An Experimental Study of Shading Devices: Orientation Typology and Material

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ABSTRACT

In hot climates, it is very important to eliminate the penetration of solar radiation into buildings, easily allowed by glazing. In Brazil, due to its low latitudes, predominantly hot and humid climate and high solar radiation, the use of shading devices is desirable. This paper describes an experimental study about thermal performance of different fixed shading devices. The typology and materials were selected considering the elements used in modern architecture buildings of Brazil, between the 1930 and 1960 decades. The investigated devices were horizontal louvers, vertical fins and eggcrate typologies, made of concrete and wood, fixed, on north and west exposures. Results show the relation of orientation, typology and material of the devices in test. The most significant response was the horizontal concrete louver on north façade. In spite of the good insulation properties of wood, the concrete devices presented the best results.

INTRODUCTION

The thermal performance of a building depends on several factors, such as site, orientation, materials and constructive components. Depending on the geographic orientation and the optical characteristics of glazing, these facades can cause an expressive accumulation of thermal energy density inside the buildings. This is translated into discomfort for the users, and/or energy consumption (Lechner, 1991).

The use of new materials and constructive technologies by modern architecture, transformed the aesthetic and functional aspects. There was a new building design concept: skin-skeleton building, envelope and structure had become dissociated. This characteristic allowed larger windows till the completely glazing facade, offer transparency and visual integration (Maragno, 2000). From the point of view of visual comfort, these larger windows are desirable. However, in hot climates, like in Brazil, it is very important to avoid as much of infrared radiation as possible, to minimize the greenhouse effect.

However, glazing is the easiest way for solar radiation to penetrate buildings. The glazing façade modifies the envelope relation of climate and internal condition, producing an overheating caused by glazing (Givoni, 1981). The use of transparent materials in building façades brings about the concern about environmental comfort and energy efficiency in buildings.

Direct radiation falling on and through the transparent surfaces on a building contributes disproportionate amounts of energy to the building's heat balance (Givoni, 1981). Glazing are selectively transparent to radiation. Clear glass transmits more than 80% of incident solar radiation and more than 75% of the visible light. (ASHRAE, 2001). The penetration of solar radiation indoors can be favorable and healthy or extremely unfavorable, depending on climate, season, building function and user's activity.

Regarding the quality of the solar radiation transmitted indoor, it is known that, from the total incident solar radiation in the fenestration system, a portion is absorbed, other reflected and the remaining, transmitted through the unprotected glass directly to the indoor environment. The proportions corresponding to the energies absorbed, reflected and transmitted vary according to wavelength, thickness, refrac-

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tion index of the glass and the angle of incidence of the radiation (Castro et all, 2005).

Solar heat gain consists of two components: the directly transmitted solar radiation through the fenestration, and the inward input caused by part of absorbed solar radiation by the fenestration elements systems themselves (Pereira and Sharples, 1991).

External shading devices are a passive design strategy to control solar heat gain in buildings, and influences energy performance. It can reduce solar heat gain more effectively than interior devices, and its efficiency depends on the provided shading (Olgyay and Olgyay,1957; ASHRAE, 2001). In hot climates, the use of shading devices is desirable, intercepting the unwanted solar rays of overheating period. These elements influence heat gain, especially in relation to location and orientation.

This research investigates the thermal performance of different fixed external shading devices, considering the elements largely used in modern architecture buildings of Brazil, between the 1930 and 1960 decades. The use of these architectural elements has a great importance in hot climates reducing the amount of direct solar radiation.

In this paper, the thermal performance of different fixed external shading devices is discussed. First, a literature review about shading devices, its functions and the aesthetics influence on Brazil builds. Then, the experimental set up is described. Finally, graphs and results are presented and discussed.

EXTERNAL SHADING DEVICES

Idealized by Le Corbusier in early XX century, the brise-soleil or sun-breaker, is a shading device, generally composed by one or more slats, parallel in most cases, external to the building (Corona and Lemos, 1972). This architect proposes the use of venetian blinds outdoors to intercept the solar rays before they reach the building envelope, mainly in openings and transparent or translucent façades. This use modifies the dimensional issues and position (Fathy, 1986), at larger scales to shield the entire façade.

Developed and intensely used by Brazilian Modern Architecture, the external shading devices respond to the necessity of solar radiation protection and light control. These elements can intercept the part of the incident solar radiation on glazing surfaces. The use of these architectural elements is desirable and has a great importance in hot climates, reducing the amount of direct solar radiation indoors easily allowed by glazing.

Besides function, in Brazil they acquire a great importance characterizing the buildings designed between the 1930 and 1960 decades, with significant aesthetic expression and deeply characterizing the Brazilian Modern Architecture buildings. It has been adopted by young Brazilians architects to control the excessive solar radiation and guarantee people comfort inside buildings. (Maragno 2000; Bruand, 2002).

This element can minimize the solar heat gain of building envelope, especially the openings and glazing surfaces. The importance of this passive device lays on the decrease of incident solar radiation on vertical surfaces, provided by its shade.

Its conception is based on functionality, although other functions are also characteristic: it modifies the appearance of buildings and can be a significant part of architectural conception and composition. The main idea is to providing an efficient shading system to the fenestration while at the same time improve an aesthetic appearance of the building facade.

Many of the buildings that are designed in hot climates tend to use window overhangs and vertical louvers as architectural elements to reduce direct solar radiation on the fenestration system while simultaneously having an aesthetic presence (Kapur, 2004).

The shading devices are considered important design parameters in hot climates, and must be carefully designed and oriented, maximizing shading during summer months to reduce solar heat gain, and allowing direct sun into the interiors during winter season to maximize solar heat gain. However, in hot climates the “winter” season generally could be a dry or wet season with warm temperatures. So, the overheating period is extended, and the need of shading is also present.

The use of shading devices is highly recommended, and their thermal benefits are recognized in several researches (Olgyay and Olgyay, 1957; Croiset, 1976; Givoni, 1981). The most commom studies were developed through geometry of sun movement and simulation studies, but they are just modeled to intercept the direct solar radiation. Although the type of material and surface properties of these elements affects the heat transfer through windows, the information available about complex fenestration systems evaluation is limited, especially information about their thermal properties.

It is also difficult to find reports about studies based in experimental data through measurements in field under real climatic conditions, to demonstrate their efficiency. The information available about the thermal performance of windows was mainly obtained from calculation and measurements under static laboratory conditions (Kapur, 2004).

The objectives of this research were to provide a comparative analysis of the thermal performance of different fixed shading devices under real weather conditions.

EXPERIMENTAL STUDY

The importance of this study is the quantitative evaluation, with the acquisition of measurable data, through test-cells under real conditions with a variety of devices and orientations, to verify their efficiency.

The typology and materials were selected considering the elements largely used in modern architecture buildings of Brazil, between the 1930 and 1960 decades.

The investigated devices were horizontal louvers, vertical fins and eggcrate, made of concrete and wood, fixed, on most problematic sun exposures under real weather conditions.

Study Area

This experiment was developed at School of Civil Engineering, Architecture and Urban Design of State University of Campinas (UNICAMP), Campinas. This city is locate in São Paulo state interior, Brazil, at latitude 22º54' S, longitude 47º03' W and altitude of 680m, and distances approximately 90 Km from São Paulo city. It has an area of 796,40 km^2 and 962.996 inhabitants, according of 2000 Brazilian census.

The climate of Campinas is classified as tropical continental Cwa by Köpen climatic classification, with a summer period from November to March, and winter from June to August. The summer is longer than winter, and therefore there is a predominance of hot season.

Although experimental studies were conduced into special conditions of investigation, this research can be extrapolated considering the statistical analyses and it validation. And also, there is an expressive population that lives in similar conditions of latitude, altitude, and climate. Only in Brazil, there is many medium cities that were located at this latitude. Other aspect that may be considerate is that the regions between the tropics, with their hot and tropical climates, contain most of the developing countries and most of world's population.

Description of the Experimental Setup

The experimental setup consists of six test-cells, each one with one kind of the shading device testing samples, and a meteorological station. Environmental parameters, indoor and surfaces temperatures were monitored.

Test-cells. The test-cells consisted of six test –cells built on a basis of concrete (3,20 x 3,70m), with walls of solid mud bricks (½ brick/10,0 cm thickness), white painted in the internal and external faces. The external dimensions were 2,20 x 2,70 m and the internal ones 2,00 x 2,50 m, with an area of 5,00 m^2, and ceiling height 2,40 m. The longer façades were oriented to north and south.

The roof was composed of vegetal fibre tiles white painted, with ventilated attic between the tiles and a concrete slab. Under the tiles, it has a thermal insulation foil. The use of foil and the white painting was to reduce the influence of the most exposed surface to solar radiation.

The test cell had two openings with dimensions 1,20 x 1,00 m and windowsill 1,10 m, north and west oriented. When one of the openings was analyzed a panel obstructs the other one. The panel had thermal resistance equivalent to that of the wall. There is no ventilation indoor. The glasses and equivalent panels are installed in a wood frame on the windowsill. The fenestration system consists of 4mm thick clear single glass, wood framing and the shading device sample in test. The glasses measure 0,86 x 1,06 m, with an area de 0,91 m^2.

Factors that were kept constant included the size of window unit, size of the external shading devices, and physical location of the shading devices in relation to the glazing.

One of the test-cells has colorless glass 4 mm width with no sunshades. It was used as reference for all measurements. This glass is completely exposed to solar radiation, and faces the same orientation as the others during the analyses period.

Shading devices testing samples. The fenestration system in test consists of 4mm thick clear single glass, wood framing and three different typology of shading device made of concrete or wood. The selected shading devices consider the most common geometric configurations in fenestration with shading current in buildings of Brazilian modern architecture.

The investigated devices were: horizontal louvers, vertical fins and eggcrate typologies (table 1), made of concrete and wood, fixed and distance 0,05m from the wall. The dimension of the slats of concrete and wood was 1,25 x 0,34m, and 0,025m width. The horizontal louvers had three slats, and the vertical fins had four slats, and both types each slat distant 0,38m from each other. The concrete eggcrate consists on 9 pieces of 0,40 x 0,40m.

The impact of the physical surface, such as texture of the sunshades, was not investigated in this study.

All the devices were gray painted with reflectance 50%, cause of different opinion found on literature review: some authors, like Fathy and Croiset, says that light color has better performance, but Givoni presents better results with black colored devices and no ventilation.

The shading devices were analyzed on two different orientation: on north and exposures, for a week in each façade, on summer and winter solstices, and equinox periods, under real weather conditions.

Table 1. The Shading Devices Samples

Test Cell	Protection Typology	Protection Material
A	Egg-crate	Concrete
B	Horizontal Lower	Concrete
C	Horizontal Lower	Wood
D	No Protection	—
E	Vertical Fins	Wood
F	Vertical Fins	Concrete

Equipment

An automatic meteorological mini-station for data collection, CR10X - Campbell Scientific Inc., was installed in the area. The sensors station records data of a variety of weather external conditions: dry bulb temperature, air moisture, global solar radiation, wind speed and direction, and rainfall. Data are recorded every 30 seconds, with averages every 10 minutes.

The station is also equipped with channels for connection of the thermocouples type T, to measure the surface temperature of glass and shading devices, and dry bulb temperature inside each test-cell.

There was one thermocouple inside the test-cells to monitor the indoor temperature. The others thermocouples measures the surfaces temperatures and were attached on the center inner surface of the sunshades (facing the glass), and the reference had one thermocouple attached to the center of the glazing.

The data recording for the experiment was done over a period of a year, being a week for each façade by season. Each experimental setup cells were monitored all day long, collecting data with an interval of 30 minutes, during one week on north façade, plus another week on west façade, for each season (summer, fall and winter, in dates near solstice and equinox). These dates were chosen to compare the measured results with geometric design of shading devices. So, the periods for data collection were: in summer, from the 10th to 18th January for north façade and from the 09th to 10th February for west façade; in fall season, from the 18th to the 25th March for west façade and from the 27th March to the 04th April for north façade. In winter from the 26th June to the July 01st July on west facade and from the 03rd to the 08th July for north façade.

RESULTS

Graphs (Figures 1 to12) shows the results for the investigated devices on north and west exposures, for a week in each façade, on summer and winter solstices, and equinox periods.

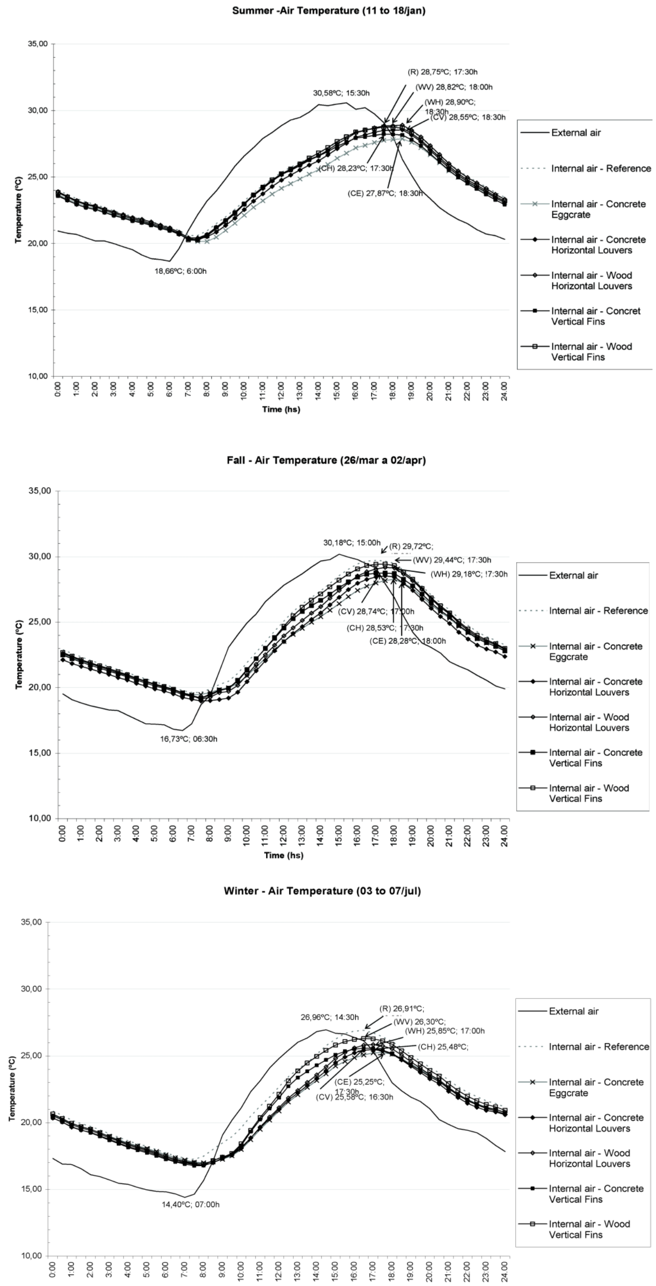
Results for Internal Air Temperature

The orientation of the façade has the great influence on the performance of the devices, and its typology responses for a better or worth performance. The material of the elements also influences the results, and concrete registered temperatures below than wood.

Results show that in all of the prototypes for north exposure, during the day, the internal air temperatures stay below external air temperature expresses. On west exposure, there is an hour witch the solar rays penetrate the fenestration system. Occur on summer and fall, and registered great difference on internal air temperature.

Results for the Device Surface Temperature

Besides orientation, the typology has the greater influence on surface temperatures, as well as the material.



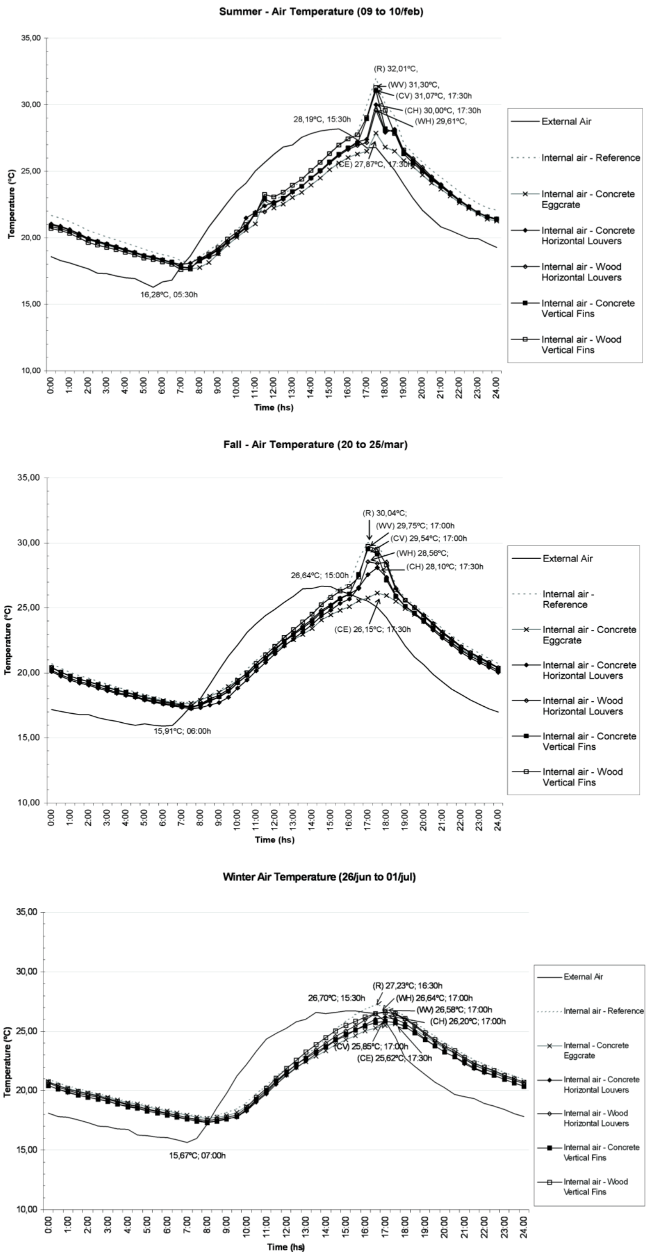
Figures 1, 2 and 3 *Internal air temperature for openings on north facade, by season.*

Although wood has good insulation properties, the concrete showed the best results.

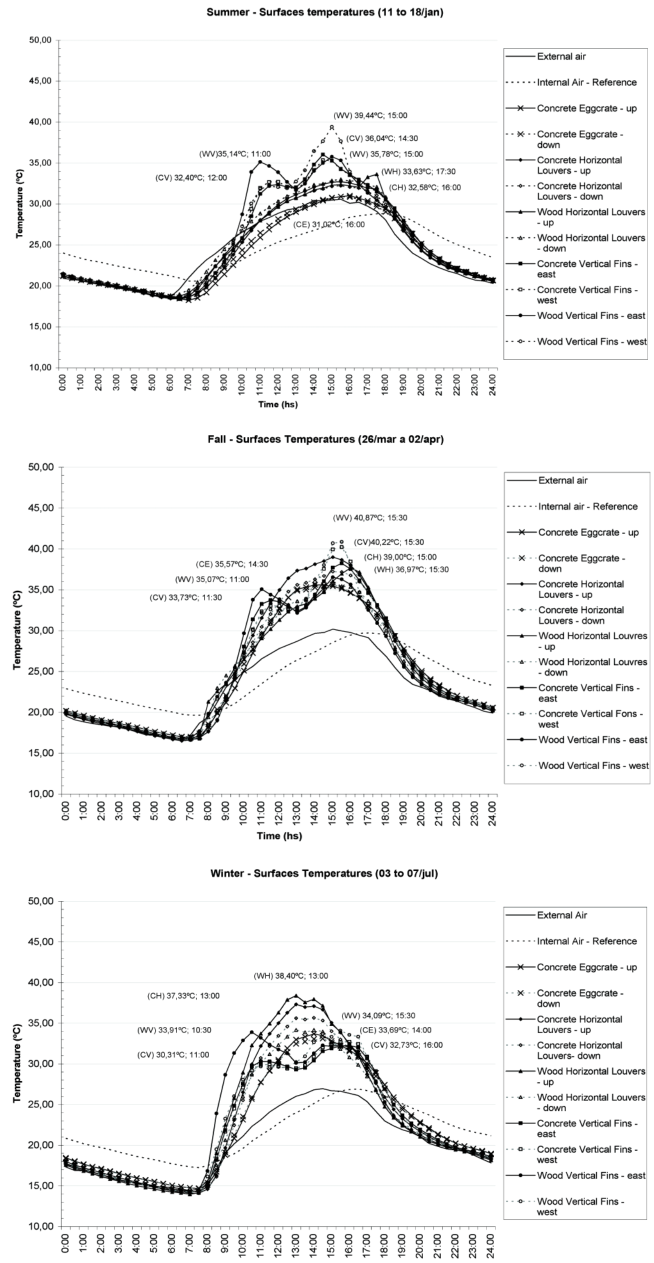
For north exposure, the typology is responsible for two typical performances; the horizontal louver shows a smooth curve and registered the maximum values, as the vertical fins present two picks along the day.

DISCUSSION

The most thermal efficient device in test is the horizontal concrete louver. This typology shows good results to west



Figures 4, 5 and 6 *Internal air temperature for openings on west facade, by season.*



Figures 7, 8 and 9 *Surface temperatures for tested elements on north facade, by season.*

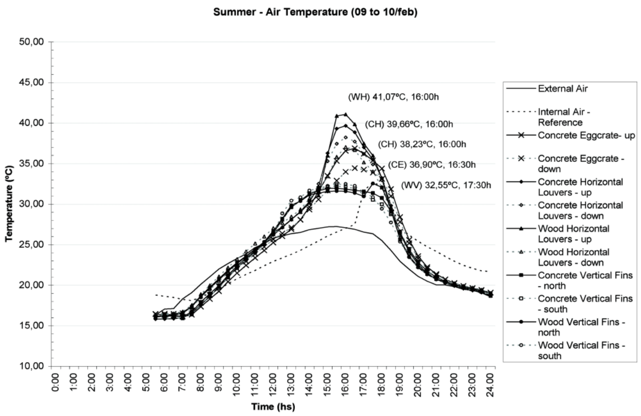
façades, better than the vertical fins, which are usually recommended when geometrical graphical design is applied.

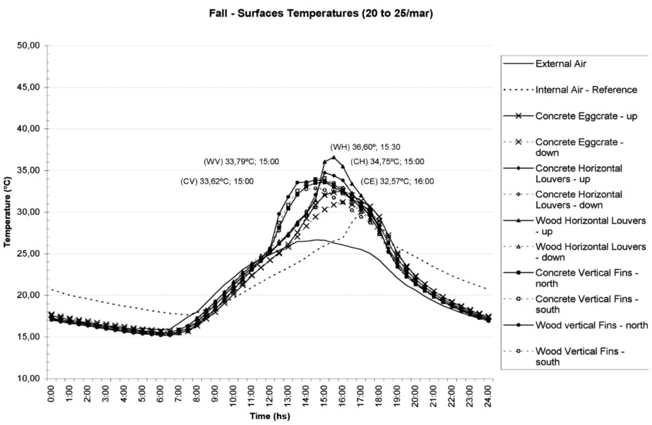
By comparing the collected data through different seasons, the worst performance is registered by the vertical wood fin, which shows temperatures values similar to the reference prototype (without protection). The vertical typology presents a less efficient performance, even in exposure to west. In spite of this fact, this typology facilitates the air circulation, and consequently heat loss.

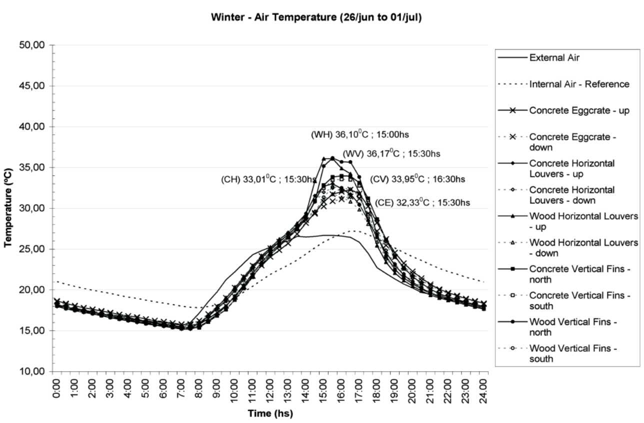
In the west orientation the shading device, whatever its tested typology, does not intercept the solar rays almost perpendicular to the façade. In graphical analysis, it can be seen null efficiency.

Usually references about architectural design indicate recommendations concerning only the orientations of the façade, without relation to latitude. Even when latitudes are considered, there are no references to the materials of the shading device.

Depending on the obstruction area of the transparent surfaces, each one will show different response to maximum temperature and to time lag, especially in west façades. This fact is not considered on graphical analyses, even in such a complete study as Olgyay charts.







Figures 10, 11 and 12 *Surface temperatures for tested elements on west facade, by season.*

The research in the prototypes aimed to detect, in a real situation, the effect of radiation absorption, in elevating their temperatures and so contributing to the heat gain inside the ambient.

It is important to remark that the evaluation of efficiency of the shading devices considering only graphical analysis method is incomplete, since it does not take into account the influence of built material, the near infrared radiation and the longwave radiation emitted by the devices. This also greatly influences the performance, and should be considered on devices design.

Shading devices can be designed in multiple shapes, sizes and materials. Many researches intended to compile some basic rules to make easier architects decisions. However, they are usually shown as topics which many times do not consider latitudes information or are incomplete. It is necessary to review this generic recommendation and to clarify the site presupposition, maybe with a quick reference guide with schematic solar charts, orientation and latitude information, giving recommendations of type, movable and material solutions more adequate for the site necessities.

CONCLUSIONS

Results show the relationship of orientation, typology and material of tested devices. The most significant response was obtained by horizontal concrete louver on north façade. In spite of the good insulation properties of wood, the concrete devices presented the best results.

In relation to devices materials, concrete presents the best performance; although it was expected that wood could be better, due to its low thermal conductivity. It is shown that different kinds of devices, with the same material, and equal shading mask, do not result in equal efficiency.

The external shading devices made of materials with high thermal mass and capacitance absorb and retain short-wave solar radiation during the day. This stored heat is finally released or re-radiated to the atmosphere and its immediate surroundings later in the day as long-wave radiation.

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