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## New green facades as passive systems for energy savings on buildings

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### Abstract

The new technologies of plants integration on buildings offer new possibilities from the sustainable construction point of view, especially in energy savings. In previous studies the great capacity of double-skin green facade or green screen to intercept solar radiation was confirmed, observing differences up to 18 °C in surface temperatures between sunny and shade areas on the wall of the building. The experiment presented here consists of two identical house-like cubicles (3 x 3 x 3 m) located in Puigverd de Lleida, Spain. The only difference between the two cubicles is the double-skin green facade installed in one of them. In a first step only the South wall was covered by a provisional green facade. As the results from first experiment were positive with interesting low electrical energy consumptions when only the 50% of the South wall was covered by plants, a new stable green facade was built covering the South, East and West facades by a deciduous specie well adapted to the Mediterranean Continental climate. With this study the confirmation of the good operation of green facades made with deciduous species as passive system for energy savings in buildings is expected to be characterized.

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### 1. Introduction

Recently, the concept of Green Infrastructure has been defined as a set of man-made elements which provides multiple functions both at building and urban scale. Among these functions, the building energy savings as well as the reduction of ambient temperatures and urban heat island effect stand out. Some of the most innovative and interesting construction systems for this purpose are the green facades and green walls [1].

Green facades and green walls act basically as passive system through four mechanisms; the shadow produced by the vegetation, the insulation provided by vegetation and substrate, the evaporative cooling through evapotranspiration, and finally the barrier effect to the wind [2]. In some previous experimental studies it was proved that the shadow effect has the greatest impact over the building wall temperature

reduction and consequently over the energy consumption reduction [3-7]. Moreover, other studies have reached similar conclusions using simulations [8-10].

However, in previous studies the difficulty of knowing about what percentage of each mechanism contributes to in energy savings was observed. Thereby, Stec 2005 highlights the difficulties to determine the properties of plants (the transmission by radiation, absorption coefficients, etc.) [8].

Moreover, the growth of plants in local climatic conditions must be taken into account because the final results may greatly differ from one climate area to another [2]. For these reasons, in terms of energy consumption it is interesting to calculate what is the real contribution of each one of these systems. Particularly, plants for vegetated facades with a specific climate are of most interest to the authors.

This study is another step of a long-term research in order to obtain data on the behavior of green facades in buildings as a passive system for energy savings in dry Mediterranean Continental climate.

Previous studies about the shadow capacity of different climber species were analyzed by the authors in order to evaluate which species protect better against solar radiation in Mediterranean Continental climate. Boston Ivy (*Parthenocissus tricuspidata*) showed the best covered area compared to the other three species analyzed [3]. Furthermore, the great capacity of double-skin green facade or green curtain to produce shade and reduce the solar radiation on the wall of the buildings was studied in a real case. It was verified also that a microclimate between the wall of the building and the green curtain is created [2,3].

In order to study the real contribution of green facades to the energy savings of a building under controlled conditions a new experimentation has been carried out in an experimental facility. The green facade contribution to the energy savings for cooling in summer as well as to know the thermal behavior during winter period is expected to be calculated.

## 2. Materials and methodology

The experimental set-up consists of two house-like cubicles (Figure 1) located in Puigverd de Lleida, Spain, with the same internal dimensions (2.4 x 2.4 x 2.4 m). Their bases consist of a mortar base of 3 x 3 m with crushed stones and reinforcing bars. The walls present the following layers from the inside out (Figure 2): gypsum, alveolar brick (30 x 19 x 29 cm), and cement mortar finish. No additional insulation was used in these cubicles. The roof is a conventional flat roof (precast concrete beams and ceramic floor arch 25 cm) with 3 cm of polyurethane insulation layer above, concrete relieved pending formation of 2%, double waterproofing membrane, and finished with a single layer of gravel of 7 cm thickness (Figure 2) [11,12]. The only difference between the two cubicles used in the present research is the use of double skin green façade systems in one of them.



Fig. 1. Experimental set-up in Puigverd de Lleida, Spain

In order to evaluate the thermal performance of the different studied cubicles, the following data were registered for each cubicle at 5 min intervals:

- Internal ceiling and roof surfaces temperatures.
- Internal East, West, South, and external South walls.
- External ambient temperature between green curtain and south wall (at the top and bottom).
- Internal ambient temperature and humidity (at a height of 1.5 m).
- Electrical consumption of the heat pump.
- Solar radiation.
- External ambient temperature and humidity.

All temperatures were measured using Pt-100 DIN B probes, calibrated with a maximum error of  $\pm 0.3$  °C. The air temperature and humidity sensors were ELEKTRONIK EE21FT6AA21 with an accuracy of  $\pm 2\%$ . The electrical consumption of the HVAC systems was measured using an electrical network analyzer (MK-30-LCD). Middleton Solar pyranometer SK08 was used to capture the horizontal global solar radiation.

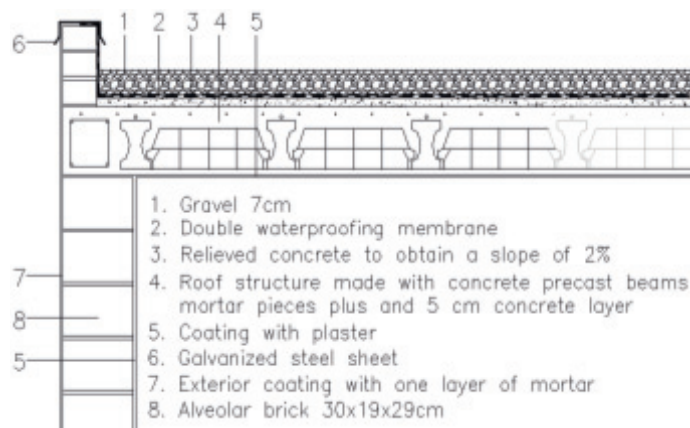


Fig. 2. Constructive section of the cubicles used in this experimentation

The experiment was conducted in two phases. In the first phase (Experiment 1) the shadow effect of the vegetated facades on the south wall of buildings was validated. Furthermore, four different types of plants were analyzed. In the second phase (Experiment 2) a permanent vegetated wire mesh on East, South and West facades was analyzed. These two experiments are depicted below.

### 2.1. Experiment 1. Previous facade system

To perform this experiment four modular trellises prepared to accommodate a container garden at the bottom were designed and built (Figure 3). The facade was installed in south orientation. The substrate used was a mixture of universal substrate for gardening and topsoil. The choice of plant species was made from a previous list of climbers made for the Mediterranean Continental climate. In the selection, the resistance of the species, the height they can reach, their adaptation to grow in modular trellis, and availability in nurseries, were considered.

The species chosen were Ivy (*Hereda helix*) and Honeysuckle (*Lonicera japonica*), as perennial plants, and Boston Ivy (*Parthenocissus Tricuspidata*) and Clematis (*Clematis sp.*), as deciduous plants.



Fig. 3. (a) Cubicle with previous façade system; (b) free space between wall and green curtain

The experimental set-up offers the possibility to perform two types of tests, controlled temperature and free floating temperature. During those days the green facade was only partially developed, covering approximately 50% of the south facade of the cubicle.

Data collection was done during three periods in summer 2011. First data were obtained during July 2011 with a constant indoor temperature of 24 °C. In early September a free floating experiment was done.

## 2.2. Experiment 2. Current facade system

To perform this experiment a wire mesh on East, South and West facades were installed as shown in Figure 4. The Boston Ivy (*Parthenocissus Tricuspidata*) is a well-adapted specie in the Mediterranean Continental climate selected to perform the experiments. The selection of the spice is based on the previous experiments.

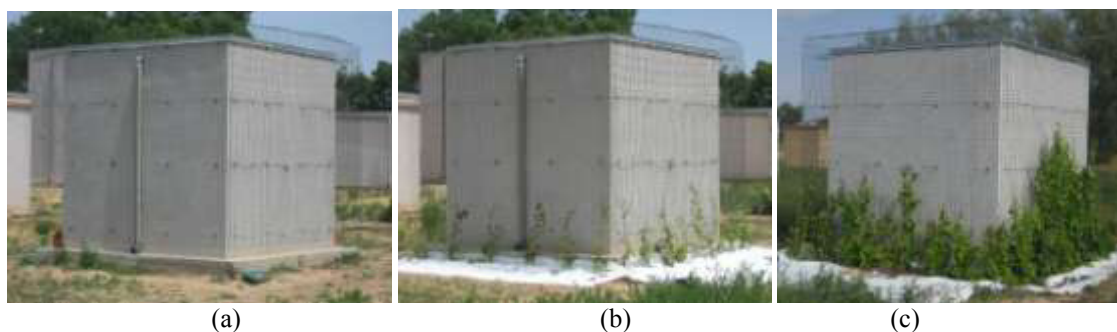


Fig. 4. (a) Cubicle with installed wire mesh; (b) newly planted Boston Ivy; (c) Growing phase of the Boston Ivy

Data from the new double skin facade are collected during the whole year. Due to the plants are in growing phase no differences between the two studied cubicles in energy demand are observed.

### 3. Results and discussion

#### 3.1. Experiment 1. Previous facade system

In the data obtained from the first experiment in 2011 (set-point 24 °C), it can be observed the great potential of green facade to intercept solar radiation. This fact is evidenced by a reduction of up to 10 °C in the south wall external temperature of the cubicle with green facade (Figure 5).

This evident shadow effect in the exterior wall only supposes a slight reduction in energy consumption. Thus the green facade cubicle has a 1% reduction in daily consumption during this period. The final cumulative reduction in the analyzed period is 5.5% (Figure 6).

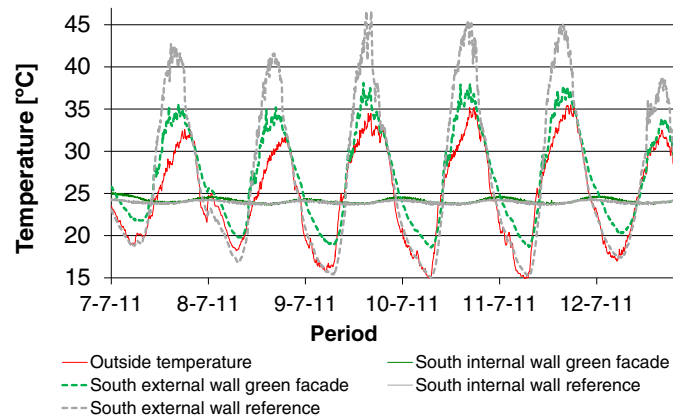


Fig. 5. South internal and external wall temperatures. July 2011. Set-point 24 °C

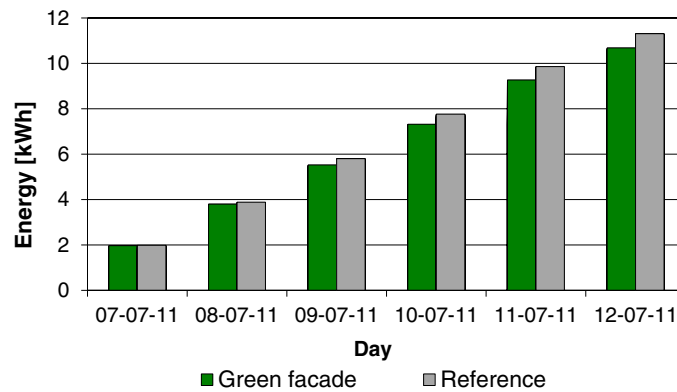


Fig. 6. Accumulated energy consumption. July 2011. Set-point 24 °C

In the results from September 2011, under free floating regime, the shadow effect was still present on the south wall, reducing the external south surface temperature up to 14 °C in the green facade cubicle (Figure 7). This is also reflected in the south internal surface temperature of the green facade cubicle which was between 0.5 °C and 2 °C lower than the reference one. In addition, the inside temperature was also about 1 °C lower in the green facade cubicle compared to the reference cubicle for this period (Figure 8).

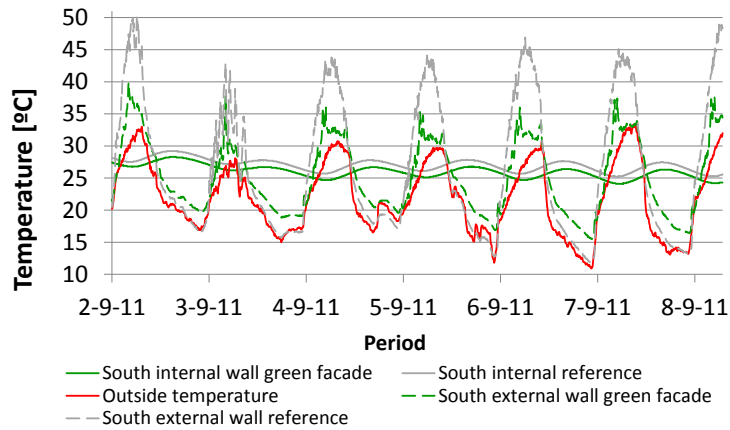


Fig. 7. South internal and external wall temperatures. September 2011. Free floating temperature

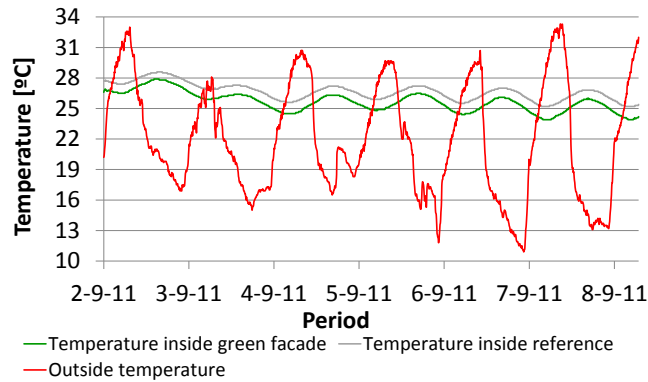


Fig. 8. Internal ambient temperatures. September 2011. Free floating temperature

### 3.2. Experiment 2. Current facade system

The validation of the initial data acquired when the both cubicles present the same values at the beginning of the experimentation is required. This validation has been carried out during April 2013 to verify that the support of the plants (wire mesh), does not affect to the thermal behavior of the cubicle. Figure 9 shows the south internal and external wall temperatures between both cubicles.

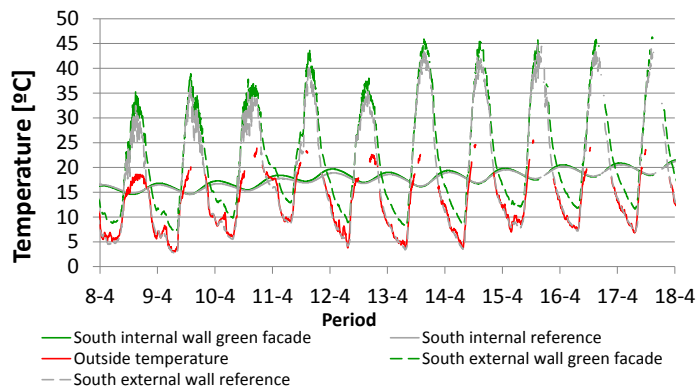


Fig. 9. South internal and external wall temperatures. April 2013. Free floating conditions.

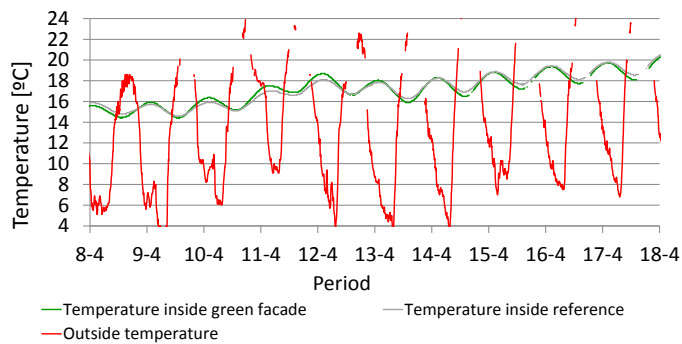


Fig. 10. . Internal ambient temperatures. April 2013. Free floating conditions.

Vegetation was planted in June 2012 and they grew 1 m from the summer until winter period, which stopped their growth phase (Figure 4c).

In the initial phase, a better growth in East facade compared to the South and West was observed. During the autumn season, the plants lost their leaves due to are a deciduous plants and then during the spring season the plants have grown back.

The same phenomenon is observed in growth phase during the spring of 2013; the plants on East façade grow more than the South and West facades. Due to this fact the plants on East facade are more developed than the other two facades. This fact has two possible explanations. The first one is that the plants situated on the East receive the solar radiation more horizontal during morning compared to the South and West facades. And the second cause is due to the constant breeze from South-West that Puigverd de Lleida suffers every day. This breeze may be affects to the growth phase in West and South facades. The vegetation is expected that achieve 100% of coverage during the summer of 2013.

In order to allow the survival of plants in front of the spring storms, an anti-hail on East, South and West facades was installed (Figure11).



Fig. 11. . East, South and West facades protected with anti-hail.

#### 4. Conclusions

Studying the behavior of green facades as passive systems for energy savings in buildings in Mediterranean Continental climate, during summer 2011 with a covering of approximately 50% of the south facade of an experimental cubicle we can conclude that (Experiment 1):

- The great capacity of the green facade to intercept solar radiation was confirmed with reductions in outside wall surface temperature up to 14 °C in July and early September.
- This effect could not be linked, in this experiment, with a great improvement in energy consumption in the periods studied.
  - For a set-point of 24 °C in July and with maximum outside temperatures between 37 °C and 39 °C, the green facade cubicle daily energy consumption reduction was only 1%.
  - In free floating regime during the first days of September, was verified that the shadow effect of the green facade has a direct impact on reducing the temperature inside the cubicle around of 1 °C.

The experiment with current green facades system (Experiment 2) has been validated to start during the summer period of 2013:



- The wire mesh installed on the East, South and West facades of the green facade cubicle not modify the thermal behavior of the cubicle compared to the reference one.
- To date, no differences in terms of energy savings between the two studied cubicles were observed during the growth phase.
- Differences in plants growth between East and the others two facades (South and West) green have been observed. Wind effect and facade orientation, must be taken in to account in future results and discussions.

Winter testing will be carried out in 2014 with the same experimental set-up. The project might allow to also carry out experiments with other plant species.

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