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Thermal Response to Heat in Buildings with Green Covers for Tropical Climate: Green Facades and Green Roofs

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Abstract: The main aims of this paper were to study and demonstrate the benefits the plant systems can provide indoors in a critical heat day. This study proposed an experimental method to try to understand the thermal response to heat of four different systems: a prototype called control (no vegetation) and three with different combinations of vegetation (green roofs and green facades) installed in a tropical climate region. The experiments were developed in four test cells with dimensions 2.0 m × 2.50 m × 2.71 m. Measurements of internal surface temperatures and internal air temperatures were collected with the use of specific equipment, a data logger (CR1000, Campbell Scientific Inc.), connected with two multiplexers 32 channels (416AM Campbell Scientific Inc.). Data were recorded over a year and a critical day heat was selected, which was September 24, 2015.The results show that the use of plant systems in buildings establishes a passive technique in reducing energy consumption because of the high incidence of summer solar radiation which is reduced and simultaneously, it maintains thermal internal conditions more pleasant than external ones, because of the best thermal behaviour, which was observed in the test cell with vegetation on both roofs and facades. The biggest difference between maximum internal air temperatures registered was 2 °C.

Key words: Green facades, green roof, thermal comfort, bioclimatic architecture.

1. Introduction

Green spaces provide essential ecological values for the city, such as species richness, as well as bring social and cultural values, as they have also a direct impact on the welfare, health, beauty, culture and the ability to form social relationships. This article has been developed in order to provide a new sustainable strategy linked to the use of vegetation in buildings in a tropical climate.

The existence of vegetation in urban areas, such as in building covers, can improve urban microclimate as well as the local climate of cities. Studies show that there is a significant potential to reduce temperature areas where the urban canyon occurs, reducing these values to a maximum of 13 °C [1].

According to Hoyano [2], one of the pioneers in this area, the calorific energy through a concrete wall is significantly less if it is covered with vegetation. Besides, through evapotranspiration, a sizeable amount of solar radiation is converted into latent heat, which prevents the temperature to increase. A facade completely covered with vegetation can protect from intense solar radiation summer, because of their leaves absorption and reflect up to 80% of the radiation received, depending on the amount and type of vegetation [3].

According to the literature reviewed, the use of vegetation in facades gives greater benefits in cooling for hot and dry climates [4]. The use of green facades for cooling environments has been studied in several cases, for example, a study with living wall systems in China, presented a reduction of surface temperature by a maximum of 20.8 °C, and interior wall by 7.7 °C [5].

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Surface temperatures of vertical greenery systems have been analysed in most of the paper revised, and the results have demonstrated that areas with vegetation are cooler than brick areas. In Japan, experiments show that climbing plants can reduce surface temperatures where the plants grow, south-western orientation [2]. In Africa, a temperature reduction of 2.6 ºC was observed with vegetated panels of climbing plants [6]. Most of the studies focus the research on surface temperatures, showing temperature differences between surfaces with and without vegetation. Nevertheless, according Hunter et.al [7] that conducted a critical review with green facades and thinks most studies are comparisons between temperatures of the exterior surface of the walls, which show very little about energy demand. In his review, it is further suggested to consider air temperatures and other parameters. Studies which contemplate the use of vegetation in both facades and roofs were not found.

This paper proposed the study of vertical gardens and green roofs in tropical climate for a critical heat day, showing experimental results of four test cells in which internal surface temperatures were measured, as well as the internal temperature of the air, to further subsequently a comparative study between cells with and without vegetation. Final results verify the potential of vegetation in terms of internal heat losses, since that reduction is one of the most useful actions in the sense of improving interior comfort conditions.

2. Materials and Methods

The experiment was conducted in the Water Resources Center and Applied Ecology, a research center linked to the Department of Hydraulics and Sanitation, School of Engineering of São Carlos, University of São Paulo in the period of a year, from June 2015 to nowadays.

In the experiment, four experimental cells were used, where the facades plants were placed (N and W) and on the roofs. Table 1 describes the structure of cells used for the experiment.

IST (internal surface temperatures) data and DBT (dry bulb temperature) were measured by the thermocouples installed in the test cells set at intervals of 30 s and were aggregated on the hourly average. The data of solar radiation and other climatic variables were recorded by the automatic weather station of the CRHEA (Centre of Hydric Resources and Environmental Studies).

To obtain the results, this study was based on the analysis of a critical heat day, it is defined as a day registered, as an exceptional climate form, a maximum temperature higher than the absolute maximum temperatures in the historical data series registered in Normais Climatológicas 1961-1990 [8].

The data were measured by thermocouples installed on the facades (north and west) and roofs of the four test cells for the period from September 21 to September 25, 2015.

2.1 Localization and Characterization of the Study Area

This project was developed in Itirapina—Spin the margins of the Lobo reservoir, at 733m altitude above sea level (Fig. 1). It is an area of difficult climate classification because of the climate origin of actions, so it may be said that, it is a region in transition polar weather systems and inter-tropical.

Table 1 Summary of test cells types used.

Construction	Location of vegetation
Control cell test: CC (control cell)	Without vegetation
Cell Test 1: GFC (green facades cell)	Green facades (north and west)
Cell Test 2: GRC (green roof cell)	Green roof
Cell Test 3: GFGRC (green roof and green facades cell)	Green roof + green facades (north and west)

Fig. 1 Location of the study area.
Source: own composition.

Fig. 2 Panoramic experimental cells. View from a drone.
Source: Eduardo Fraccaroli, 2015.

Fig. 3 View of green façade.
Source: own composition.

It is located in an area considered tropical altitude, according to the International Classification of Köppen, which corresponds to a Cwa climate, which is characterized as a hot weather and dry winter, in which the average temperature of the coldest month is less than 18 °C and the hottest months exceed 22 °C [9]. Fig. 1 shows the area under study.

The dimensions of the test cells is 2.0 m × 2.50 m × 2.71 m, and its groundwork of cement and sand mass done, and its walls are made of solid bricks, with dimensions 10 cm × 20 cm × 5 cm, gasket placed 1.5 cm thick. All cells have wooden doors with east direction and size of 2.10 m × 0.60 m as well as, a window also of wood, orientated to the north, measured standard with 1.00 m × 0.70 m, as shown in Figs. 2 and 3.

The test cells were designed with the same orientation, so that they receive equal solar radiation, wind and other atmospheric events. This allows the climatic conditions to act simultaneously and at the same intensity in each cell, as shown Figs. 2 and 3. Also, they do not create shadow zones among them.

2.2 Construction System and Development of Green Facades and Green Roofs

Green facades were installed in the north and west because they are those that receive more sunlight hours. They consist, basically, of a metal hexagonal mesh of 2.40 m wide by 3 m high, and anchor to the ground and facades by hooks. The solution adopted was one that did not maintain direct contact with the wall, so it was decided to set up it at an angle of 30º to the top of the wall.

After placing the necessary mesh to enable upward growth of the plants and cover the entire surface of the facades, a *Thumbergia Grandiflora*, part of the

Acanthaceas's family was sown at the bottom of the mesh, directly on the ground. This plant is a great low-maintenance vine from tropical and subtropical areas of the world. It is herbaceous and includes within *Acanthaceae's* family, twining, dark green and simple, opposite and whole green leaves. *Thunbergiagrandiflora* is commonly known as blue Tumbergia (Fig. 4 (A and B)), blue trumpet vine, blue Bignonia [10].

Plants' annual cycle and their growth are two important components to ensure the role of plant facades. Despite the consequences of working with living beings, plants are still in fairly constant cycles in relation to development. However, these guidelines are specific species and depend on the climate in which the plant is located [11].

Green roofs were concreted in situ, through a pre-moulded ceramic slab with concrete beams, a slope of 23% and parapets ceramic brick with size of 0.40 m, to receive the substrate, as a shown in Fig. 5, the set of the green roofs is composed by a slab, a waterproof layer, drainage blanket, substrate and vegetation.

2.2.1 Vegetation/Grass

Paspalum notatum grass was used as vegetation to cover the green roofs (Fig. 6). It is a native grass of the American continent; it is known in Brazil as the Batataisgrama, grass-forquilha, grama-mato-grosso, grama-de-pasto and grass-common [12].

This type of vegetation has leaves concentrated in the basal part of the plant. One advantage of the structure is the ease of coating, forming large mats, and the protection it brings to the soil against erosion [13]. It is a species able to adapt to poor soils, water deficit conditions and the resistant to the action of sunlight and treading. Although it needs to be cut frequently to maintain good quality [14].

2.2.2 Automatic Measurements

Each of the prototypes is made up of 15 T-type thermocouples 2 × 24 AWG (American Wire Gauge), as shown in Fig. 7. Thermocouples are characterized as a very precise instrument. The temperature can be measured with an error of ±0.1~0.2 °C [15]. The measurements were used to study the thermal behaviour. For this reason, there were located 64 thermocouples, 16 per constructive elements, 15 (for each test cell) measuring surface temperatures and a thermocouple was placed at the geometric centre of

Fig. 4 Plants used (A: plants growth on wire meshes ; B: *Thunbergia Grandiflora'* flower detail).
Source: own composition.

Fig. 5 Profile of green roof.
Source: own composition.

Fig. 6 Detailgrass. Grama Batatais—forquilhaspecies.
Source: own composition.

each test cell at a height of 1.20 m approximately, to carry out measurements of the DBT, as the ABNT NBR 15575-1 Standard [16] referred to in Annex A.

The registry data were set at intervals of 30 s and were aggregated at the hour. Data is stored in a data logger (CR1000, Campbell Scientific Inc.), connected with two multiplexers 32 channels (416AM Campbell Scientific Inc.). The battery is powered by a solar panel that ensures autonomous equipment.

Fig.7 shows the thermocouples' distribution.

2.3. Comfort Limits Calculation

Comfort limits were obtained from the following Eqs. (1) and (2) [18]:

$$\text{Upper 80\% acceptability limit} = 0.31T_{pma(out)} + 21.3 = 28\ ºC \quad (1)$$

$$\text{Lower 80\% acceptability limit} = 0.31T_{pma(out)} + 14.3 = 21\ ºC \quad (2)$$

where, $T_{pma(out)}$ corresponds to average daily temperatures of the last 15 days. The comfort temperature is located in the middle of the comfort range.

In addition, it was quantified the total of degrees hours of discomfort by the adaptive method indicated by ASHRAE-Standard 55-2013 (American Society of Heating, Refrigerating and Air-Conditioning Engineers). This methodology sets the limits of comfort for each day of the year, both 80% and 90% of people satisfied in naturally ventilated buildings.

To quantify the degree hours of discomfort was necessary to compare hourly the temperature limits (upper and lower) and the operative temperature in each test cell. Grades hours of discomfort are generated when the internal temperature exceeds the limits set by the standard, with positive numbers for heat and negative numbers for cold, as shown in Fig. 8.

3. Results and Discussion

3.1 Climate Analysis of the Experimental Critical Heat Day, September 24, 2015

Under the climate perspective used in this work, the experimental critical day was defined considering dominant atmospheric state in the testing period. It was used as a reference by the Normais Climatological 1961-1990.

According to Vecchia [19], to do a more accurate climate estimate, a climate analysis can be made using representative episodes or observation periods of clime types, that is, studying the intensity and duration of each air mass domain on a particular place, related to the atmospheric circulation's phenomena.

From a point of view of the dynamic climatology, Itirapina is characterized as a region of passage of cold fronts pass throughout a year. The domain of the

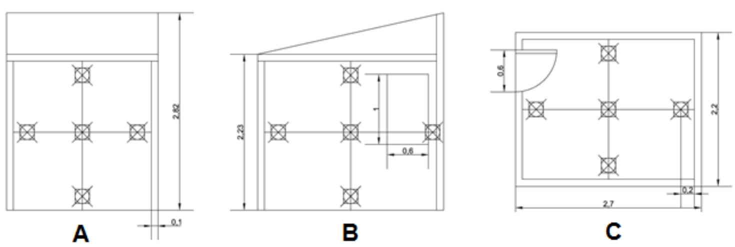

Fig. 7 Distribution of thermocouple type T (Copper-Constantan) (A in west facades, B in north facades and C on roofs).
Source: own composition (unscaled).

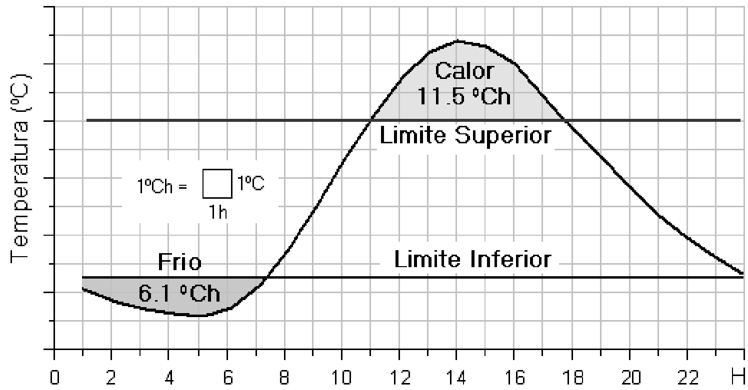

Fig. 8 Degrees-hour discomfort.
Source: Ref. [17].

acting masses in the region can be divided into two main stages, pre-frontal and post-frontal, which are then subdivided into two other stages, harbinger and advance, which happen before the penetration of the MPA (Polar Atlantic Mass) with war features.

Afterwards there will occur domain and transition phases, where the MPA imposes weather conditions with cold features and sometimes wet features [20].

This classification is beneficial because, according to the requirement of analysis climate facing thermal behaviour, it can decide the most appropriate stage to conduct experiments [21]. Data from external climatic variables used in this experiment from the day in question, were collected by the Climate Station of the CRHEA of the School of Engineering of Sao Carlos (EESC-USP).

This study case was considered to analyse the episode from September 21 to September 25, 2015, days when the north-west region of the state of São Paulo was on the domain of a mass of hot and dry air. In Fig.8, a climatic analysis of the selected day is shown.

The day September 24, 2015 (critical heat day) was taken as a reference day for the study of behaviour and thermal performance of four test cells equipped with green facades and green roofs, due to its characteristic of remarkable warmth (Fig. 9), exceeding the value of 35.8 ºC, that is, it exceeds the value which corresponds to average maximum recorded in the historical series of São Carlos for that period, which was 27 ºC. The thermal amplitude recorded that day was 23.3 ºC, being that a minimum temperature of 15.12 ºC and a maximum temperature of 35.8 ºC, as it was told above. The day was clear, with solar radiation values reaching 859 W·m^{-2}.

3.2 Experimental Test: Analysis of the Thermal Behaviour (Internal Air Temperature) and Thermal Performance (Internal Surface Temperature) of the Test Cells

The thermal behaviour of the indoor environments studied, can be analysed by Fig. 10, in which it can be observed that when the maximum external temperature reaches 35.8 ºC, the highest value recorded in the period in the afternoon (15:00 p.m.), the value of the internal temperature in this day, ranged from 29.6 ºC at 18:00 p.m. in the cell made of conventional materials, ceramic brick wall and ceramic tiles roof (control cell).

The second record highest temperature was in the cell built with green roof with a value of 29 ºC at 18:00 p.m. The test cell equipped with green facades in the north and west walls has the third highest value of temperature, 28.52 ºC at 18:00 p.m. Finally, the cell with green facades and green roof, provided the value of the lowest temperature up to 27.5 ºC at 18:00 p.m. There is a thermal delay in all test cells of 3 h as it is shown in Table 2.

In Fig. 10, it is seen that at dawn, around 6:00 a.m., when air temperatures are lower, in treatment with

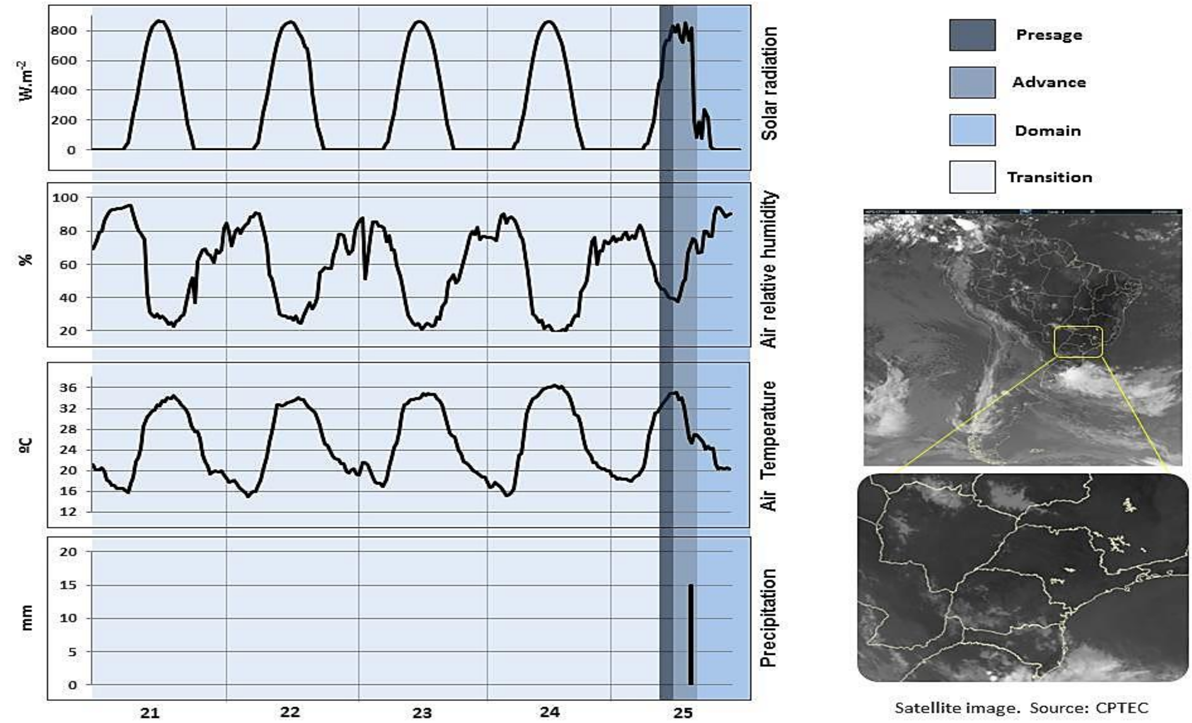

Fig. 9 Climate analysis. Episode 21-25 September 2015.
Source: own author.

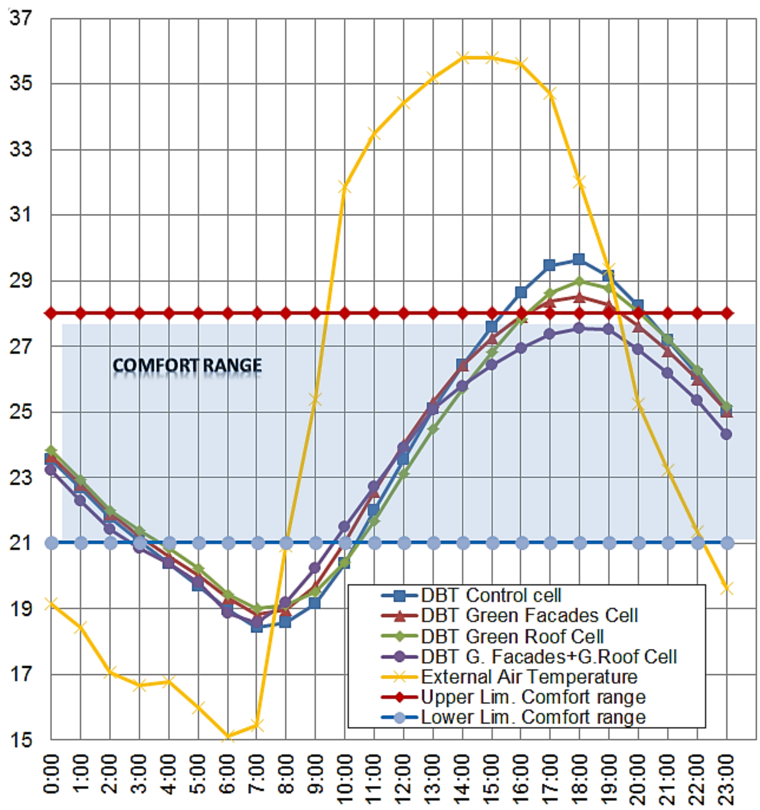

Fig. 10 Internal air temperature of test cells vs. external air temperature.

Table 2 Thermal delay and thermal amplitude in internal air temperature.

	CC	GFC	GRC	GFGRC
External air temperature 35.8 °C (15:00 p.m.)	29.62 °C (18:00 p.m.)	28.52 °C (18:00 p.m.)	29 °C (18:00 p.m.)	27.5 °C (18:00p.m.)
Thermal delay (h)	3 h	3 h	3 h	3 h
Thermal amplitude (°C)	11.2	10	10	8.9

Table 3 Degrees—hour discomfort to heat and cold.

Grades hours of discomfort		
Cases	Heat	Cold
DBT CC	4.98	-11.48
DBT GFC	1.11	-8.66
DBT GRC	2.39	-8.53
DBT GFGRC	0.00	-9.21

vegetation, both wall and roof, there is no significant differences in the internal air temperature recorded, as in the day of the experimental, the temperatures are near 19 ºC. However, it is noted that when the value of external air temperature is lower, 15 ºC at 6:00 a.m., and the value of the internal temperature is significantly higher; there is a difference between them of about 4 °C.

Regarding the thermal amplitude (Table 2), we see that the highest values recorded in the cell constructed with conventional materials (11.2 ºC) and the lowest in the cell that has green walls and green roof (8.9 ºC), which shows most appropriate thermal behaviour with the use of vegetation.

Observing Fig. 10, in the early hours of the day, we can see that within the limits of thermal comfort calculated as indicated by the ASHRAE Standard [18], from 4:00 a.m. until 10:00 a.m., all the cells in test are in discomfort to cold. From 4:00 a.m., all cells are within the thermal comfort range, up to 15:00 p.m., where all come into heat discomfort, except cell equipped with green facades and green cover, located within the limits of thermal comfort throughout the evening period. In Table 3, the degrees—hours heat and cold calculated for the critical day experimental heat, are shown.

The comparison between the four test cells studied could be concluded: the cell test with green facades and green roofs has the highest thermal performance compared to other cells in response to heat, which takes between 14:00 p.m. and 16:00 p.m. in the evening period. The difference between this cell (green facades + green roof), which recorded 27.6 ºC, band solid brick and ceramic tiles cell test, which recorded an internal air temperature of 29.62 ºC, was approximately 2 ºC.

Therefore, it can be defined that the natural thermal conditioning depends; firstly, on solar radiation and external air temperature, and so, according to Ref. [22], the feeling of comfort can be evaluated through the skin because its temperature is between 33~34 ºC, that is, if the atmosphere temperature is well above or well below this value, the feeling will probably be of discomfort thermal.

3.3 Thermal Performance Analysis (Internal Surface Temperature)

The thermal performance study is involved to analyse the different temperatures of facades and roofs, at different points, and compare them between four test cells, one built with conventional materials (ceramic tile and ceramic brick), one with a green roof, other with green facades (north and west) and the last one with green facades (north and west) and green roof.

3.3.1 Internal Surface Temperature of the North Facades

Fig. 11 shows surface temperatures of the north facades of the four test cells to compare their thermal performance.

Regarding the thermal performance of north facades, two main points are noted on the graph of internal surface temperature, arranged above in Fig. 11. Firstly, the thermal delay is observed. The highest thermal delay (4 h) was registered in the test cell which has

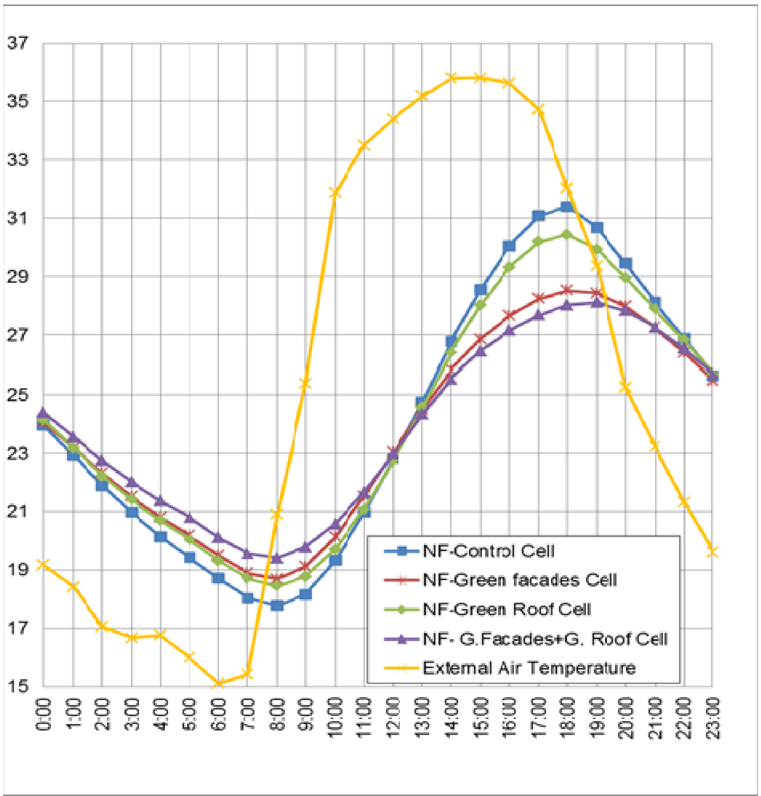

Fig. 11 Internal surface temperature of the north facades of each test cells vs. external air temperature.

Table 4 Thermal amplitude in north facades.

Thermal amplitude (ºC)	CC	GFC	GRC	GFGRC
North facades	13.6	10	11.9	7.2

green facades and green roof (28.1 ºC at 17:00 p.m.) and the lowest value of thermal delay (3 h) was recorded in the north facade of the control cell, that is, the one built with conventional materials.

The test cells with green facades have a thermal delay of 3 h, as well as test cell with green roof, they displayed 28.5 ºC at 18:00 p.m. and 30.4 ºC at 18:00 p.m., respectively. Furthermore, it can be analyzed the concept of thermal amplitude, the difference between maximum and minimum temperatures recorded which are shown in Table 4. The lowest amplitude, and therefore, the best performance occurs in the cell with vegetation on both facades and on walls (7 ºC).

In the analysis of surface temperatures of the test cells, Fig. 11 can be observed that in the hours where there are lower temperatures, although the differences between the minimum temperatures are low, there is a difference recorded about 2.5 ºC between the control cell (conventional material) and the cell with green facades (N and W) and green roof. Regarding the internal surface temperature and the external air temperature, it is noted that there is a thermal delay of about 4 h and a difference of 2.5 °C between internal surface temperature of control cell and the green facade and green roof cell. The peculiarity is appreciable that when all temperatures are 23 °C at 12:00 p.m.

In the vespertine period, the highest value recorded for internal surface temperature corresponding to 31.5 °C at 18:00 p.m. in the control cell, indicating a thermal delay of 6 h and amplitude of about 5 °C in relation to the external air temperature. It is worth noting that 31 °C is pretty close to 33º C, which Docherty and Szokolay [22] considered as an upper temperature limit, it generates an unpleasant wind chill.

Therefore, when the test cell with green facades and

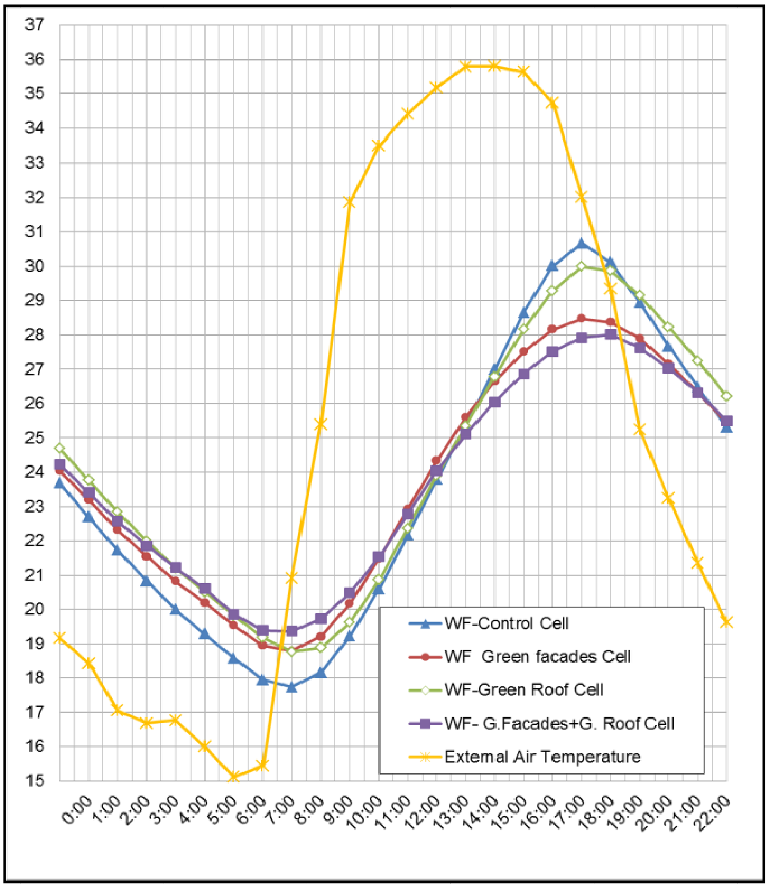

Fig. 12 Internal surface temperature of the west facades of each test cells vs. external air temperature.

green roof is compared with other systems, it presents the best thermal performance, since it has the smallest thermal amplitude (7.2 ºC) as Table 4 shows. Furthermore, the north surface temperatures contribute to thermal behaviour providing energy at night (as it remains higher temperatures than internal air temperature).

3.3.2 Internal Surface Temperature of the West Facades

Fig. 12 shows the internal surface temperatures of the west facade to proceed with its discussion. It is

shown that in the early hours of the day, although the thermal behaviour of all cells is quite approximate, it can be appreciated a significant difference between the test cell constructed with brick and ceramic tile, in which was registered a temperature of 17 ºC at 7:00 a.m. and the test cell with green roofs and green facades, which has a minimum temperature of 19.4 ºC at 7:00 a.m.

In the afternoon period, the behaviour is reversed to record the highest temperatures in the test cell constructed with conventional materials, 31 °C at 17:00 p.m., and the lowest temperature in the cell with green walls and green roof, 28 °C at 18:00 p.m. That is, a difference of temperature of 3 ºC and a thermal delay of 1 h.

The western surface temperature of this cell is followed by the temperature of the cell with green facades, which showed a temperature of 28 °C at 17:00 p.m., that is, a difference in the cell control 3 ºC. In this case, there is no thermal delay. Finally, the cell with green roof, presents the highest temperature after the control cell with a record of 30 ºC at 17:00 p.m., similar to the cell of brick and ceramic tile behaviour, being that, in this case their facades are devoid of vegetation.

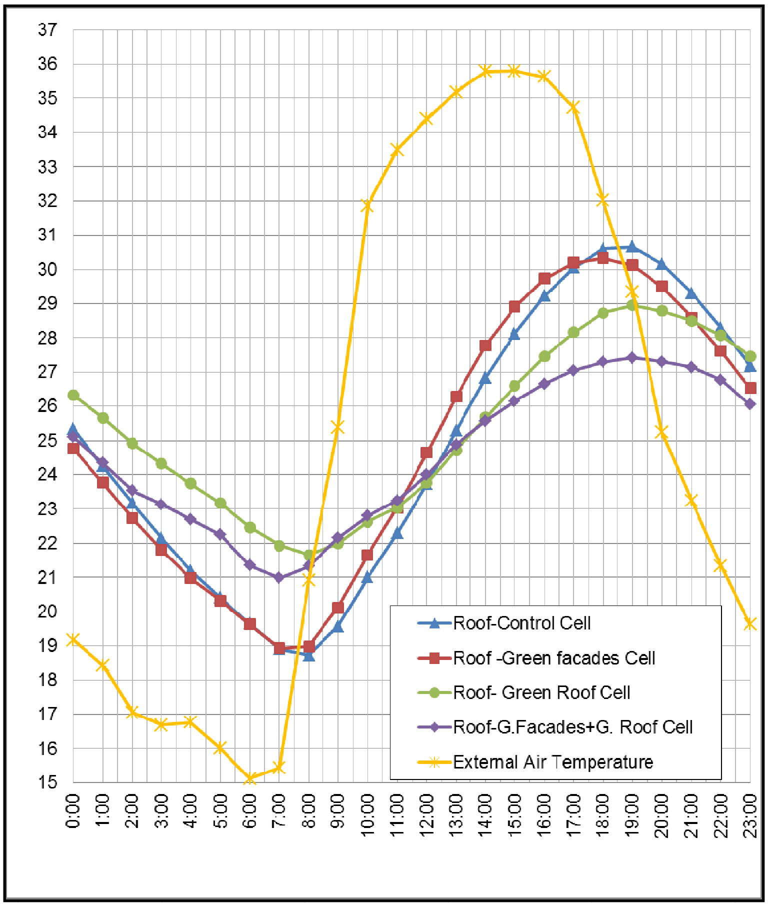

Fig. 13 Internal surface temperature of the roofs of each test cells vs. external air temperature.

Table 5 Thermal amplitude in west facades.

Thermal amplitude (ºC)	CC	GFC	GRC	GFGRC
West facades	13	9. 7	11.2	8.6

Table 6 Thermal amplitude in roofs.

Thermal amplitude (ºC)	CC	GFC	GRC	GFGRC
Roofs	12	11.3	7.2	6.4

Thermal amplitudes in west facades are contemplated in Table 5, where it shows the lower amplitude were registered in green facades and green roof cell, 8.6 ºC.

3.3.3 Internal Surface Temperature of the Roofs

The following Fig. 13 shows the evolution of internal surface temperatures of the four roofs along the analysed period.

Thermal amplitudes in roofs are contemplated in Table 6, where it shows the lower amplitude were registered in green facades and green roof cell, 6.4 ºC.

During the first hours of the day, when the lower external temperatures are recorded (15ºC at 6:00 a.m.), it is noted that, two of the cells whose roofs were constructed with ceramic tiles show the lowest temperatures, such as the cell with green facades, with a minimum recorded temperature of 19.6 ºC at 6:00 a.m., as in control cell.

However, the two cells built with green roof, present the highest superficial temperatures, although this difference does not exceed 2 °C. Nevertheless, there is a difference between external temperature and internal surface temperature of test cells equipped with vegetation on their roofs, approximately 7 °C.

Therefore, it can be concluded that, vegetation works as thermal insulation, because when the lowest outside temperatures are recorded, the highest internal temperatures remain.

In the evening, when the highest temperatures were recorded, the highest one was observed in the test cell constructed with conventional materials (30.6 ºC at 19:00 p.m.), it is followed by test cell equipped with green facades (27.4 ºC at 19:00 p.m.). There is a difference between them 3 ºC approximately. Instead, the lowest temperature occurs in the test cell with green roof and green facades (24.7 ºC at 19:00 p.m.), followed by the cell with green roof (28.9 ºC at 19:00 p.m.).

So it can be concluded that vegetation with shadow effect, prevents the overheating of indoor environments, since when the highest external temperatures are recorded, the lowest internal temperatures remain.

4. Conclusions

The use of vegetation in building facades and roofs is a bioclimatic method which, as this paper's results demonstrated, can entail many benefits, among them, thermal benefits.

Comparing internal air temperatures to external air ones, it is observed that the maximum values for cell without vegetation are within the limits of discomfort. Likewise, it is noticed the highest thermal amplitude observed is found in the test cell constructed with ceramic solid brick and ceramic tile. Instead, it can be appreciated that the lowest thermal amplitude, the difference between the maximum temperature and the minimum temperature recorded, occurs in the cell with green facades and green roof.

The jet lag between the maximum and minimum temperatures is called thermal delay. It is said that a material has more or less thermal inertia, as higher or lower is thermal delay and its thermal damping. The thermal delay in any of the studied cases has exceeded 1 h.

The cell in which green facades were installed in north and west facades, recorded a temperature of 29.6 ºC and the cell with green roof registered 29 °C, both cells are below to the upper limits thermal comfort, despite having higher values than the option with green facades and green roof (27 ºC).

In the period when higher external air temperatures were registered, the test cell with green facades and green roof has minor variations. The major thermal amplitudes are recorded in the control cell. The biggest differences between internal maximum air temperatures presented between the cell built with conventions material and the cell which has green walls and green roof, 2 °C.

The internal temperatures of surfaces with vegetation, both in facades as in roofs, remain more resistant to daily temperature variations. The biggest difference between the internal surface maximum temperatures recorded, it was occurred between north facades, with a value of 3.3 ºC.

Using plants in building, both walls and roofs, may have important benefits against excessive heat gains caused by solar radiation, as vegetation prevents the penetration of this, by its ability to generate shadow so that reduce heat gain by both conduction and radiation into buildings. It can aver that it can prevent the heat received due to the effect of radiation in 3 ºC, (both in facades and roofs). This is because the impact of direct radiation is avoided and simultaneously the temperature of air adjacent to the wall is reduced.

The use of vegetation in building covers can increase thermal resistance value and it can be derived in energy cost savings, in both heating and cooling, which leads to a reduction of greenhouse gas emissions. Finally, it is noted that the use of vegetation in architecture is a viable technique with several possible uses for the kind of climate studied, which contributes, not only to environmental benefits, but also to provide internal thermal benefits which can improve the thermal comfort for occupants.

Acknowledgments

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