Thermal performance of different glazing surfaces in a hot climate

A.P.A.S. Castro, L.C. Labaki and G.C.R. Gutierrez
School of Civil Engineering, Architecture and Urban Design, University of Campinas, Brazil

R.M. Caram de Assis
Department of Architecture and Urbanism, University of São Paulo USP, São Carlos, SP, Brazil

ABSTRACT

This paper describes an experimental study about thermal performance of different glazing materials in prototypes. In Brazil, due to its low latitudes and predominantly hot and humid climate, high solar radiation provokes strong heat gain in almost all the regions of the country. The worst building exposure conditions are on north and west façades. In previous work, the transmissivity to solar radiation for the more frequently used window glasses in buildings in Brazil was obtained through spectrophotometric analyses. The aim of this work is to study the behaviour of transparent materials regarding solar heat gain, through measurements in prototypes. Thermal properties of different float and reflective glass samples were analyzed, through data collection of ambient and surfaces temperatures. Glazing façade was west-oriented. There was no ventilation indoor. Results show that in all cases, during daytime, the internal air temperatures stay below external air temperature. A difference of up to 3ºC in the indoor air temperatures of prototypes was observed. Thermal-absorbent glasses present high surface temperatures, due to absorption of solar radiation, but in spite of that, they show a significant decrease in indoor air temperature.

1. INTRODUCTION

Buildings with exterior walls consisting mainly of glass façades are a worldwide phenomenon. In the last two or three decades, however, studies are pointing to problems of environmental comfort caused by glazing (Lechner, 1991). Depending on the geographic orientation and the optical characteristics of the glasses, 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 via air-conditioning of the building.

One of the primary functions of buildings is to provide shelter for human beings. They function like a filter of the external environment, by excluding undesirable conditions and allowing the penetration of those that can be advantageous for the building user. The penetration of solar radiation indoors can be favourable and healthy or extremely unfavourable, depending on the climate, season, and the function of the building, as well as the user's activity.

Glazing is the easiest way for solar radiation to penetrate buildings. From the point of view of visual comfort, the penetration of solar radiation indoors is 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.

Glasses like other transparent materials are selectively transparent to radiation. Window glasses transmit short-wave radiation that is absorbed by internal surfaces of buildings. These become heated and consequently emit long-wave radiation, for which glasses are opaque. This so called greenhouse effect is responsible for most of the heat gains due to window facades.

Regarding the quality of the solar radiation transmitted indoor, it is known that, from the total incident solar radiation in the glass, a portion is absorbed, other reflected and the remaining, larger, transmitted directly to the indoor environment. The proportions corresponding to the energies absorbed, reflected and transmitted vary according to wavelength, thickness, refraction index of the glass and the angle of incidence of the radiation. Therefore, each type of glass has characteristic transmittances to solar radiation, as a function of the region of solar spectrum. An ideal glass for tropical regions should be that one with a high transmission to visible radiation and low transmission to infrared.

Caram de Assis (1996 and 1998) through spectrophotometric analyses obtained the transmissivity to solar radiation for the more frequently used glasses in buildings in Brazil.

The aim of this work is to study the behaviour of transparent materials regarding solar heat gain, through measurements in prototypes. The analysed elements: float and reflective glazing of different colours were installed in west façade.

2. GLAZING SAMPLES

Nowadays, there are different types of glasses, obtained through a variety of treatments, applied on different types and thicknesses. These treatments can be combined and result in products such as laminated, reflective or multiple glazing. Recent technological advances have searched for solutions to control heat gain in hot seasons.

Coloured glasses, due to the addition of oxides in the glass composition, absorb solar radiation selectively in relation to intervals of wavelengths; this is why they have different colours. The increased absorption causes a reduction in the transmission of the glass. The amount of absorbed radiation depends also on the thickness of the glass.

The reflectivity of the glass depends basically on the incidence angle, and also of the index of refraction of the glass. Since the refraction index is always the same for glasses used in building facades, reflectivity is the same for all of them, except for reflective glasses.

In this work the tested samples were float, sputtered reflective and pyrolitic reflective glasses.

2.1 Float glass

Float glasses may be coloured or not. They do not present optical distortions; generally have homogeneous mass and uniform thickness. Float glasses are recommended for those places with the need for a very good visibility and high daylight transmission. Their optical quality may be compared to old valuable crystal, product of handmade fabrication. More than 90% of glasses produced in the world are float.

Float glasses are also used as raw material for the production of other types of glass, like reflective and laminated glasses. The optical properties of 3 mm float colourless glass are usually adopted as standard for other transparent materials.

Coloured glasses are produced by the same system of the colourless glasses, with the incorporation of addictive minerals to the vitrifiable mixture, in agreement with the desired colour. One can mention selenium (Se), iron oxide (Fe_2O_3) and/or cobalt oxide (Co_3O_4), for the production of the green, bronze and grey glasses, respectively (Santos, 2002).

The main purpose of the coloured glass is the reduction of the solar transmittance, through the absorption of a great portion of the incident energy, so reducing the direct solar heat gain, as well as the glaring inside the building. Therefore, it is also known as heat-absorbing glass.

2.2 Reflective glasses

The reflective glasses have the function of filtering the solar rays through the selective reflection of the incident radiation in relation to the frequencies. They can be produced from the float colourless or coloured glass, by receiving in one face a layer of metallic oxides (or salts).

Nowadays, two processes are used: vacuum-sputtered reflective and pyrolytic reflective glasses.

2.2.1 Sputtered reflective glass

In the process of vacuum sputtering, the reflective layer is deposited in cameras of high vacuum, through ionic bombing and in plasma atmosphere.

The result of this process is reflective glasses with good solar protection, and a reflective layer in one surface. For this type of glass this layer must be placed facing the indoor ambient, thus providing larger comfort and savings, through the control of daylight and heat admission.

2.2.2 Pyrolytic reflective glass

In pyrolytic glasses, the reflective layer is applied in the superior face of heated glass. In that way, the oxides penetrate a little in the surface so that the reflective layer becomes very resistant.

These glasses are not so efficient to radiation protection. Generally the external reflectivity is greater, so that the relationship internal/external reflectivity is better. These glasses show a high luminous transmission. To obtain a larger thermal efficiency, the treated surface should be placed facing the exterior, thus offering privacy during the day, obstructing the vision to the interior.

3. MATERIALS AND METHODS

3.1 Study area

The research is performed in the city of Campinas, Brazil, at latitude 22º54' S, longitude 47º03' W, and altitude 680m. The climate of Campinas is classified as tropical continental, 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.

3.2 Equipments

An automatic meteorological mini-station for data collection, CR10X, from Campbell Scientific Inc. was installed in the area. Data are recorded every 30 seconds, with averages every 10 minutes.

The station sensors record the following external atmospheric elements: air temperature, relative humidity, direction of predominant wind, wind speed, global solar radiation, and rainfall.

The station is also equipped with channels for connection to thermocouples type T, to monitor in the prototypes the following parameters: surface internal and external temperatures of the glass, surface internal and external temperatures of the wall, dry bulb temperature inside the model.

3.3 Description of the prototypes

The six prototypes (Fig. 1) were built on a basis of concrete (3,20 x 3,70m), with walls of solid mud bricks (½ brick/0,10m thickness), white painted in the internal and external faces. The external dimensions are 2,20 x 2,70m and the internal ones 2,00 x 2,50m, with an area of 5,00m^2, and ceiling height 2,40m. The longer façades are oriented north and south.

Figure 1: The prototypes

The prototypes have two openings, with dimensions 1,20 x 1,00m, and windowsill 1,10m, oriented to north and west. When one of the openings is analysed, the other one is obstructed by a panel with thermal resistance equivalent to that of the wall. In this work, results are presented for opening facing the west.

The glasses and equivalent panels are installed in a wood frame on the windowsill. The glasses measure 0,86 x 1,06m, with an effective area of 0,91m^2.

One of the prototypes has colourless glasses 4mm width, used as reference for all measurements. All the glazing samples tested have 4 mm width.

3.4 Glazing samples

In this work, results are presented for the following glasses on west façade.

- Colourless (float, 4 mm); reference
  Float glass group:
- Green; brown (bronze); and grey.
  Reflective pyrolytic glass group:
- Green; brown (bronze); and grey.
  Sputtered reflective glass group:
- CEB blue medium 130; and CEB blue intense medium 114.

4. RESULTS

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

For each period of analyses, the hottest and the coldest days the periods of measurement were selected, since the analysis of different climatic situations allows a general understanding about the behaviour of the glasses.

In the period from March, 08 to 15, 2004, the float glasses monitored. The presented graphs correspond to March, 9 and March, 15, the hottest and coldest days of the period respectively.

In the period from May, 07 to 14, 2004, the reflective glasses were tested together with the reference (colorless float). In the same way, the graphs are presented for May, 10 and May, 12, also the hottest and coldest days of the period respectively.

4.1 Results for float glasses

The analyzed parameters are: the temperature of the external air, the internal temperatures of the prototypes and surface temperatures of the glasses. Figures 2 to 5 show the results for float glasses, respectively glass surface temperature and dry bulb temperature indoor, as well as external air temperature, for the two selected days.

4.2 Results for reflective glasses

Figures 6 to 9 show the results for reflective glasses, respectively glass surface temperature and dry bulb temperature indoor, as well as external air temperature, for the two selected days.

5. DISCUSSION

Results show that in all of the prototypes, during the day, the internal air temperatures stay below external air temperature. The heat-absorbent glasses (green, gray and bronze) are less transparent to solar radiation than the colourless glass, since the absorbed portion of radiation is significant. As a result their surface temperatures are increased, so that they work as a kind of "radiator", re-emitting heat to the interior of the building. In spite of that, a difference of about 3ºC in the indoor air temperatures of the prototypes was observed, showing a decrease in indoor air temperature when reflective glasses are used.

The same behaviour is observed for float coloured glasses, which show higher surface temperatures and smaller indoor temperatures.

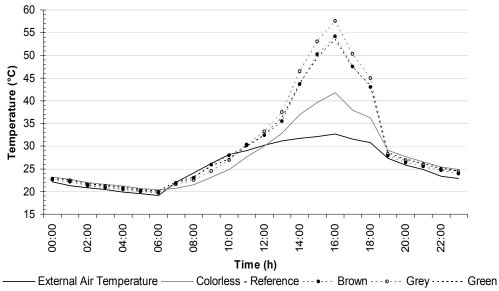

Figure 2: Glass surface temperature, 03/09.

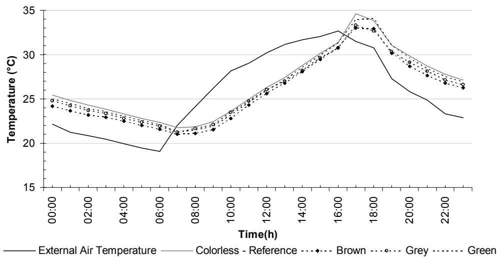

Figure 3: Dry bulb temperature indoors, 03/09.

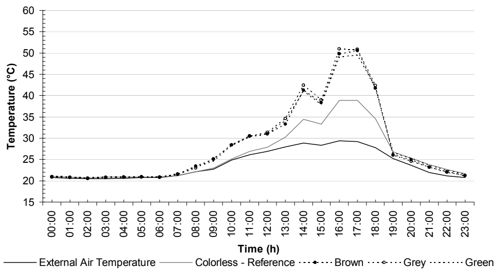

Figure 4: Glass surface temperature, 03/15.

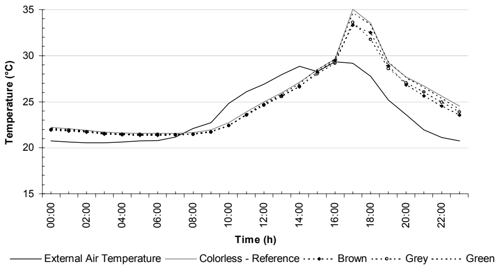

Figure 5: Dry bulb temperature indoors, 03/15

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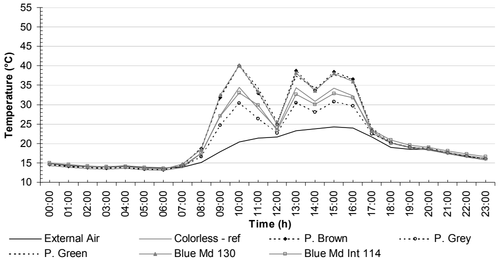

Figure 6: Glass surface temperature, 10/05.

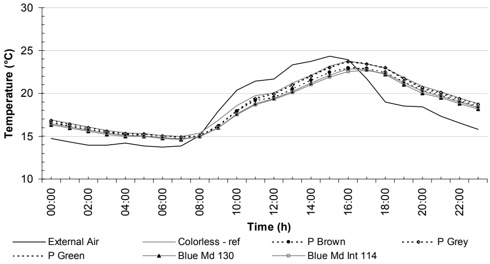

Figure 7: Dry bulb temperature indoors, 10/05.

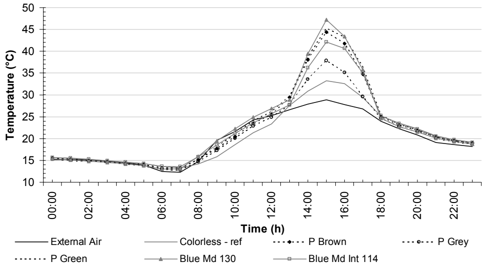

Figure 8: Glass surface temperature, 12/05.

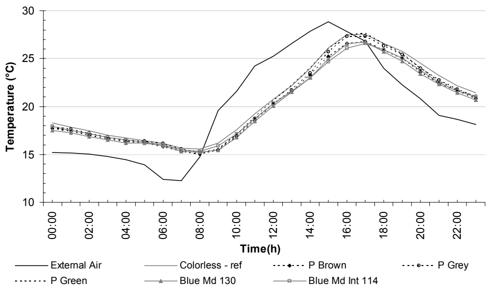

Figure 9: Dry bulb temperature indoors, 12/05.

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