Thermal performance of two vertical greenery system in warm sub humid climate

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ABSTRACT: The objective of this study was to investigate the cooling potential of two types of vertical greenery system: traditional system (direct) and double skin system (indirect) to minimize heat flow between the interior and exterior into experimental modules. The monitoring was performed for 30 days in two phases (with and without insulation roof) in two climatic seasons on a warm sub humid climate. The experiment was realized in three modules (one control and two experimental). The walls experimental modules were covered by climbing plant Parthenocissus quinquefolia. Its dimensions are 1:2 scale for allowable living space. Devices were installed into the modules for recording temperature and humidity. The results showed a greater decrease in the indoor temperature respect the exterior into the module with the indirect system compared with direct system. It is presumed that the existence of an insulating layer, the hot air below in the direct system bindweed reduces the flow of air, which in the case of indirect system does not. The differences in recording temperatures were the order of 0.7 to 2.6 ° C.
Keywords: Vertical greenery system, Indoor temperature and relative humidity, Warm sub humid climate

1. INTRODUCTION

The unstoppable urbanization currently generated largely by the migration of rural population to the cities, is causing the loss of large amounts of vegetation, and instead leaves concrete buildings and surfaces with high heat absorption rate, decreasing permeability of soils and lack of evapotranspiration in urban areas, which together contribute to the development of urban heat islands [1]. Furthermore, under conditions in which the temperature exceeds the limits of comfort, the population demands to cooling systems or mechanical heating rises considerably and therefore energy consumption. For this reason it is important to analyze and evaluate alternatives to reduce significant thermal loads in buildings.

The use of vegetation to cover walls in our cities is not new. The first example dates, back to the seventh century. C., with the hanging gardens of Babylon. During the fourteenth and sixteenth centuries belonging to the Renaissance, in haciendas and monasteries originated a "fashion" among owners and monks respectively to develop walls with fruit plants [2]. By the mid-twentieth century, arises a new interest in the use of vegetation, and this takes an important role as a support system in architectural sustainability [3], mainly by reducing the roof's exposure to solar radiation. The green walls were considered then as urban design elements to recognize the ease of being implemented and as a way to back green to the cities and also reduce air pollution [4]. Several studies have shown that the use of vegetation to cover walls help reduce the hot air flow between the inner and outer, as well as reducing the thermal load of the building [5, 6, 7].

2. VERTICAL GREENERY SYSTEM

When mention is made of green facades, green walls, living walls or vertical gardens, referring to surfaces that have vegetation on their walls. A name that may include all these names is that of Vertical Greenery Systems (VGS's), defined as the greening of the walls of the buildings through the use of plants, whether these are planted directly into the ground or by systems modular [2, 4, 8]. Table 1 shows a classification of VGS's where you can see the existence of extensive and intensive systems. This classification takes as main features the type of plant used and the way how it grows in the walls [9]. According to the classification made by Ottele, the traditional green system can be called direct system where vegetation directly uses the facade to grow to up. Furthermore, the double green skin facades can be called indirect system when vegetation being spaced from the facade by an air chamber.

3. EXPERIMENTAL METHODOLOGY

The research was conducted at the Faculty of Architecture and Design (FayD) of the University of Colima, located in the Municipality of Coquimatlán with warm sub humid climate in the State of Colima. We used three of the twelve experimental modules are there in the FAyD in their facilities. One module served as control and the other two were implemented both vertically vegetation types: direct and indirect systems as shown in Figure 1 and 2. The modules have a square base of 1.50 x 1.50 m outside and a height of 1.60 m. The wall thickness is 8.5 cm, consisting of a brick layer, cement-sand flattened and

Tab1e 1: Classification of Vertical greenery systems

Vertical greenery systems	Extensive systems		Intensive systems
Green facades	Traditional Green Facades (direct)		
	Double-skin green facade (indirect)	Modular trellis	
		Wired	
		Mesh	
			Perimeter flowerpots
Living walls			Panels
			Geotextile (hydroponis systems)

white paint outside. Floor and slab concrete 10 cm thick. In north orientation has an opening which performs the function of gate and whose dimensions are 0.50 m wide and 1.06 m high. Was used the climbing plant Parthenocissus quinquefolia to offer a lot of tolerance to water stress, the stress from wind and sun exposure.

Figure 1: Direct system development.

Figure 2: Indirect system development.

In the experiment used three HOBO's U12 four channels with an accuracy of ± 0.35 ° C for temperature and ± 2.5% for relative humidity that placed in the geometrical center of the interior of the modules, in order to obtain temperature data dry bulb and relative humidity. To record the environmental conditions of temperature and humidity outside was used a HOBO Micro Station model H21-002 and an intelligent sensor model S-THB-M002. All instruments were scheduled to record data every hour. The monitoring was conducted in two phases over 30 days of the certain seasons: in the first stage the roof was isolated for 15 days in the three modules with a polystyrene plate 1 ", in the second phase were removed polystyrene plate 1 ". Also the gates of the three experimental modules placed a polystyrene plate of the same thickness placed in the roof. Table 2 shows the dates of monitoring in each season. For this research we used the classification shown in Table 1, but only evaluated the first group called green walls in two of its three variants, corresponding to extensive systems: traditional green facades and green double skin facades. In the latter, the support system selected corresponds to modular trellis.

Table 2: Monitoring dates VGS's

Object of study	Humid warm season	Warm season
Direct and indirect systems insulated	4 – 18 September (2012)	5 – 19 January (2013)
Direct and indirect systems without insulated	24 September – 8 October (2012)	16 – 30 December (2012)

4. DISCUSSION OF RESULTS

4.1 Humid warm season

Table 3 contains maximum dry bulb temperatures (Tbs) recorded during fifteen days of monitoring for each of the phases. In both phases the double skin (indirect) had lower maximum temperature records, followed by the traditional (direct) and ultimately the control module. During insulated roof phase indirect system had the lowest record on September 12 compared to the direct system to make a difference of 0.7 ° C. In not insulated roof phase this difference

Table 3: Maximum dry bulb temperature in humid warm season.

Insulated roof phase	Direct system	Indirect system	Control module	Outdoor temperature	Not insulated roof phase	Direct system	Indirect system	Control module	Outdoor temperature
4 -l 8 de September, 2012	30.8	30.5	32.3	34.7	24 September - 8 October, 2012	34.2	33.1	35.0	34.6
	29.6	29.2	30.6	33.4		30.0	29.3	29.8	32.1
	28.5	28.1	29.5	32.8		29.3	28.2	29.6	33.0
	30.3	29.9	31.8	33.8		32.5	31.2	33.1	35.3
	28.8	28.4	29.4	31.3		29.0	28.1	28.9	30.3
	28.5	28.0	29.6	34.2		33.6	32.2	34.7	33.9
	28.6	28.0	29.6	33.5		34.8	33.5	36.0	34.8
	28.3	27.7	29.1	32.2		34.0	32.8	35.0	32.2
	27.5	26.8	28.6	30.8		32.4	31.1	32.6	30.8
	29.8	29.4	31.5	35.6		34.4	33.2	35.1	35.6
	29.4	29.1	31.0	34.2		34.8	33.5	35.2	34.2
	30.9	30.6	32.5	35.7		34.4	31.8	34.8	35.7
	30.4	30.2	31.9	35.4		35.2	33.8	35.4	35.4
	29.7	29.2	31.2	34.3		35.4	34.0	35.6	34.3
	28.2	27.7	29.0	32.2		35.7	34.2	35.8	32.2

increased to 2.6 ° C on October 5. When compared direct system against control module, the maximum differences are 1.7 ° C in the insulated roof phase, and 1.2°C during not insulated roof phase. If the comparison is between indirect systems against control module, the differences are 2.1 °C and 3.0 °C in the insulated roof phase and not insulated roof phase respectively. Figure 3 shows the graph of maximum Tbs record performance in both phases. In the insulated roof phase, control module, direct system and indirect system remains below the outside temperature records, getting a difference of 6.2 °C for the indirect system at September nine and thirteen. In the not insulated roof the situation above doesn't occur, because the direct system records higher temperatures than the outdoor temperature in five days, seven days in the control module and two days in indirect system. Figure 4 shows the behavior of the average temperature dry bulb time during the fifteen monitoring days in the three modules in two phases. In both phases, the indirect system has lower average temperatures records. Meanwhile the direct system in insulated roof phase recorded higher temperatures compared to the control module from 04:00 hours to 12:00 hours. In not insulated roof phase almost all hours, the data of direct system module temperatures are higher compared with the module control.

The largest dry bulb temperatures difference of the indirect system respect to direct system was 1.4 ° C during the not insulated roof phase, and 0.8 °C of difference obtained in insulated roof phase.

It is also possible to appreciate that with or without roof isolation, minimum temperatures recorded in the three modules are similar. But not with maximum temperatures because not in insulated roof phase temperatures are higher: direct system had an increase of 4 °C, 3.5 °C for indirect system and 3.3 °C the control module. Heat gain through the roof can be considered in this temperature which increases inside the space. Figure 5 shows the relative humidity behavior in the evaluated systems during insulated roof phase. It has an almost parallel behavior during 24 hours at an average day and always direct system remained below. This could be attributed to a better development of the plant used in the indirect system and also because of the insulated roof that did not allow the moisture concentration could dispel.

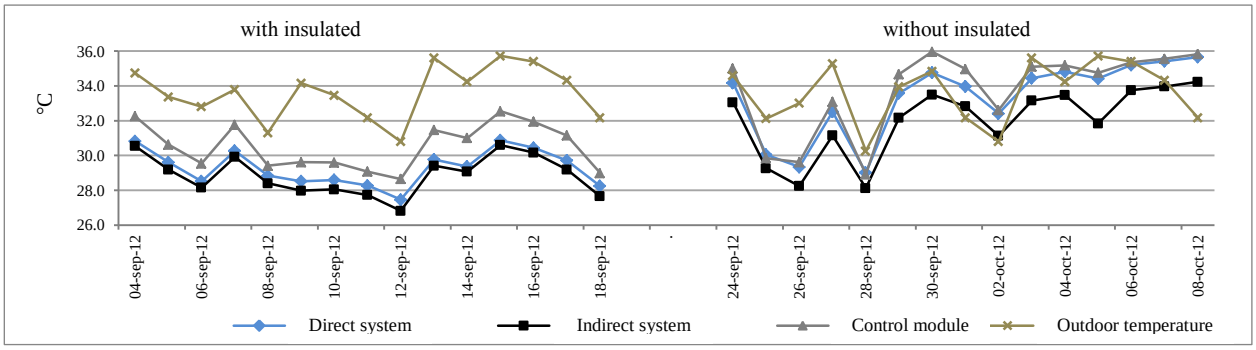

Figure 3: Maximum dry bulb temperature in humid warm season.

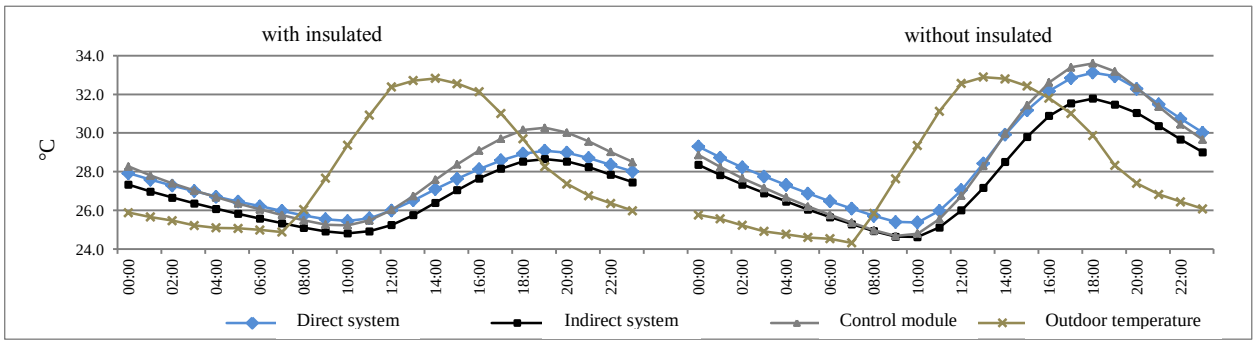

Figure 4: Average hourly dry bulb temperature in humid warm season.

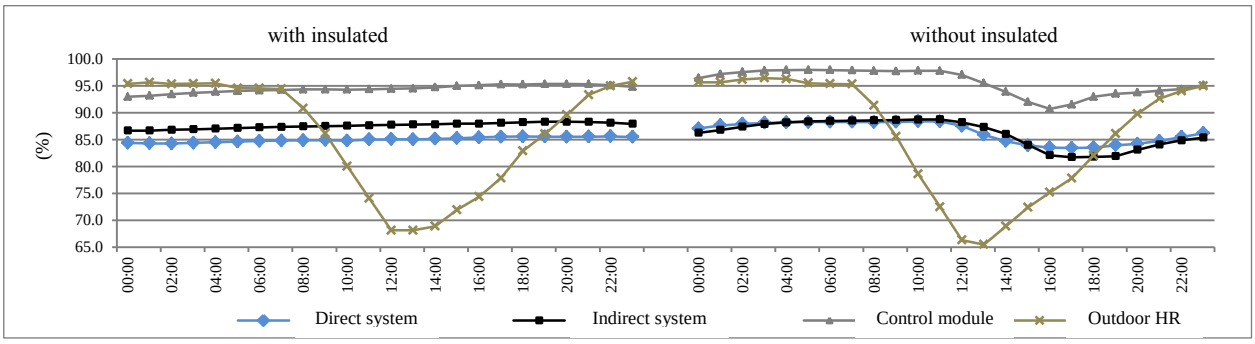

Figure 5: Hourly average relative humidity in humid warm season.

Although in not insulated roof phase, the behavior of relative humidity in both systems can be considered in parallel, although there is an alternation between the highest and lowest records in moisture percentages of evaluated systems. In the first four hours and in the last eight hours of an average day, the indirect system has lower values of moisture and in the remaining hours it is above the direct system. There is an alternation of 12 hours for each system. Vegetation systems help reduce moisture concentration compared to the control, but they have higher values on the outside.

4.2 Temperate Season

The maximum dry bulb temperatures recorded in this season are shown in Table 4. As in the warm-wet season, the indirect system registers lower records in the two evaluation phases. The differences between the indirect and direct system in insulated and not insulated roof phases were respectively 1.9 °C and 2.2 °C for the indirect system. During the insulated roof phase the direct system recorder a 0.8 ° C and indirect system 2.5 ° C, in comparison with the control module. Also comparing against control module and in the same order at the not insulated roof phase, reductions were 1.0 °C and 2.8 °C. The recorded data are shown in Figure 6. Is evident the difference between the recorded data to the indirect system compared with the direct one and the control module in both monitoring phases. Although the direct system remained less extreme high temperatures compared to the control module, they were not very representative.

This may be due to the decrease of develop of direct system plant in this season, and also because of their decreased growth and density. In some areas of the facades. The figure also shows the behavior of experimental modules compared to the outdoor temperature.

The behavior of the hourly average temperature is shown in Figure 7. The behavior was similar to the warm-wet season. Indirect system further improved the indoor temperature in both phases. The direct system remained the same alternating maximum temperature records with control model. From 23:00 hours to 10:00 hours direct system has higher

Tabla 4: Maximum dry bulb temperature in temperate season.

Insulated roof phase	Direct system	Indirect system	Control module	Outdoor temperature	Not insulated roof phase	Direct system	Indirect system	Control module	Outdoor temperature
5 -1 9 de January, 2013	30.8	30.5	32.3	34.7	16 - 30 December, 2012	34.2	33.1	35.0	34.6
	29.6	29.2	30.6	33.4		30.0	29.3	29.8	32.1
	28.5	28.1	29.5	32.8		29.3	28.2	29.6	33.0
	30.3	29.9	31.8	33.8		32.5	31.2	33.1	35.3
	28.8	28.4	29.4	31.3		29.0	28.1	28.9	30.3
	28.5	28.0	29.6	34.2		33.6	32.2	34.7	33.9
	28.6	28.0	29.6	33.5		34.8	33.5	36.0	34.8
	28.3	27.7	29.1	32.2		34.0	32.8	35.0	32.2
	27.5	26.8	28.6	30.8		32.4	31.1	32.6	30.8
	29.8	29.4	31.5	35.6		34.4	33.2	35.1	35.6
	29.4	29.1	31.0	34.2		34.8	33.5	35.2	34.2
	30.9	30.6	32.5	35.7		34.4	31.8	34.8	35.7
	30.4	30.2	31.9	35.4		35.2	33.8	35.4	35.4
	29.7	29.2	31.2	34.3		35.4	34.0	35.6	34.3
	28.2	27.7	29.0	32.2		35.7	34.2	35.8	32.2

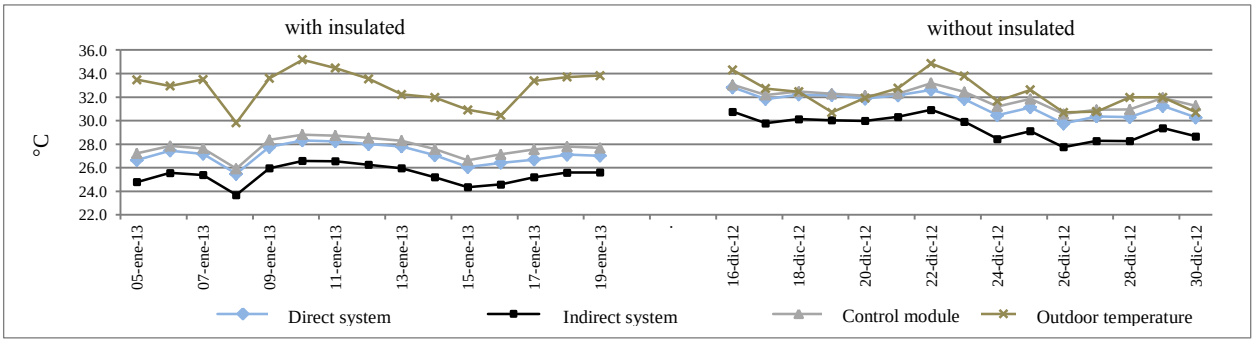

Figure 6: Maximum dry bulb temperature in temperate season.

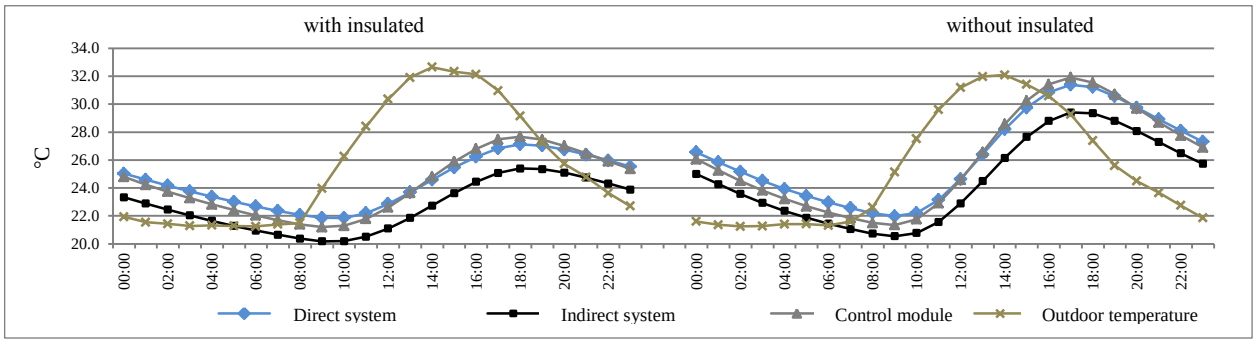

Figure 7: Average hourly dry bulb temperature in temperate season.

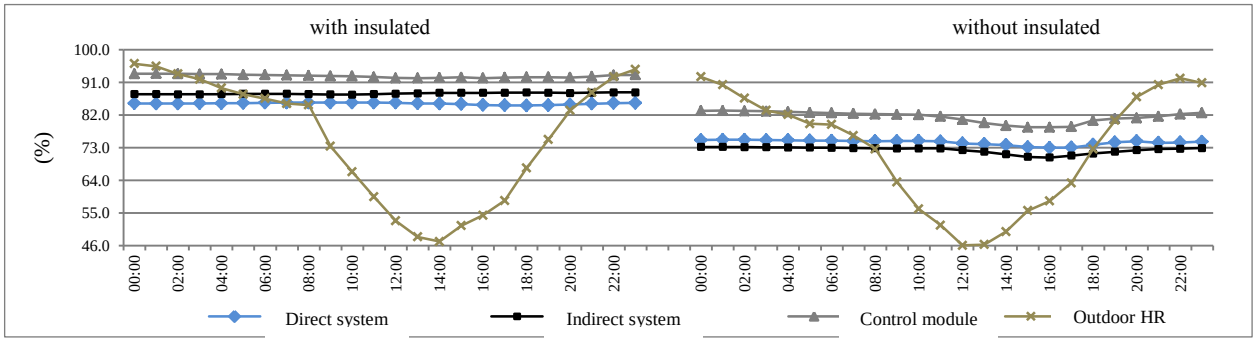

Figure 8: Hourly average relative humidity in temperate season.

temperatures. In the hours following the control module that recorded higher temperatures. This suggests that the air contained under the foliage of the plants works as trap decreasing the heat loses because of the radiative cooling of wall during night. This does not happen in the indirect system, because the gap between the facade and vegetation allow air circulation. In the insulated roof phase a thermal reached of five hours was obtained and three hours in not insulated roof phase. Regarding the relative humidity results are shown in Figure 8. In the insulating roof phase the direct system records with children and the not insulated roof phase was the module with the indirect system which recorded lower percentages. Although in both cases is accomplished a reduction humidity in the modulus control, in hours of afternoon the humidity is far superior to the registers from the outside.

5. CONCLUSIONS

The results support the use of vertical greenery system to improve the conditions of temperature inside the buildings. Indirect system performed better behavior compared to direct system, but both are able to decrease the temperature inside the experimental modules. For maximum dry bulb temperature the greater difference in favor of indirect system took into not insulated roof phase in warm humid season to 2.6 ° C. In the warm season the difference was 2.2 ° C on the stage again without isolation.

The best system performance of indirect system can be attributed to a distance between the façade of the module and the vegetation, as it allows ventilation through the façade improving exchange between the cattle heat during the day and the outside. The direct system creates an insulating layer within the plant foliage thus maintaining higher temperatures at night and low during the hours hottest in the day. Insulate the roof improves temperature conditions inside the space, and even if it has a higher concentration of moisture, this can be slow to allow ventilation of the space, which in this research was not done. It is important to make measurements in habitable space to check the scope real of the evaluated systems.

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