Solar and heat protection techniques. Evaluation and design recommendations for different types of fabric awnings.

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ABSTRACT

Cloths and fabrics have always being used as solar protection. Interior and exterior curtains, urban and building awnings are common resources in Mediterranean architecture to create comfort in hot summers. Solar and heat control (for cooling) through external opaque protections present two main functions: a) On transparent elements of the envelope: the regulation of impinging radiation direct transmission to the interior space. b) On opaque elements of the envelope: the control of the impinging radiation on massive materials that would absorb and storage heat to release it to the interior space with a time delay (thermal inertia). In this paper, results of temperature monitoring of two different awnings (65% and 90% shading fabric / within and over vertical parapets) in similar courtyards in the city of Mendoza are presented. Mendoza, located in central western Argentina (32º40' southern latitude, 68º51' western longitude, 750 m above sea level), has a temperate continental climate with hot summers and cold winters. Therefore, the use of solar and heat protection techniques in the hot season are crucial. Results analyse comfort conditions that lead to design recommendations to achieve optimal responses with fabric awnings in courtyards.

INTRODUCTION

For many years now it is obvious that energy consumption of buildings has to be reduced in order to develop a sustainable architecture. Residential and tertiary buildings being responsible for around the third of energy consumption in western countries, their impact on the achievement on Kyoto protocol's objectives is significant.

To develop such energy-efficient buildings, designers may find themselves on two sources of knowledge: personal background acquired on former studies and experience from other buildings, description of technological choices, controls, and monitored results. As such publications are scarce, generic studies handling with a systematic approach of a particular or global design method are used as the second source of knowledge. (Van Moeseke et al., 2007). Therefore the great importance of evaluation and design recommendations for monitored real case studies.

Bioclimatic conditioning of buildings relies on the design strategies applied, associated with formal and material definition of the project and its immediate surroundings. Solar and heat protection techniques are thus key strategies to ensure natural comfort, specially in high heliophany hot summer urban locations with slow air movement.

It seems that a permanent yardstick would be established by relating their importance to human reactions, where a reasonable ratio would be 1 to 2. According to this, shading at overheating times is twice as important as heat gain during the unheated period. (Olgyay et al, 1957)

On open space design, site specific characteristics are always determinant and, even though architectural tradition and culture have always addressed urban open space issue, there are still scarce works that revise environmental quality funded in scientific studies and validation. (Sala et al, 2000)

Open spaces un cities play a decisive role in their thermal behaviour. The courtyard, as a structuring element of the architectural project, is a significant open space through which heat exchanges between interior and exterior occur. (Canton et al., 2006) Improving microclimatic conditions in courtyards in summer depends on controlled dynamic shading.

Shadow is the dark area behind an opaque matter that obstacles the radiant heat and direct light from radiant source. It will be possible to produce shadow if the location of sun as the light and solar energy source is known and determined. The effectiveness of a shading device depends on the proportionate success with which it covers a given surface during the overheated period without interception of the sun's energy during unheated times.

Operable external shading devices can be of many types, including shutters (hinged, sliding, etc.) routable fins horizontal plates, retractable venetian blinds or canvas awnings. They can be made of many materials, such as wood, metals, asbestos-cement, fabrics and so on. The common feature to all operable devices is that they can be adjusted at will to either exclude or admit solar radiation. As with fixed devices, they intercept the sun's rays before the rays hit the envelope. (Givoni, 1994)

Solar and heat control (for cooling) through external opaque protections present two main functions:

a) On transparent elements of the envelope: the regulation of impinging radiation direct transmission to the interior space. Operable external shading devices can reduce solar heat gain through windows and other glazed areas down to about 10 to 15% of the radiation impinging on the wall. (Givoni, 1994).

b) On opaque elements of the envelope: the control of the impinging radiation on massive materials that would absorb and storage heat to release it to the interior space with a time delay (thermal inertia).

Cloths and fabrics have always being used as solar protection. Interior and exterior curtains, urban and building awnings are common resources in Mediterranean architecture to create comfort in hot summers.

Fabrics, commonly used as sun screens, awnings and curtains, conform a varied world of materials. Their behaviour depends on their thickness and colour. A light fabric -in thickness and in colour- will allow an important amount of incident radiation and also it will reflect a part of it, absorbing little. A thick, dark canvas will have a low transmission but also a low reflection, therefore it will have an important absorption and will irradiate heat. (Paricio, 1997). In wet climates membranes made of impermeable fabric are usually used, while in hot dry climates perforated membranes are preferable, to make the screen airily and light and thus to function as solar and heat protection. (Sala et al, 2000)

Besides the material properties of the shading device it is also important its design as it can be related to the space in a variety of solutions that may change the microclimatic situation of the protected exterior. Awnings can be attached to a window or to the entire courtyard, they can also go from one wall to the other, acting as a roof or be suspended over the walls acting as a ventilated roof.

If the space between the exterior protection and the glass is perfectly ventilated, the shadow coefficient and thermal transmittance respect to a single glass can be around 0.16 (Paricio, 1997).

In this paper two different awnings (65% and 90% shading fabric material / within and over vertical parapets) that protect similar "box type" courtyards belonging to single family houses in the city of Mendoza are studied.

1. CASE STUDY

1.1 Climate and location

The study cases are located in Mendoza, in central western Argentina (32º40' southern latitude, 68º51' western longitude, 750 m above sea level), in a semi-arid continental climate with low percentages of atmospheric relative humidity and high heliophany (See Figure 1). It corresponds to a BWk climate, according to the climate classification of Koeppen-Geiger-Pohl (1953). Some meteorological records are shown in Table 1.

Table 1 Climatic data of Mendoza, Argentina

Annual values	
Maximum mean temperature	24.5 ºC
Minimum mean temperature	9.6 ºC
Mean temperature	16.5 ºC
Global horizontal irradiance	18.4 MJ/m^2
Relative humidity	56%
Relative heliophany	63%
July	
Maximum mean temperature	15.7 ºC
Minimum mean temperature	0.8 ºC
Mean temperature	7.3 ºC
Global horizontal irradiance	10.2 MJ/m^2
Relative humidity	63%
Relative heliophany	58%
January	
Maximum mean temperature	32.3 ºC
Minimum mean temperature	17.4 ºC
Mean temperature	24.9 ºC
Global horizontal irradiance	26.1 MJ/m^2
Relative humidity	49%
Relative heliophany	66%
Heating degree-days (T_b = 18 ºC)	1384 ºC
Cooling degree-days (T_b = 23 ºC)	215 ºC

Source: Servicio Meteorologico Nacional – Fuerza Aerea Argentina.

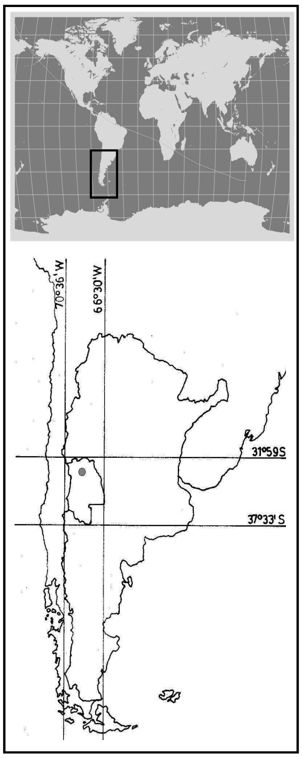

Figure 1: Location of Mendoza, Argentina.

1.2 Compared courtyards

Both courtyards belong to houses in which the main façade faces North (towards the Equator in the South Hemisphere). In both cases they are wider on the North – South axis (lenght) and narrower on the East – West axis (width). Courtyards also have similar area: Case 1 with 20.46 m2 (3.10 x 6.60 m) and Case 2 with 23.76 m2 (4.40 x 5.40 m). On both cases width and height proportions are approximate to 1.5 to 2, that is, the vertical parapets prevail over the horizontal ones, therefore their morphology is called "boxed – type courtyard" (Cantón et al, 2009). See Figure 2.

Courtyards also present similar constructive materials and finishes: uninsulated massive brick walls painted in a light colour and massive floors made of concrete floors tiles and grey mosaic respectively. As solar and heat protection they present shading – fabric awnings that run horizontally on the North-South axis. Both awnings are green but their shading fabric has different thickness. Even though their height from the floor is the same (4.40 m) an important difference between the two awnings is their relative position to the walls. Case 1 is boxed within the perimeter of the walls that run 0.60 m over the awning in every orientation; while in Case 2 the awning is located 0.30 m over the East wall and 0.60m over the West wall. See Figure 3.

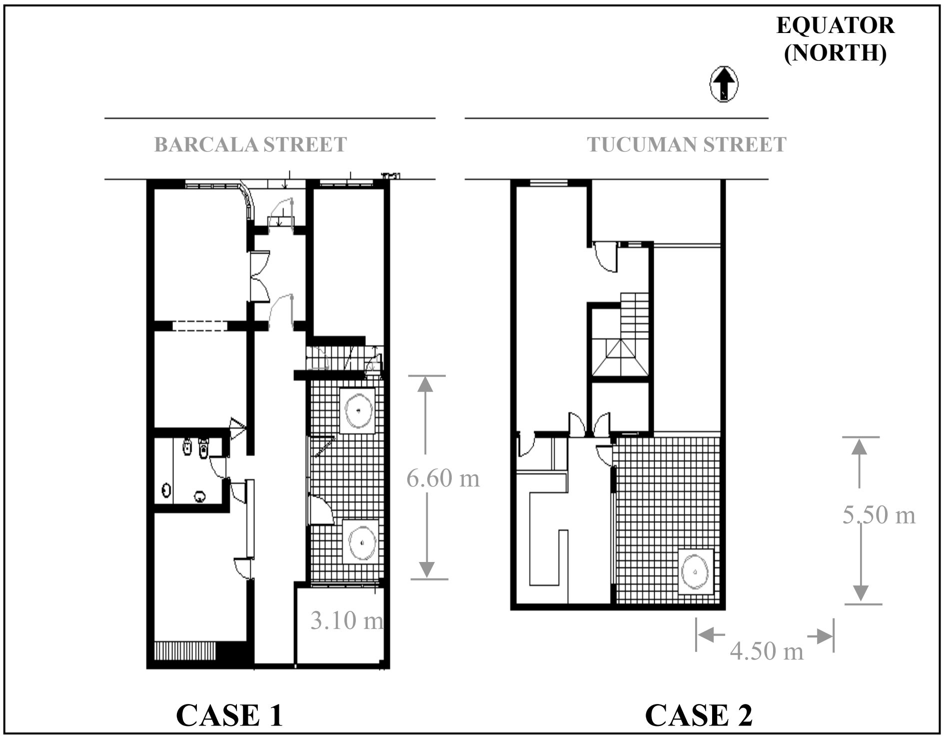

Figure 2. House's plans and courtyard location for Cases 1 and 2.

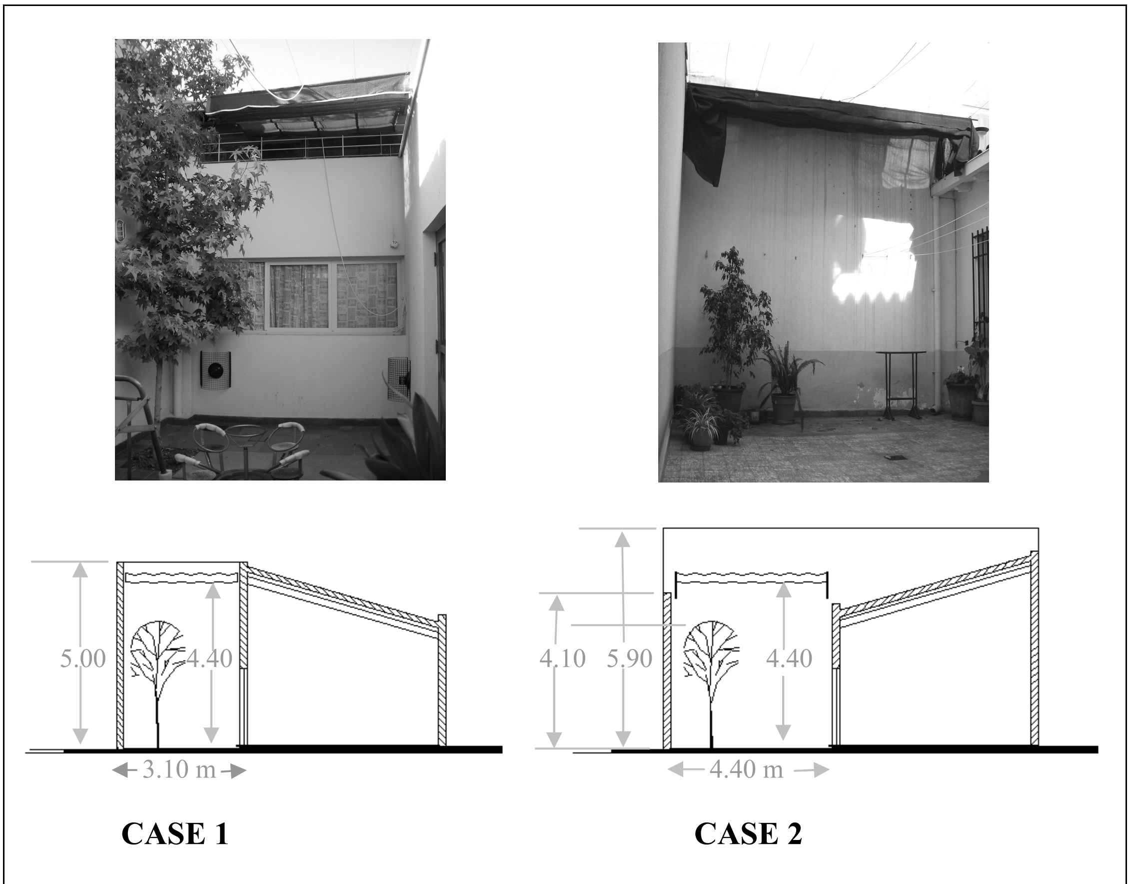

Figure 3. Photograph images and sections from North (Equator) view point for Cases 1 and 2.

1.3 Solar protections

Shading fabrics are usually commercialized for agriculture purposes, nevertheless their use on awnings in the urban context is becoming more common than before due to their longer life, low maintenance and low prices. They also offer a wider variety of options (textures, densities, weights, resistances, colours) when compared with the traditional canvas.

Shading fabrics are made of 100% HDPE. HDPE is a thermoplastic SPI resin with an identification coding system 2 and Unicode U+2674. High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a polyethylene thermoplastic made from petroleum. It takes 1.75 kilograms of petroleum (in terms of energy and raw materials) to make one kilogram of HDPE. HDPE is commonly recycled. In 2007, the global HDPE market reached a volume of more than 30 million tons. (Ceresana Research, 2008)

Even though we are dealing with a petroleum derivate whose emissions are 1100 kg of carbon dioxide per kg of product (Clough et al., 1995) it is important to take into account first that it is being widely used so it is important to know how it works for this purpose and second that to produce shading fabrics it is used almost pure and therefore it can be easily isolated and recycled. This information along with less pollutant alternative materials should be given to users so they make a choice among available possibilities and so they dispose the shading fabric when no longer needed responsively.

On Figure 4 are presented five types of shading fabrics that change their tissue as they graduate from 35% shading to 90% shading. Case study 1 presents an awning with 90% shading fabric and Case study 2 has an awning with 65% shading fabric. Both materials are identified in Figure 4 and their characteristics, as given by the manufacturer are presented in Table 2.

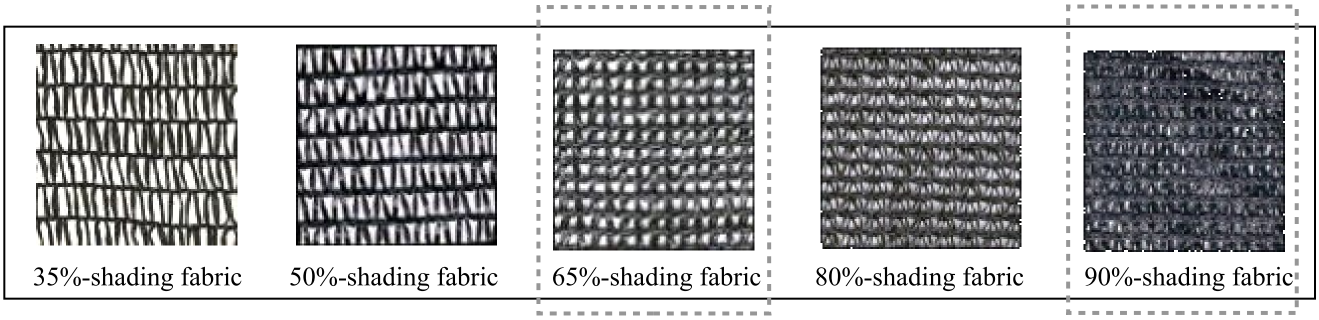

Figure 4: Commercial “shading fabrics” and identification of the ones used on each case study: Case 1: 90%-shading fabric and Case 2: 65%- shading fabric.

Table 2. Properties of the shading fabrics used on each case study.

	CASE 2 **65%-shading fabric (MS6541)**	**CASE 1** **90%-shading fabric (MS9041)**
Width [m]	4.20 – 2.10	4.20 – 2.10
Lenght [m]	100-50	100-50
Weight [gr/m2]	70 (+-5%)	100 (+-5%)
Shadow percentage	0.65	0.90
Resin	HDPE 100%	HDPE 100%
Colours	Black / Green	Black / Green
Additives	Anti-UV	Anti-UV

Source: Agroredes S.R.L.

2. MEASUREMENT METHOD

Air temperature and relative humidity monitoring were performed with data loggers ONSET HOBO H12 every 15 minutes for a summer representative period of 20 days on each case. Case 1 was measured from January 3rd to January 22nd 2008, and Case 2 from January 3rd to January 22nd 2010.

On each case, a sensor was placed "under the shading fabric awning" and a control sensor was placed outside the influence of the fabric awning named after "exterior". Every data logger was suspended at a mean height of 2 metres.

3. RESULTS

On Figures 5 and 6 are presented the measured temperatures for Cases 1 and 2 in the complete period. Even though on the measured period, temperatures on summer 2010 were about 1ºC higher in average compared to the ones measured on 2008, differences in each awning's behaviour are noticeable.

On Case 1, around 6:00 p.m. when maximum temperatures were recorded on the exterior, temperatures under the 90%-shading fabric canopy are around 4ºC under; while on Case 2 their are about 9ºC below the exterior ones. That makes a difference of 5ºC between cases and can be the turning point from comfort to the lack of it. At night, if the awnings are closed and the courtyard massive surfaces "see" the sky, as most nights are clear temperatures lower near exterior ones allowing radiative cooling. On Case 2 there were some clear nights, specially January 6th, 7th and 8th, in which the awning was not closed and therefore temperatures remained about 4ºC over the exterior ones .

Temperature daily variations on sunny days are also much higher on Case 1 (around 10 – 12ºC) that almost follows external behaviour (14 – 16 ºC), than on Case 2 (4 – 6ºC) been easier to maintain the comfort sensation even though temperatures rise over pre-established comfort limits. As these are exterior spaces temperature ranges within comfort are.

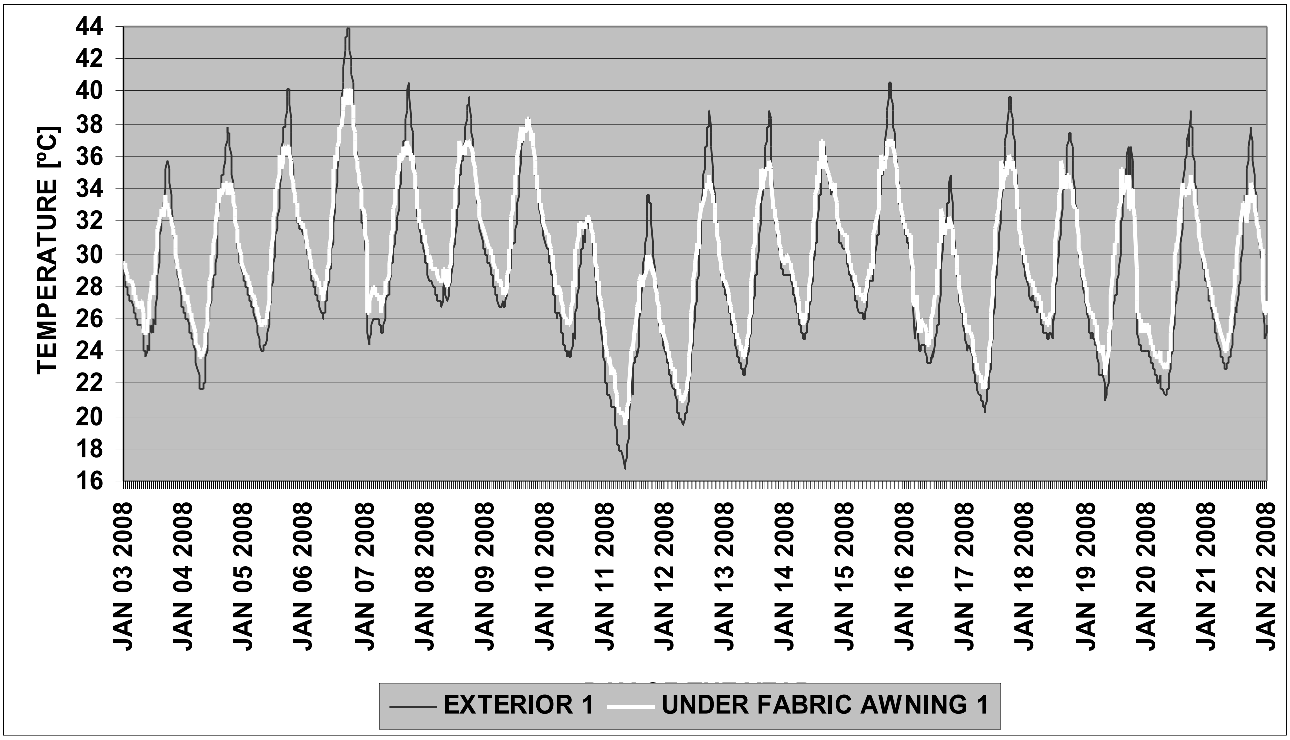

Figure 5. Case 1: Temperature measurements from January 3rd to January 22nd 2008.

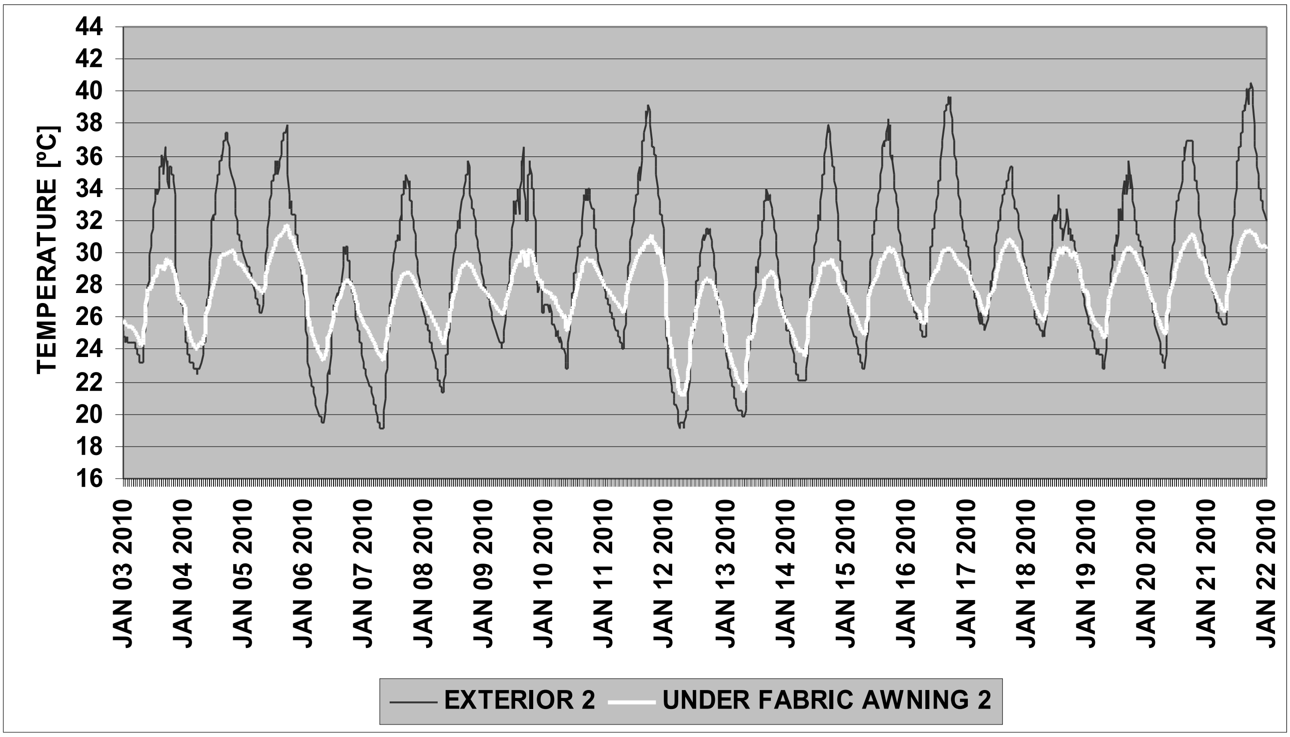

Figure 6. Case 2: Temperature measurements from January 3rd to January 22nd 2010.

On Figure 7 two similar clear sky days are compared. For Case 1: January, 13th and 14th 2008 and for Case 2 :January, 15th and 16th 2010). Thick black and white lines show Exterior temperatures and the ones under the fabric awning's influence respectively for Case 1. Thin lines represent the same two conditions for Case 2.

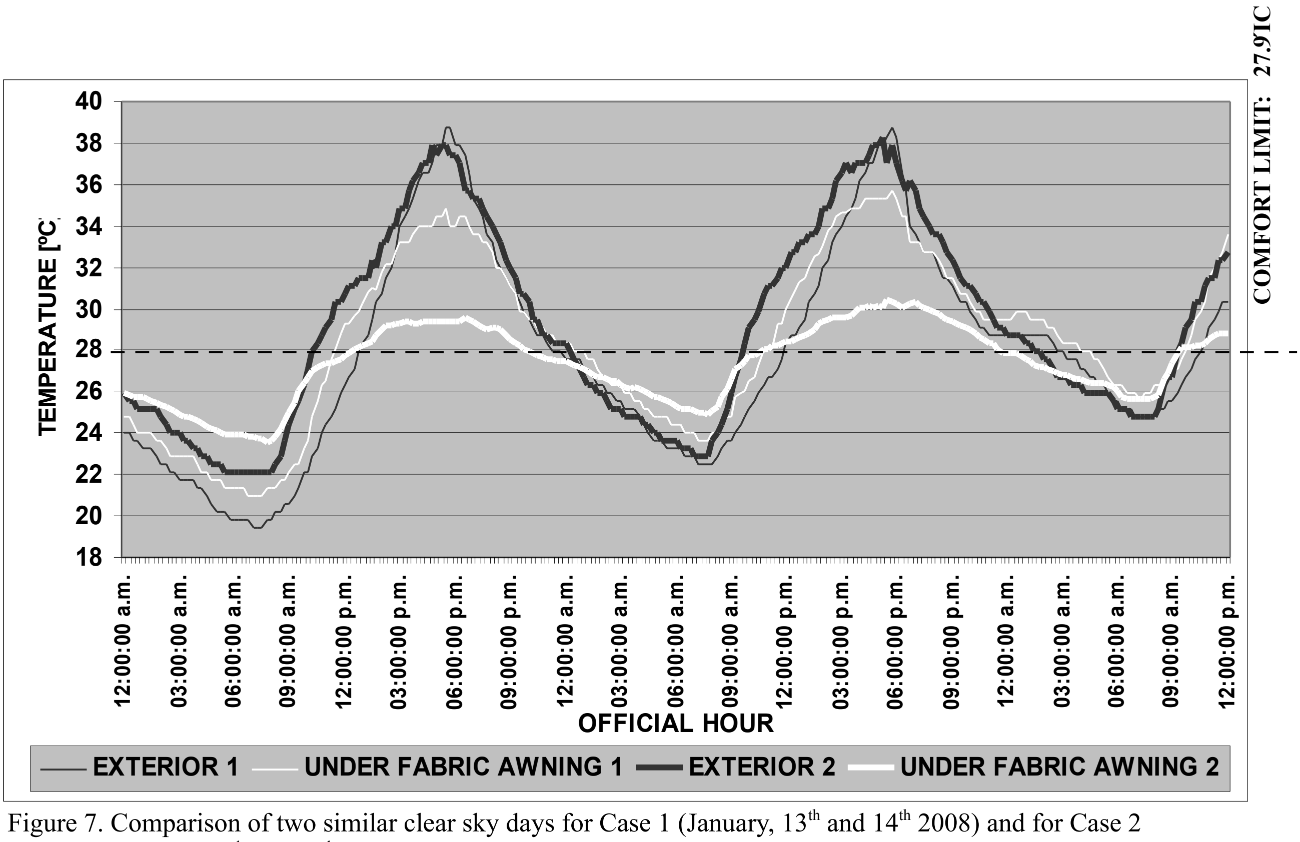

Figure 7. Comparison of two similar clear sky days for Case 1 (January, 13th and 14th 2008) and for Case 2 (January, 15th and 16th 2010).

On Table 3, mean temperatures of total measured days and for the two compared similar clear sky days are presented. It can be noticed that mean temperatures on selected days are lower than total mean temperatures. Even though that, differences between exterior measurements and the ones performed under the fabric awnings are similar between selected days an the total of studied days.

It is also important to notice that under the awning on Case 1 temperatures are almost 1ºC higher than in the exterior, even though maximums are lower than the highest temperatures in the exterior. See Figure 5 and its analyses.

On Case 2 a different result is obtained as mean temperatures are close to 1.5ºC lower under the fabric awning than in the exterior. This goes along with the obtained results from Figure 6.

Ventilation possibilities due to its upper location in relation with courtyard's walls and the possibility of air movement through the fabric change drastically the conditions between Cases 1 and 2, even though some days the awning remained open at night time in Case 2. ventilation possibilities through the fabric itself is a material possibility very different from traditional canvas that are even thicker than the fabric used on Case 1 and therefore prevent air movement and concentrate heated air under the shading device.

Table 3. Mean temperatures of total measured days and for the two compared similar clear sky days.

	TOTAL OF MEASURED DAYS	COMPARED SELECTED DAYS
EXTERIOR 1	28,18	27,77
UNDER FABRIC AWNING 1	29,05	28,49
TEMPERATURE DIFFERENCE	-0,87	-0,72
EXTERIOR 2	29,28	29,07
UNDER FABRIC AWNING 2	27,86	27,36
TEMPERATURE DIFFERENCE	1,42	1,72

4. COMFORT CONDITIONS

The comfort conditions in the different scenarios analyzed have been evaluated by calculating the percentage of hours in which the open spaces are within the comfort range. The range's definition for each of the considered variable – dry bulb temperature– was determined through the use of the following procedure:

Thermal Comfort: using the analytical equation of the Thermopreferendum (Auliciems et al, 1997) the comfort temperature for a specific location in a given period of the year and considering the variations of the location's climate.

$$Tn = 17.6 + 0.31 \times Tm$$

Where: Tn: Comfort temperature
Tm: Mean location's temperature

The range is determined by a variation of 2.5 ºC above and below Tn's calculated value for the location. For the city of Mendoza, during the warm season, Tn = 25.4 ºC and the range's limits are 22.9 and 27.9 ºC.

The contours obtained for temperature show, for each measured courtyard, that the comfort conditions related to temperature vary between day and night. During daytime the temperatures are within the comfort range and above it, with significant differences between the assessed scenarios and, at night time, below the range with less pronounced differences. See Figure 7.

The quantification in terms of percentages of the different comfort ranges on selected days indicates that, in the daily behaviour, Case 2 features the larger quantity of hours in comfort (59 %). For Case 1 such percentage decreases to 46 %. The main difference stands on the higher temperatures registered on Case 1 on disconfort hours (28 – 35ºC) that are notoriously over the ones registered on the same period on Courtyard 2 (28 – 30ºC). On Case 1 27% of the time temperatures are over 30ºC while on Case 2, 100% of the time temperatures are under 30ºC.

5. DESIGN RECOMMENDATIONS

Traditional exterior awnings are efficient if they present the following characteristics:

- Colour: usually green. It can allow to the courtyard only 5% of the impinging radiation. It will absorb radiation so the following variables are crucial:
- Light density fabric: usually half-shadow fabric. It consents air movement at all times that prevents overheating by retaining hot air under the awning.
- Separation from vertical parapets: usually from 0.30 to 0.60 m. It should be a temporary ventilated roof allowing horizontal air movement at all times.
- A dedicated user. Awnings demand a daily movement so they will be open during daytime and closed at night or in very windy days.

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