THERMAL ANALISYS OF AVAILABLE WHITE COATINGS IN BRAZIL

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Abstract *In general, lands between the tropic lines receive a great quantity of solar radiation all months during the year. However, countries in this area do not usually have financial resources to develop building technologies. Horizontal surfaces in houses are more exposed to sun radiation than other building elements in tropical and subtropical regions. Some countries located in high latitudes have developed technologies or improvements to reduce the heat gain into the buildings such as coatings with high solar reflectance or pigments that change colour when exposed to solar radiation or materials which change their physical condition according to heat transferring. These advanced technologies are not available in Brazil yet. This research is about two kinds of white coatings which are available in Brazil, one ordinary and another with indication to thermal attenuation on roofing. The purpose is to verify thermal behaviour of main commercial paintings which are indicated to be applied on horizontal and vertical surfaces. For this study, acrylic and impermeable painting were applied on the roofing. NTC sensors, with scale from -25ºC to 70ºC, were affixed in the underside of materials and the internal surface temperatures of coatings were monitored. Each sensor was connected to a portable individual mini data logger with precision of +/- 0.3ºC. Climate data were collected each ten minutes at the meteorological station of the Agronomic Institute of Campinas (IAC). The experiment was carried on some months during the year. Results show a decrease in surface temperature of white coatings compared to the original coating, according to local environment conditions. Adverse surface temperatures were registered on impermeable coatings. These results allow the conclusion that the use of white coatings requires more information than available on labels or company websites. In most cases, Chemical components are generically described on the products which make their application uncertain. There is incomplete information in some cases which may induce consumers to choose a non-appropriate option to optimize the decrease of roofing solar heat gain into the buildings. It is tightly recommended to study the consequences of exposure of coatings to UV radiation for more time and to monitor thermal behaviour.*

1. INTRODUCTION

For scientists of tropical countries, the main goal in energy efficiency and thermal comfort of users in buildings is to obtain coatings which absorb less solar radiation and/or infrared radiation. The thermal behaviour of buildings depends on several agents such as implantation, orientation, materials and constructive components. It should consider the local climatic conditions, in considering that the built environment acts as a control mechanism of the climatic variables, through the building envelope (walls, floor, roofing and openings) and the nearby climatic elements (presence of water masses, vegetation, buildings in neighbourhood, soil type and others) to provide indoor comfort and energy saving to acclimatization.

In particularly, Brazil has made efforts to develop standards, build code and regulations to minimize discomfort and energy saving in buildings exposed to climate conditions. Many sectors are involved in bringing about new habits and strategies for users and designers, as well as testing concepts and ideas developed in other countries and adapting them to local climate conditions. While some countries develop latest technologies and advanced solutions, others like Brazil have had its standard for houses up to two floors for the last 10 years where there are recommendations about traditional materials to be applied in the envelope. Recently, procedures to other kinds of buildings have been developed; however, it is just in the begging. More scientists are requested to monitor and investigate the several ways to construct, different and available constructive materials and Brazilian climate conditions.

In this context, roofs are the constructive components which receive the strongest thermal load of solar radiation for a long period during the day. The aim of this paper is to present the thermal behaviour of white coatings monitored in subtropical climate.

2. BRAZILIAN BIOCLIMATIC ZONING

A country as Brazil, with a great area of its territory in tropical zones, several thermal comfort and energy saving requirements become a challenge for designers.

In this direction, many efforts have been made to improve the Brazilian regulation that considers recommendations and guidelines for residential constructions up to 2 floors. This regulation brings details of strategies for passive thermal conditioning and for that it proposes the territorial division in eight zones with similar climatic conditions (Fig. 1). It also supplies data about thermal resistance, thermal delay and other thermal properties for most of constructive materials and components used in the country, as well as their combinations for horizontal and vertical surfaces on the envelope.

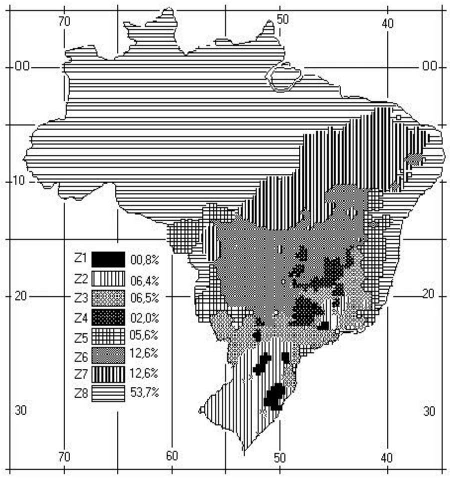

Figure 1. The eight Brazilian bioclimatic zoning.

Brazilian zoning regulation is based on ASHRAE's comfort parameters and Givoni's Bioclimatic Chart as shown in Fig. 2 for bioclimatic zone 3 where the city of this study is located [1]. The standard provides a Bioclimatic Chart for each zone, as well as recommendation for designers. In Fig. 2, each letter corresponds to specific strategies to obtain thermal conditions. Letters "F" and "I" refer to passive cooling in warmer months, letters "B" and "C" refer to passive techniques to achieve comfort in colder months in bioclimatic zone 3. Crossed ventilation and preventing heat transfer through envelope are passive strategies for summer period. Best orientation and site implantation are proposed to optimize solar heat gain during the winter, thus, including heavy internal walls which may contribute to indoor comfort. Details of each strategy have several combinations of constructive materials which observed thickness and thermal conductibility, but there is no mention about the kind of coatings such as use of clear colours of materials or painting on roofing.

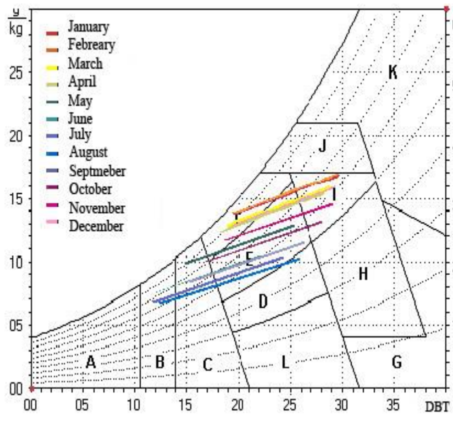

Figure 2. Bioclimatic chart for zone 3 (the zone for the city of Campinas)

Nevertheless, there are yet few studies about passive techniques when considering Brazilian territory dimensions. Unfortunately, this fact contributes to stimulate indifferences between designers and civil construction professionals to apply energy saving design solutions as well as to motivate the regional architecture for improvement on indoor thermal comfort.

3. COOL ROOFS

Passive cooling of buildings is not a new concept - several civilizations have applied it in some ancient age. It was a specific technique useful for the particular location that made buildings peculiar and comfortable in thermal conditions. Several data about passive techniques available to apply in building envelope, mainly roofs, have their publications concentrated in the last 20 years [2], [3], [4], [5], [6], [7], [8], [9].

Using colours which reflect more than absorb is one of the passive strategies to obtain less thermal load into buildings. However, the use of colours in roof interferes significantly in increasing the albedo in the urban context. White or clear coatings may contribute to lessen the effect of heat island. However, when it is discussed about making every roof a white surface, some authors affirm that action mainly when it is applied in low and horizontal buildings because it may result in a visual discomfort for users in skyscrapers due to great reflective surfaces [10].

According to the ASTM 1980-01 regulation, there are two roof categories when referring to energy efficiency. One is plane or low inclination roof and the other has an inclination larger than 9.5º. In Brazil, plane roof or roof with low inclination is applied in simple houses, garages, commercial and industrial buildings. On the other hand, roof with larger inclination is applied in residences, which commonly have ceramic tiles and around 30º of inclination [11].

Coating materials that have high solar reflectance are denominated "cool" or "selective" coatings. These coatings absorb less heat in a certain region of electromagnetic spectrum when exposed to solar radiation. They present lower superficial temperatures in relation to the same ordinary material despite having the same appearance. The use of passive techniques or the development of technologies for "cool" or "selective" coatings may contribute to obtain efficiency on roofing.

Presence of "cool" tiles and paintings with reflective pigments are more common in some countries in North America and Europe than in Brazil. Energy efficiency on roofing should have preferentially high solar reflectance and/or long waves high emissivity. To obtain low superficial temperatures in roof material exposed to solar radiation implicates it should provide smaller heat penetration to the building and less heat load to remove preserving indoor thermal comfort conditions. Therefore, high solar reflectance is obtained from the material ability to reflect more solar radiation in relation to incident solar radiation into the material. On the other hand, the high emissivity to long waves is obtained through surface ability to lose energy of total absorbed solar radiation. Both material properties are related to physical characteristics of material.

Solar reflectance is commonly measured with a pyranometer, spectrophotometer or a reflectometer. According to methodologies proposed by ASTM E903-1996 EN 14500, CIE130-1998 and ASHRAE 74-1988 it is common to have a spectrophotometer for obtaining solar reflectance index in homogeneous surface, however there are possibilities to obtain it using a portable solar reflectometer through procedures described in ASTM C1549-2002 or using a pyrometer according to ASTM E1918 -1997. In case of surfaces have heterogeneous characteristics due to actions of weather conditions there are procedures in Cool Roofing Rating Council to obtain reflectance index using a portable solar reflectometer by CRRC-1 Test Method #1 [12]. The use of pyrometer is recommended for wrinkled and not uniform surfaces through methods described in ASTM E1918 -1997. The ASTM C1371-04 and the ASTM E408 bring procedures used to determinate the thermal emissivity through portable emissometer use, as well the EN 12898 describes methods using the infrared spectrometer of Fourier [13]. However, according to some authors, for the determination of solar reflectance, there are several uncertainties in these procedures that involve or example samples, geometries, temperatures and others [11].

However, there is no standard to reflective measure procedures as much as materials or coatings with reflective or selective properties available to sell in Brazil as there are in others countries. Because of this, two ordinary paintings available on market were selected for this thermal behaviour study and they bring no information about this kind of properties.

4. METHODOLOGY

The study was performed in the city of Campinas, Brazil, at latitude 22º54' S, longitude 47º03' W, altitude 680m, located in the southeast region of the country (Fig. 3). The climate of the city is classified as subtropical or tropical continental. It has a summer period from October to March with rainy concentration from December to March. There is a mild winter from June to August predominantly a dry period. The summer is longer than winter, and therefore there is a predominance of warm period during the year.

Figure 3. Campinas location on Brazilian map.

The experiment was carried out on a roofing of 11.0 m x 4.5 m. The monitored roofing is made of fibber cement tiles with 2% of inclination. There is an open area under the roof. It was divided in three parts: two received clear coatings: impermeable white and acrylic white painting. The third part was the reference area: natural coating of tile. Both white paintings are available on market and they do not bring special reflective or selective pigments. They are ordinary paintings indicates to external walls and roofs.

Figure 4. Roof area: natural coating, white impermeable and acrylic paintings.

Air temperatures were collected each ten minutes at the meteorological station of the Agronomic Institute of Campinas (IAC) [14]. NTC surface temperature sensors, with scale from -25ºC to 70ºC, were affixed in the underside of the tiles. The sensors were covered with a fixed layer of expanded polystyrene to avoid the influence from outside temperatures. Each sensor was connected to a portable individual mini data logger with precision of +/- 0.3ºC (Fig. 5). There is no shading over the roofing from the neighbourhood, mainly in the afternoon. Data were collected at each ten minutes in November during the warm period and also in June during the mild winter.

Figure 5. Surface temperature sensor under tiles and mini logger.

5. RESULTS AND DISCUSSION

Roofing was monitored in two periods (November and June) for comparison of thermal behaviour of coatings. *AirT* was used for air temperatures curves (°C), *Imp* for impermeable white coating (°C), *Acr* for acrylic white coating (°C) and *Nat* for natural coating of tiles (°C). In Figure 6, temperature curves of coatings show that impermeable white painting and natural coating had a similar thermal behaviour during the day while acrylic coating had small values of surface temperatures on tiles. The differences between white coatings presented a variation from 2°C to 4°C in warmer hours. Air temperature curves presented maximum values around 34°C and minimum around 16°C which shows there was a thermal variation of 17°C in 24 hours. However, both white coatings presented smaller values than natural coating at night. Tiles that suffered modification of its natural coatings presented thermal behaviour similar to air temperature curves at night to data collected in November.

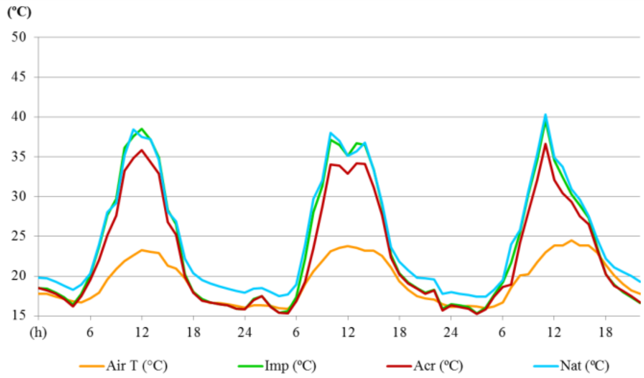

Figure 6. Surface temperatures of tiles and air temperatures in November.

When the same experiment was monitored in June, the cold period, temperature curves showed differences between coatings during the day as shown in Fig. 7 shows. Impermeable tiles reached values of surface temperatures around 45°C and 46°C while acrylic tiles reached values around 35°C and 36°C (10°C between white coatings). Natural tiles presented a variation from 31,5°C to 33°C and air temperatures curves have presented a maximum value of 25°C and minimum of 11,5°C, a thermal variation around 13ºC in 24 hours. During the night, all monitored tiles presented very similar thermal behaviour and have small values of air temperatures.

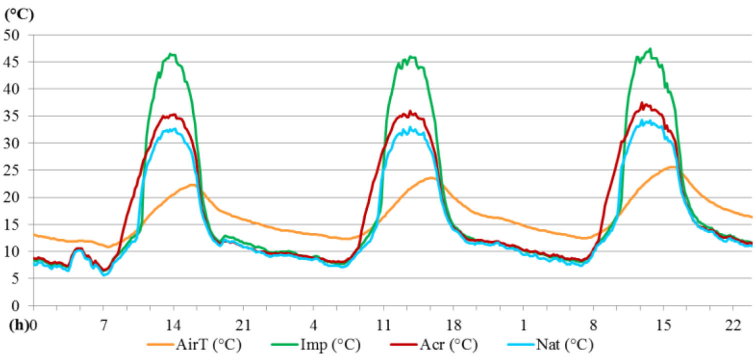

Figure 7. Surface temperatures of tiles and air temperatures in June.

6. CONCLUSION

Thermal analyses of surface temperature curves allow to draw two statements. First, even tiles being exposed to solar radiation and having reached high temperatures, at night and with small values of air temperature, all tiles presented very similar temperature curves. This fact indicates that in spite of its modified coating, the smaller air values of air temperature the more easily thermal loss of material to environment.

The last condition is, despite of white coatings have the same appearance, the difference in chemical composition may permit impermeable coating to have more similar thermal characteristics to natural tile than acrylic coating. And as it was presented in June, the impermeable coating did not reach the same maximum values of natural tile and even both coatings begin rising their surface temperatures at the same moment.

Surprisingly, the impermeable coating is sold in Brazil as ordinary painting and its label informs that it is specially recommended for roofing because it can attenuate thermal load transferred into tile. There is no reference to selective or reflective properties in its chemical components related on the label. On the other hand, the acrylic coating is also an ordinary painting indicated to external surface and on its label there is no thermal recommendation.

This fact shows 2 aspects about Brazilian civil construction. When this study was done there were no special paintings available in the market (either selective or reflective properties). In this direction, information about chemical components was minimum and general on the labels, which disable a common person to decide which one is better to buy. And maybe the most important is when there was information on the label it could induce to false conclusion about thermal behaviour as impermeable painting has not showed the best conditions to attenuate surface temperatures. Then, it is necessary to unite efforts to regulate which kind of information should be on painting labels and this information should have conditions to explain and help its application. In addition, time of exposure to solar radiation (ultraviolet radiation and near infrared) and polluted environment may modify values of the thermal behaviour as well as it is necessary to add chemical analysis in future studies.

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REFERENCES

[1] Associação Brasileira de Normas Técnicas – ABNT (2005): Norma Técnica 15220-3. Desempenho Térmico de Edificações. Parte 3 Zoneamento bioclimático brasileiro e diretrizes construtivas para habitações unifamiliares de interesse social, ABNT, Rio de Janeiro, pp. 1-23

[2] H. B. Cheikh, A. Bouchair, "Passive cooling by evapo-reflective roof for hot dry climate" *Renewable Energy*, n. 29, pp. 1877–1886, 2004.

[3] H. B. Cheikh, A. Bouchair, "Experimental studies of a passive cooling roof in hot

arid areas" *Revue des Energies Renouvelables,* vol. 11, n. 4, pp. 515 – 522, 2008.

[4] B. Givoni, "Experimental performance of the cooling shower tower in Japan" *Energy and Buildings*, n.28, pp.25-32, 1998.

[5] B. Givoni, "Performance of the shower cooling tower in different climates" *Renewable Energy*, v.10, n.2/3, pp. 173-178, 1997.

[6] K. Kant, S. C. Mullick, "Thermal comfort in a room with exposed roof using evaporative cooling in Delhi" *Building and Environment*, v. 38, pp.185 – 193, 2003.

[7] R. Tang, E, Etzion, E. Erell, "Experimental studies on a novel roof pond configuration for the cooling of building" *Renewable Energy*, n. 28, pp. 1513-1522, 2003.

[8] R. Tang, E, Etzion, "Cooling performance of roof ponds with gunny bags floating on water surface as compared with a movable insulation" *Renewable Energy*, n. 30, pp. 1373-1385, 2005.

[9] E. Bozonnet, M. Doya, F. Allard, "Cool roofs impact on building thermal response: A French case study" *Energy and Buildings*, n. 43, pp. 3006–3012, 2011.

[10] S. Boixo, M. Diaz-Vicente, A. Colmenar, M. A. Castro, "Potential energy savings from cool roofs in Spain and Andalusia" *Energy*, n. 38, pp. 425-438, 2012.

[11] R. Levinson, H. Akbari, P. Berdahl, "Measuring solar reflectance—Part II: Review of practical methods" *Solar Energy*, n. 84, pp.1745–1759, 2010.

[12] Cool Roof Rating Council – CRRC (2012): CRRC-1 Test Method #1: Standard Practice for Measuring Solar Reflectance of a Flat, Opaque, and Heterogeneous Surface Using a Portable Solar Reflectometer, CRRC, Oakland, pp.1-5.

[13] M. Santamouris, A. Synnefa, T. Karlessi, "Using advanced cool materials in the urban built environment to mitigate heat island and improve thermal comfort conditions", *Solar Energy*, vol. 85, pp. 3085-3102, 2011.

[14] Instituto Agronômico de Campinas – IAC (2010): Séries históricas de dados meteorológicos de Campinas, IAC, Campinas.