an exposed bare concrete roof. Hence, the two types of roofs under testing are developed on the same site, almost side by side and subject to the same climatic conditions, with the bare concrete roof covering the Room A and the green roof covering the Room B, as shown in Fig. 1 below:

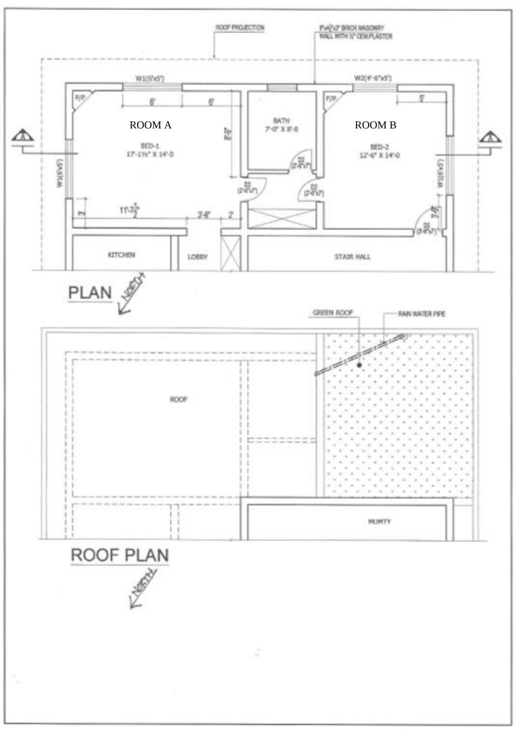

Fig. 1: Plan and roof plan of the as-built existing structure for the study

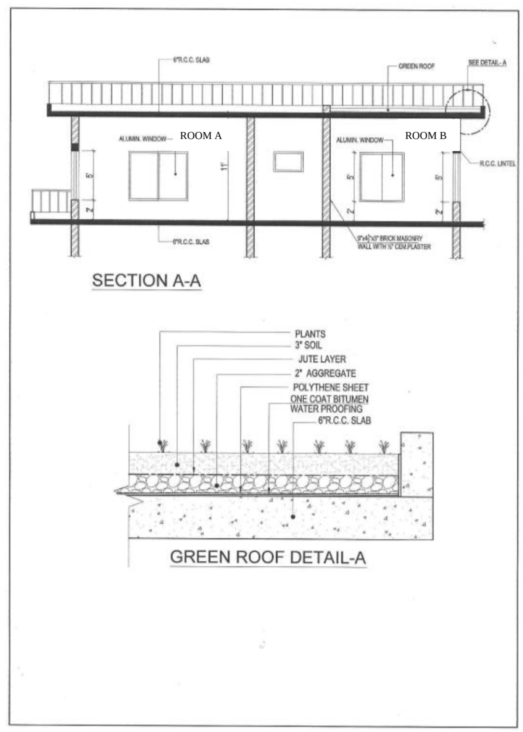

Fig. 2: Section and the green roof detailing

The two test rooms A and B beneath the two types of roofs under testing, are installed with data loggers to monitor ambient air temperatures and relative humidity at every 5 minutes interval per day basis. The sensors and data logging instruments were commercially available instruments. One sensor is installed outside, near the structures, in a shaded location to record ambient air temperatures and relative humidity at every 5 minutes interval per day. The data monitored and collected is downloaded onto a computer. The recorded period of activity for monitoring is for an entire warm month of September.

It is expected that the Room B with the green roof installed above would perform better in terms of human thermal comfort as compared to the Room A with the bare concrete roof above. This applied research would quantify the difference of comfort levels between the rooms A and B, one with the bare concrete roof and the other with the green roof respectively.

2. Climate of Islamabad

The city of Islamabad is situated at 33.6 N and 73.11E and is 518 meters above sea level. The climate is subtropical humid type requiring heating in winters and cooling in summers in buildings for thermal comfort. The summer period is from mid April to mid October and winter period is from December to February. The months of March to mid April and mid October to November are transitional periods, when the climate is moderate and may or may not require cooling or heating of buildings. Monthly mean maximum temperatures in May, June, July and August are 38C, 39C, 38C and 35.5C respectively; monthly mean maximum humidity in those months are 38%, 38%, 65% and 75%. July and August are the monsoon months when high relative humidity but low temperatures are experienced. Typically cooling is warranted in the daytimes during mid April till end of September or mid October and heating is required from mid November to mid March. Exterior design conditions at 2.5% are 41.5 °C in summer and 27.2 °C in winter (BECP). Mean temperatures, relative humidity and wind directions are listed below in Tab. 1.

Tab. 1: Climatic Data of Islamabad (ENERCON)

Monthly Mean	January	February	March	April	May	June	July	August	September	October	November	December
Max. temp.˚C	18	18.5	25.5	36.5	38	39	38	33.5	33.5	32	26.5	20
Min. temp.˚C	1	3.5	10	13,5	18.5	24	24	24	20	13	4.5	-1
Range temp.˚C	17	15	15.5	23	19.5	15	14	9.5	13.5	19	22	21
Max. RH%	82	80	63	51	38	38	64	75	60	58	68	85
Min, RH%	46	50	40	30	17	30	48	53	37	30	30	40
Average RH%	64	65	52	41	28	34	57	64	49	44	49	63
Wind Prevailing	SW	SW	SW	SW	SW	SW	SE	SE	SW	SW	SW	SW
Wind Secondary	W	W	NW	NW	NW	SE	SW	SW	NW	NW	W	W

3. Test Roofs' Construction

Two rooms chosen on the site for a comparative thermal analysis, were room A (17'-0" x 14'-0" square x 9'- 6" clear height from the floor) and room B (12'-6" x 14'-0" square x 9'- 6" clear height from the floor), in the existing structure. The roof on top was 6" thick reinforced concrete. For the green roof construction, a coat of bitumen waterproofing was applied on the roof. A polyethylene sheet was laid over, on which was laid 3" thick layering of coarse aggregate, a layer of jute, then 3" thick organic soil as the growing medium. Finally, the roof was planted with two types of plants in rows, as shown in Fig. 2.

The wetted soil was maintained manually with spraying water through the pipe (Fig. 4) attached to the overhead tank on the roof as shown in Fig. 5, by a person appointed for this purpose and other maintenance purposes.

Fig. 3: Watering pipe to wet the soil

Fig. 4: Watering pipe connected to the overhead tank installed on the roof

The other portion of the roof was kept bare and exposed as is normally the case with most structures built in Pakistan. This portion of the roof was located next to the green roof, but sufficiently at a distance so that the spaces do not influence one another.

The two rooms, room A with the bare concrete roof and room B with the green roof, were monitored for thermal performance during the entire summer month of September 2017.

Monitoring Room A with a Bare Concrete Roof above

A sensor to record the inside temperatures and relative humidity at 5 minute intervals was wirelessly connected to a remote data logger to document the results, as shown below in Fig. 5.

Fig. 5: Temperature sensor kept in room A.

Monitoring Room B with a Green Roof above

Similarly, a sensor to record the inside temperatures and relative humidity at 5 minute intervals was installed in the room that was wirelessly connected to a data logger to document the results, as shown in Fig. 6.

Fig. 6: Temperature sensor kept in room B.

Monitoring Outside Air Atmosphere near both the roofs

In addition to the above data logging equipment was also a third sensor to record the outside ambient air temperatures and relative humidity that was installed in a shaded area.

Fig. 7: Sensor and transmitting modules.

Fig. 8: Sensor module monitoring outside air and relative humidity

4. Roofs' Performance

<u>During the warm climate of Islamabad</u>

The months of July, August and September are typically the monsoon months when Islamabad is visited by rains and thunderstorms. The humidity increases substantially, while the temperature drops considerably, when compared to the hot and dry months of May and June. There was intermittent data loss, but meaningful and readable data was received in the month of September 2017.

On September 14, 2017, the highest outside temperature was 39.4 °C at 16:15 and the lowest temperature was 24.3 °C on the same day at 04:05. At those times the behavior of the room A with the bare concrete roof and room B with the green roof are summarized below in Tab. 2 and Tab. 3.

When observed over a 24 hour period commencing on September 14, 2017 from 00:00 to 11:55 (highest as well lowest temperature) the following data was recorded:

Tab. 2: On September 14, 2017 highest temperature of available data

Time	**Outside Conditions**	**Inside the test Rooms**	
		Room A with Bare Concrete Roof above	Room B without Green Roof installed above
	Temp. °C / RH %	Temp. °C / RH %	Temp. °C / RH %
16:15	**39.4 / 32**	**31.4 / 52**	**29.8 / 52**
	Very Warm	Warm/dry Zone	Warm/dry Zone

Tab. 3: On September 14, 2017 lowest temperature of available data

Time	**Outside Conditions**	**Inside the test Rooms**	
		Room A with Bare Concrete Roof above	Room B without Green Roof installed above
	Temp. °C / RH %	Temp. °C / RH %	Temp. °C / RH %
04:05	**24.3 / 64**	**29.4 / 54**	**28.5 / 56**
	Very Humid/Warm	Warm/humid Zone	Warm/humid Zone

Using 24 °C as a benchmark for summer comfort level, the outside conditions were not in the comfort zone in a 24-hour period that ranged from a low of 24.3 °C to a high of 39.4 °C. Similarly, the room A with the bare concrete roof above was not in the comfort zone for the entire 24-hour period that ranged from a low of 29.4 °C to a high of 31.4 °C. The room B with the green roof installed above did not fare any better than the room A as it too did not remain in the comfortable zone during the entire 24-hour period with a low of 28.5 °C to a high of 29.8 °C; however, the temperature difference of room B was only 1.3 °C, which was less than the room A with a temperature difference of 2 °C, and the outside conditions with a temperature difference (diurnal) of 15.1 °C. Although both the rooms did not afford any comfortable conditions within the internal spaces, it could be concluded that, if both the rooms were using energy for cooling, the room B with the green roof installed above would have been better than the room A in terms of energy savings. It can thus be concluded that the room B with green roof above performed slightly better than the room A with bare concrete roof; this was mainly by virtue of the thick layering of the growing medium, which afforded thermal lag to the heat throughout the day.

However, much of the heat was conducted through the un-insulated walls of the test rooms and single pane windows, resulting in the less temperature difference between the two rooms.

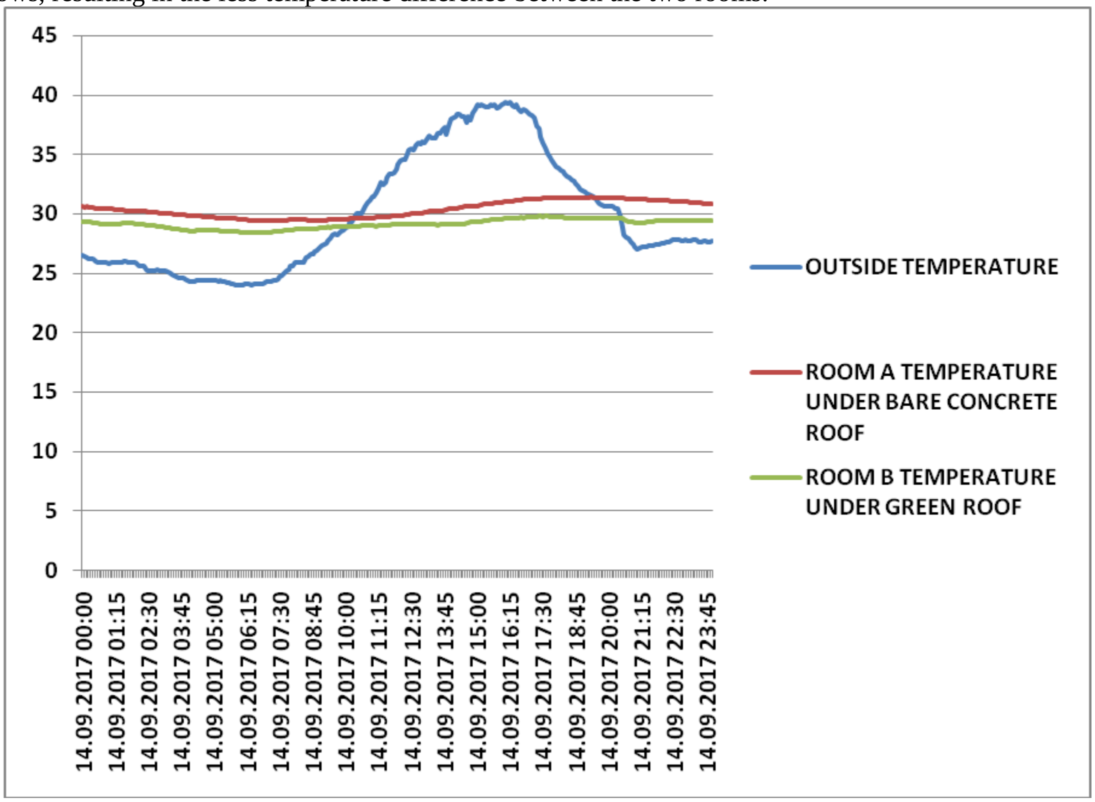

Fig. 8: Graph for exterior, room A and room B temperatures for a 24-hour period on September 14, 2017.

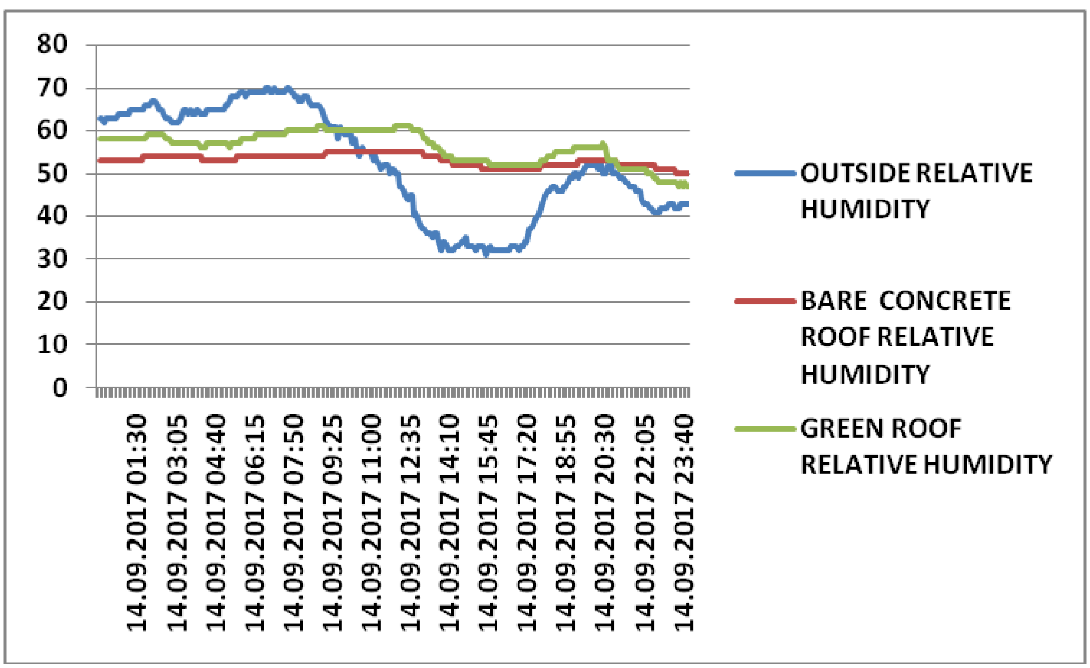

Fig. 9: Graph for exterior, oom A and oom B relative humidity for a 24-hour period on September 14, 2017.

5. Conclusions and Outcomes

Green roof construction systems have been much promoted for being advantageous in buildings for human thermal comfort, this being the system used in the past as was done in the hanging gardens of Babylon and also in buildings today. This system could be most easily adaptable in Pakistan's urban and rural areas. This research sought to investigate the thermal advantages of space under a green roof top by comparing it with a similar space under a concrete roof top, which is the current building practice in Pakistan. Two similar rooms were chosen side by side on an existing building. Sensors were installed in the rooms below the two types of roofs and the outside area near the roofs to monitor temperatures and relative humidity in the respective spaces. It was observed and concluded that:

I. At all times, the difference in temperature in the two rooms under the bare concrete roof and the green roof remained only 2°C to 3 °C, because the existing walls were un-insulated and the windows were single pane glass; therefore, not much difference in temperature was found between the two test rooms.

II. The rooms faced different directions such as the room A with the bare concrete roof above faced towards the south-east side and the room B with the green roof installed above, faced towards the south-west side; therefore, there were heat gains from the windows which negated the positive effects of the green roof.

III. The room B with green roof was slightly warmer at night then the room A with bare concrete roof because in the night the bare concrete roof lost heat faster than the green roof due to the insulation effects of the green roof.

IV. The green roof was also not fully shaded by the plants not covering the entire soil area, so there was less shading by the plants.

V. The less number of plants caused lesser evapotranspiration - a phenomenon by which water is evaporated from the leaves of the plants; hence, keeping the immediate area cool.

Outcomes of Conclusion

In the process of observation and study of the green roof as compared with the bare roof on an existing structure, there were other variables, which affected the comfort levels in the room with the green roof above. Therefore, for the accurate performance of the Green Roof which couldn't be identified properly at this time, future research would consider the following:

1. Identical structures with same orientation and same fenestration, one with the bare concrete roof and other with the green roof would be constructed.
2. All envelope walls and roof would be insulated so as to prevent excessive outside heat transfer through wall and roof surfaces to properly detect heat conductance through the green roof.
3. The windows would be insulated glass.
4. More vegetation would be planted to increase shading and evapotranspiration.

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