Testing the performance of a green wall system on an experimental building in the summer

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ABSTRACT: It is known that a green wall brings some advantages to a building. It constitutes a barrier against solar radiation, thus decreasing and delaying the incoming heat flux. The aim of this study is to quantify such advantages through analytical comparison between two facades, a vegetal facade and a conventional facade. Both were highly insulated (U-value = 0.3 W/m^{2}K) and installed facing south on the same building in the central territory of Spain. In order to compare their thermal trend, a series of sensors were used to register superficial and indoor air temperature. The work was carried out between 17th August 2012 and 1st October 2012, with a temperature range of 12°C-36°C and a maximum horizontal radiation of 1020 W/m^2. Results show that the indoor temperature of the green wall module was lower than the other. Besides, comparing superficial outdoor and indoor temperatures of the two walls to outdoor air temperatures, it was noticed that, due to the shading plants, the green wall superficial temperature was 5 °C lower on the facade, while the bare wall temperature was 15 °C higher. The living wall module temperature was 1.6 °C lower than the outdoor, while the values of the conventional one were similar to the outdoor air temperature.
Keywords: Green wall; Experimental building; Comparative analysis; Summer performance.

INTRODUCTION

Green systems carry out important functions in environmental control. The green is a living system and it is able to absorb the incident solar radiation on the leaves, assimilating one part for the photosynthesis and dissipating the other in the atmosphere. For this reason, they are also called living walls. In the summer the leaves prevent rear overheating, thanks to the double effect of shading and evapotranspirating. [1]. In winter the green layer contributes to the insulation of the enclosure [2]. There are different types of green walls, made of plants that directly stick to the wall, as the ivy, or to a vertical support made of nets and stainless steel cables. Another type of green system uses a panel whose interior is divided into cells where the substrate is placed. The panels are modular and they are anchored to the wall through a light support structure, covering a whole facade [3].

The aim of the study is both to quantify thermal advantages brought by a vegetal facade system inserted in a highly isolated enclosure in comparison to a conventional system and to check if the latter has also these kinds of advantages.

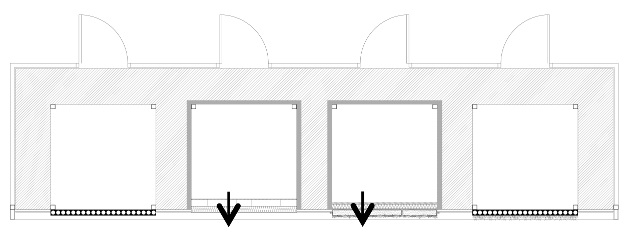

Figure 1. Experimental building plan

DESCRIPTION

Two kinds of facade were analyzed, a vegetal one (V.F.) and a conventional one (C.F.). They were installed facing south on an experimental building in Colmenar Viejo (Spain), with latitude 40°39'15.94"N and longitude 3°45'24.83"O. This town has a Mediterranean-continental climate. The average temperature in July is 23.6 °C with relative average daily solar radiation of 7.6 kWh/m^2. The average temperature in January is 4.7 °C with relative average daily solar radiation of 2.2 kWh/m^2 [4]. The south facade was divided into four modules. We analyzed the two middle modules. Each of them was 1.8 m wide and 2.4 high and they had an adiabatic space of about 3 m2 at the back (Fig. 1). Both facades had 8-10 cm a thermal insulation. Thermal

transmittance of the bare wall was 0.315 W/m^2K and that of the green wall was 0.12 W/m^2K. The green facade was made of 600mm x 600 mm panels with felt layers containing nutrients for the plants. There was also an irrigation system that conveyed exceeding water to the panels base (Fig.2), while the conventional wall only had a white polyethylene sheet on the external surface (Fig. 3).

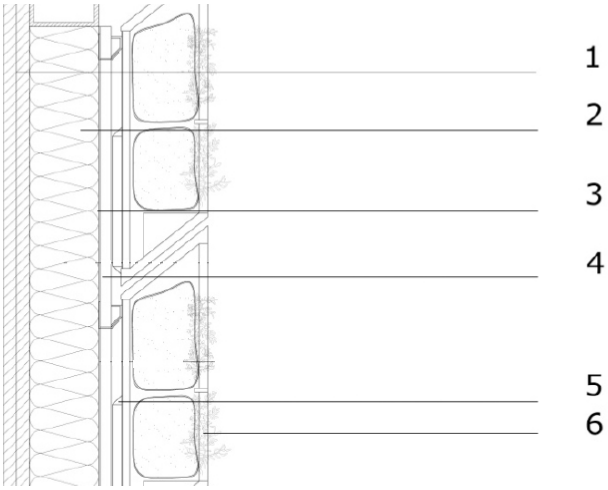

Figure 2. Vegetal Facade System section

1. Boards of laminated plaster s= 15 mm
2. Insulating s= 80 mm
3. Impermeable sheet s= 1.8 mm
4. Cement plates s= 12.5 mm
5. Brackets
6. Modules prevegetados

METODOLOGY

Data were collected from 15th July 2012 to 30th September 2012 thanks to a series of resistance thermometers, but the vegetal wall was positioned on 17th August 2012. Four of the eighteen used sensors were selected in this study, which were those used to measure indoor temperature, indoor superficial temperature, indoor layers temperature and outdoor superficial temperature [5]. The system recorded the temperature every 15 minutes. The weather station was 100 m far from the experimental building and recorded weather data such as air temperature, relative humidity, solar radiation, both vertically and horizontally every 15 minutes.

The two facades could be compared before and after positioning the vegetal layer (since it was positioned later), in order to quantify the benefits that such a wall could generate in the inside. Both with high and low radiation, the temperature of the conventional facade was always higher than the other, both with or without the green, but in a different way: once the vegetal facade had been positioned, the indoor temperature difference between the two facades was constant (2-4°C) depending on the weather (cloudy or sunny), while without the green, indoor temperatures were almost the same at night.

Table 1. Sunny days

	4/09	5/09	6/09
Max hor. radiation [W/m^2K]	882.4	868.2	856.1
Max ver. radiation [W/m^2K]	690.8	683.4	692.0
Max Humidity [%]	47.9	52.3	60.1
Max ext temperature [°C]	26.4	28.0	30.7
Max o. s. s. VF [°C]	23	23.3	22.1
Max o. s. s. CF [°C]	43.5	44.8	46.7
Max i. s. VF [°C]	25	25.5	26.5
Max i. s. CF [°C]	26.1	26.9	27.9

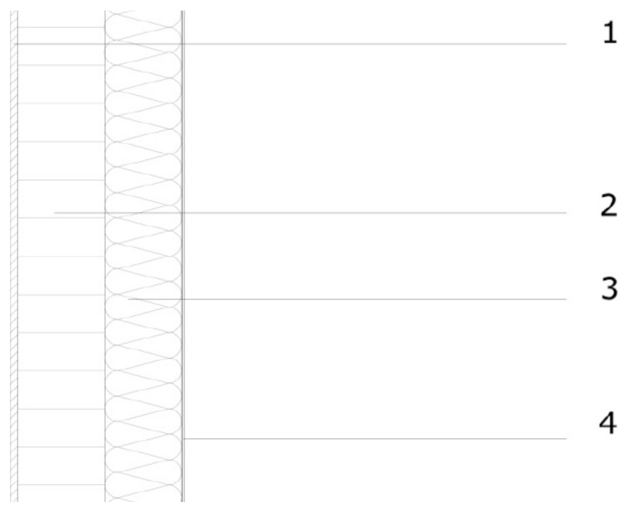

Figure 3. Conventional Facade System section

1. Plasterboard s= 10 mm
2. ½ foot of perforated brick s= 115 mm
3. Insulating s= 100 mm
4. Metal plates with polyethylene core s= 4 mm

DISCUSSION

To understand if and how outdoor environmental conditions can affect the two systems, we decided to carry out an analysis on a sunny day and one on a

cloudy day, choosing 3 consecutive days that would be representative of these two conditions and characterized by average values of solar radiation and air temperature [6].

Starting from these assumptions we carried out some analysis from different points of view:
-comparison between temperature difference of the two facades and outdoor weather conditions;
-comparison between outdoor superficial temperature of the two systems and outdoor conditions;
-comparison between indoor temperature of each facade and corresponding outdoor superficial temperature.
Outdoor conditions and outdoor superficial temperature difference between the two facades were analyzed: on September 6th (sunny day), where the conventional wall had the highest temperature, the biggest temperature difference was 27.7 °C. In fact, radiation (measured on the vertical plane), outdoor air temperature and relative humidity were the highest of the three sunny days (Table 1). This difference varied a lot throughout the day. We noticed a strong oscillation between day and night. Getting gradually closer to the interior, sensors detected a significantly diminished difference compared to external surface temperatures. In the indoor space the maximum difference was, in fact, 2.6 ° C.
Among the cloudy days, the biggest temperature difference on the external surface between the two facades was recorded on September 29th, with a value of 20.8 °C (Table 2); in the inside space the maximum recorded difference was 1.7 °C.

Table 2. Cloudy days

	28/09	29/09	30/09
Max hor. radiation [W/m^{2}K]	140.8	394.9	794.4
Max ver. radiation [W/m^{2}K]	140.8	401.0	819.5
Max humidity [%]	95.0	94.4	89.4
Max ext temperature [°C]	16.1	18.0	19.3
Max o. s. s. VF [°C]	15.1	16.3	17.3
Max o. s. s. CF [°C]	18.2	35.4	38.2
Max i. s. VF [°C]	16	16.5	18.3
Max i. s. CF [°C]	17.4	17.5	19.4

Max hor. radiation [W/m^{2}K]: *Maximum horizontal solar radiation*
Max ver. radiation [W/m^{2}K]: *Maximum vertical solar radiation*
Max ext temperature [°C]: *Maximum external air temperature*
Max o. s. s. VF [°C]: *Maximum temperature outdoor superficial sensor Vegetal Facade*
Max o. s. s. CF [°C]: *Maximum outdoor superficial sensor temperature Conventional Facade*
Max i. s. VF [°C]: *Maximum indoor sensor temperature Vegetal Facade*
Max i. s. CF [°C]: *Maximum indoor sensor temperature Conventional Facade*

Another analysis concerning the type of relationship between outdoor superficial temperature of the two facades and outdoor environmental conditions was carried out to understand how they could affect both the superficial and the indoor temperature. On September 5th (sunny day) the green wall recorded a maximum temperature of 23.3 °C. The bare wall recorded 44.8 °C on September 6th , when there were extreme outdoor conditions (Fig. 4).
As for the cloudy day, both the green and the reference facade recorded a maximum external surface temperature on September 29th: 16.3 °C the first, 35.4 °C the second. (Fig. 5).

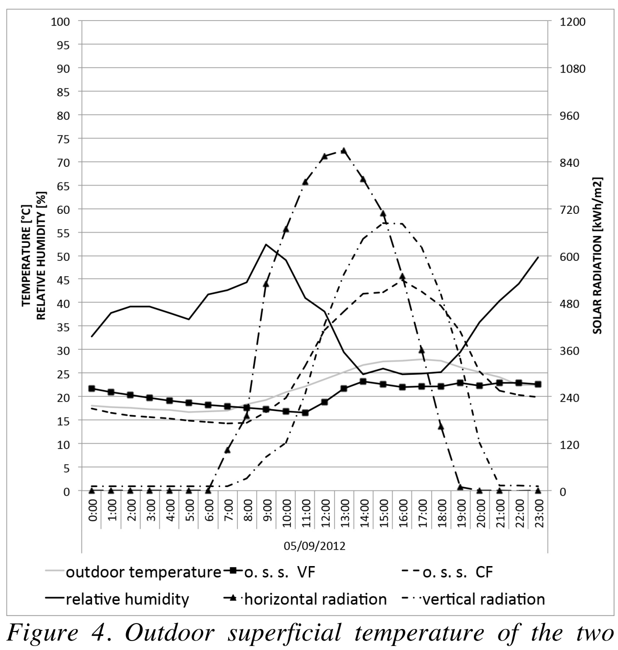

Figure 4. Outdoor superficial temperature of the two systems on sunny days

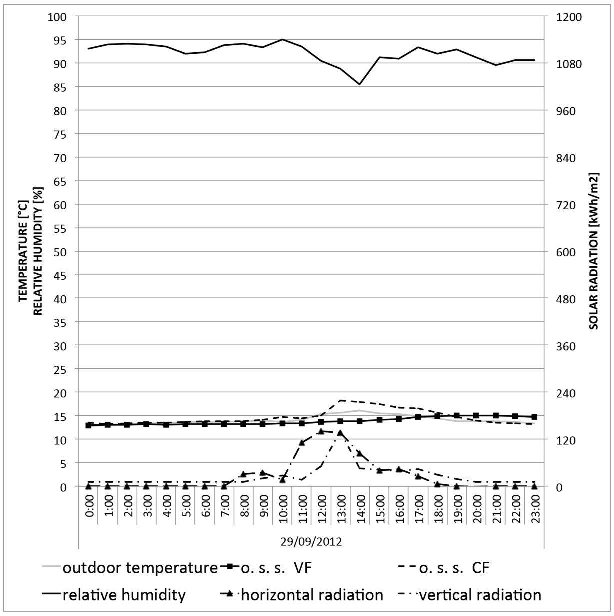

Figure 5. Outdoor superficial temperature of the two systems on cloudy days

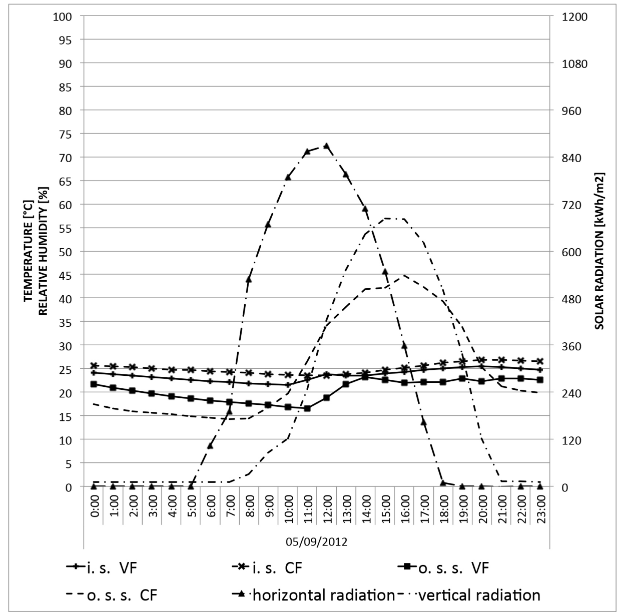

Figure 6. Outdoor superficial temperature and indoor temperature of the two systems on sunny days

In both cases, on the sunny day and on the cloudy day, the vegetal facade temperature was higher than the conventional one in the early hours of the morning and at night, that is when air temperature decreases and there is no solar radiation. The outdoor superficial temperature trend of the conventional facade follows the solar radiation trend. This also means that there is a strong oscillation between night and day. The solar radiation effects on the vegetal facade appeared after some hours, when the maximum outdoor superficial temperature was recorded. The trend was, nevertheless, more stable, with no big variations, unlike the other system.

Finally, we examined outdoor superficial temperature trends and the indoor temperature of both facades. First of all, we noticed that both on the sunny and on the cloudy day the bare wall temperature was always higher than that of the green wall. In the first case, the temperature was 1.7 °C higher (on average); in the second case it was 1.3 °C higher. Beside this, we noticed that this difference between the two walls remained the same during the low solar radiation period; a small difference increase was detected, instead, between the two systems on high solar radiation days in the early hours of the morning. In both cases (high and low solar radiation) (Fig. 6-7), the outdoor temperature of the bare wall, as before mentioned, clearly followed the solar radiation trend. The green wall was less affected by the radiation; on the contrary, the vegetation clearly affected the temperature of the air inside the two modules, where the maximum difference between the two systems was 2.6 °C and the smallest was 0.4 °C on the sunny day; on the cloudy day the biggest difference was 1.7 °C and the smallest was 0.7 °C.

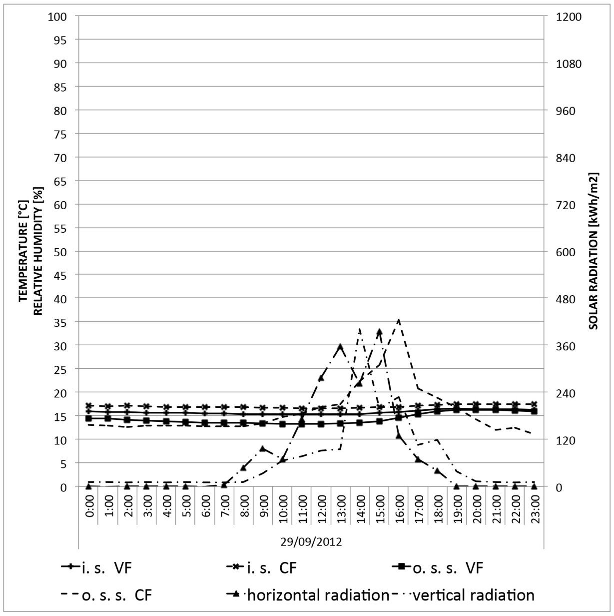

Figure 7. Outdoor superficial temperature and indoor temperature of the two systems on cloudy days

CONCLUSIONS

The aim of this study is to quantify the thermal trend of a green wall in the summer compared to a normal wall and verify if very thick thermal insulation nullifies the effect of the vegetation inside. From the studies that we carried out, comparing different variables, the main conclusions are the following:

- The external climatic conditions strongly affect the temperature of the facades, but in a different way for the green system. We noticed, in fact, that the external temperature difference, where the temperature of the conventional facade is higher, increases when solar radiation and air temperature increase, while inside the difference values are significantly lower and maximum values do not correspond to the most extreme outside conditions. It was found also that the temperature of the green facade is higher at night hours, when there is no radiation, because the bare wall is characterized by a strong thermal daily oscillation, while the vegetal facade maintains a more constant trend throughout the day;

-The outdoor superficial temperature is affected by the solar radiation, especially for what concerns the conventional wall. In fact, with the same conditions of solar radiation we have a very different maximum temperature on the surface: 46.7 °C on the bare wall and 22.1 °C on the green wall;

-The results show that, despite the high insulation thickness, within the modules temperature, difference varies between 1.7 ° C and 1.3 ° C, recording the highest values on sunny days. This shows that vegetation effect is stronger when external conditions are extreme, with high values of radiation and air temperature.

Therefore, on the basis of these data, the use of vegetal facades seems recommendable in case of climates characterized by many hours of solar radiation, confirming that their use brings thermal benefits compared to a conventional wall.

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