The impact of the warmth thermal sensation into non-air-conditioned and naturally ventilated office environments of tertiary refurbished buildings in tropical climate

T.C.F. Queiroz-Gaudin*, L.E.G. Bastos

Universidade Federal do Rio de Janeiro, Faculdade de Arquitetura e Urbanismo, Programa de Pos-Graduação em Arquitetura/PROARQ, RJ, Brasil

ABSTRACT

This paper provides a research about rapid methods and simplified tools to assist the project actors, such as architects, designers and engineers, involved in the building design, in the earliest conception during the preliminary design. We examine the quality criteria of indoor thermal environment in non-residential existing buildings, with failure in the pre-energy conservation. The main objective is how well to predict a mean thermal comfort sensation for workers under warm conditions over the tropical climate. The occupants could change their activity (metabolic rate) and their clothing. The approach is to apply an available quality about the warmth thermal comfort sensation in a typical design-base of a traditional refurbished industrial building, non-air-conditioned, to be re-used for an office building. The study has been based as an extension of the predicted mean vote model (PMV) (Fanger and Toftum, 2002). The extension combines the best of the PMV model's classical thermal parameters, adjusted to a proper activity, with impact on the human metabolic rate and taking into account an adaptive model, including an expectancy factor to a new PMV, adjusted for climate expectation. Thermal simulations have carried out by dynamical computer codes, examining established discomfort weather and focusing the correlations between building opaque and glazing envelope characteristics and the operative temperature variances. Simultaneously, we calculate the available new extension of the PMV for same discomfort sequence. The numerical results are modelled in graphics to demonstrate tendency curves.

INDEX TERMS

Comfort; Energy conservation; Envelope; Office building; Operative temperature

INTRODUCTION

Most of the traditional buildings which have been built in urban regions, both in Europe and South America, during the first decades of the 20th century are degraded and, simultaneously, failing on the fabricated components of building envelopes by corrosion (roof, opaque and glazing envelopes). Most of these were typical industrial buildings.

Each traditional industrial building has its unique architectural, engineering and energy performance related characteristics and a possible retrofitting action can be necessary. The retrofitting actions in this type of buildings are to improve the indoor environment and reduce the energy consumption. Besides, the retrofit would provide low environmental impact and indoor quality, from life cycle of building sustainability and, economically, cost less than demolition to construct a new building.

Our approach is to apply an available quality about the warmth thermal comfort sensation in a typical design-base of a traditional refurbished industrial building, to be re-used as an office building. We focus on the envelope, which contains all the opaque (walls, roofs, floors, doors) and non-opaque (glazing windows) components of the building. The building envelope

* Corresponding author. E-mail: teresaq@amcham.com.br

is an important element related with the building's energy conservation. It separates the indoor and the outdoor environments. Retrofitting actions can improve heat exchange between the indoor building and the outdoor environment. It can reduce the heat transfer through the building envelope components and provide natural air infiltration, as well as the control of solar radiation.

In this work, we consider the warmth thermal comfort sensation in a tropical climate, taking into account an expectancy factor for workers in non-air-conditioned buildings. These workers are typically people who have been living in warm environments indoors and outdoors. This conception is based on a new extension of the PMV model (Fanger and Toftum, 2002). In our case study, it is used as a passive HVAC system of heating, cooling and ventilating.

METHOD

Our method concerns to evaluate a building design prototype, modelled with the constructive characteristics as a traditional refurbished industrial building to be re-used as an office building (see Figure 1).

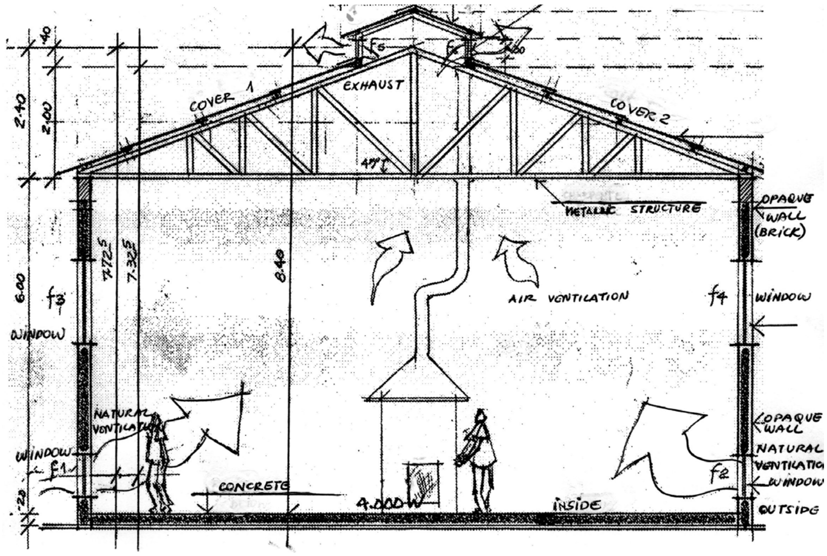

Figure 1 Prototype design of re-used building.

Retrofitting actions aim to provide well-designed envelopes in order to reduce heating loads and warmth thermal comfort sensation in tropical climates, during the work. Faced with the evaluation of the adaptation of the building design to the tropical climate characteristics, the opaque envelope components have been classified into three categories: a poorly, a medium and a high designed envelope. These categories are based on the thermal inertia mass (Queiroz and Bastos, 2002a).

Based on the AICVF model (Engineering Association of Ventilation and Heating in France), we have calculated the solar factors and have defined a total glazing envelope coefficient. The total glazing envelope coefficient can determine the addition of global aggregate parameters of glazed surfaces (facades), based on solar parameters as: size area (m²); solar factor (%); net effective size area (%); solar position related with solar surface azimuth (°), inclination angle (°), global solar flux on the horizontal plane (W/m²), global incident solar flux (W/m²), the mean solar transmission coefficient through glazing envelopes (%).

Heat transmission through building opaque and non-opaque envelopes is characterized by its resistance to heat flow by the effects of solar radiation and the air infiltration from the outside surfaces. The solar orientation of the building and the glazed envelope surfaces have been evaluated, concerning transmission solar factors through transparent windows, taking solar gains and internal loads due to the human presence.

Based on computer code simulations, we have calculated the variances of the mean resultant temperature during a warm discomfort over a summer day. The variances can provide the temperature differences between the mean resultant temperature and an established thermal criterion index of comfort (based on the operative temperature), during a discomfort sequence (hour-per-hour). The correlations between the outdoor temperature, the indoor temperature, the mean resultant temperature (based on the operative temperature) and the indoor relative humidity can provide a predicted mean vote, taking into account the metabolic rate to a proper activity and clothing.

EXTENSION OF PMV MODEL

Our approach takes into account a thermal criterion of quality that is based on the extension of the index PMV (predicted mean vote), developed by Fanger and Toftum (2002). The extension combines the best of the PMV model's (Fanger, 1970) and an adaptive model for non-air-conditioned buildings (Dear and Brager, 1998), while maintaining the PMV model's classical thermal parameters that have a direct impact on the human heat balance. The classical PMV model considers the thermal–humid–corps–ambient relation, with good prediction of the thermal sensation in buildings with HVAC systems over a tempering climate; while the adaptive model, from field studies in warm climates in buildings without air-conditioning, has shown that it predicts a warmer thermal sensation than the occupants actually feel. The adaptive model relates the neutral temperature indoors to the monthly average temperature outdoors.

Another factor that has been sugested as an explanation to the difference is the expectations of the occupants. The hypothesis considers that the PMV overestimates the thermal sensation of the occupants in non-air-conditioned buildings in warm climates. It is explained by the adaptation of the occupants who are typically people who have been living in warm environments indoors and outdoors. It is considered that people would judge a given warm environment as less severe and less discomforting than the people who have used the air-conditioned environment. This fact can express an expectancy factor, to be multiplied with PMV adjusted to proper activity for occupants of the actual non-air-conditioned building in a warm climate.

The expectancy factor is estimated to vary between 1 and 0.5. There is a classification of the expectancy factor to non-air-conditioned buildings in warm climates during warm seasons. In our case study we consider a low expectation (expectancy factor = 0.5) in regions where there are no or few other air-conditioned buildings, with the warm weather all year or most of the year. If there are many other buildings with air conditioning, the expectancy factor is 0.7. The new PMV extension predicts a higher upper temperature limit when the expectancy factor is low.

THERMAL SIMULATIONS

First, we have calculated the mean resultant temperature for each hour during a typical day and over a summer season in a tropical climate, by a zone dynamical computer code. This numerical code has been applied to evaluate the building thermal performance (Brau *et al.*, 1999). The thermal design parameters are the climatic conditions, the internal charges and the passive HVAC, as well their regulation mode. The database is the architectural geometry and the constitution of the indoor environment (walls, windows, volumes).

Then, we have applied an analysis of variances on the average resultant temperature in correlation with a thermal index criterion, based on the operative temperature for thermal comfort (T_i = 27°C). We have calculated the difference between the mean resultant temperature and this index of comfort during a warm sequence (from 12:00 to 22:00) (Queiroz *et al.*, 2001).

Based on the variances hour-per-hour, we have carried out the calculation of the PMV index by a computer code based on these data: outdoor temperature, indoor temperature, resultant temperature, indoor relative humidity and air velocity, considering the metabolic rate (medium activity) and clothing. The PMV variances have been based on the neutral PMV scale (0.5) (Queiroz and Bastos, 2002b). Finally, we have applied the PMV adjusted for expectancy in each predicted mean vote to proper activity.

THERMAL EVALUATION PROCEEDS

In order to evaluate the numerical results, we have calculated a variety of the most influent parameters to reduce heat gains and losses through the glazing and opaque envelope: solar orientation (0°, 90°, 180°, 270°); profundity ratios of glazing surfaces (0.0, 0.40 m); solar transmitted coefficients (0.3, 0.5, 0.7, 0.9). We have accounted for 32 simulations for each category of thermal inertia mass: a poorly, a medium and a high designed opaque envelope. We have defined eight base simulations (solar orientation = 0°) and we applied the PMV extension for expectancy in each base.

Two variations of clothing (0.6 clo; 1 clo) have been considered for evaluating a quality of indoor comfort adjusted to proper activity and expectation of occupants. During the discomfort sequence, there was a variation on the renewable air (3–6 vol/h) to provide thermal comfort for occupants.

The addition of PMV adjusted for expectancy factor has shown the numerical results, input in graphics to model tendency curves of expectation. The tendency curves of points express the correlations between the PMV adjusted for expectancy and the total glazing envelope coefficient. We can observe the thermal comfort quality criteria of each category of inertia mass. See Figures 2 and 3 with the best results for high inertia.

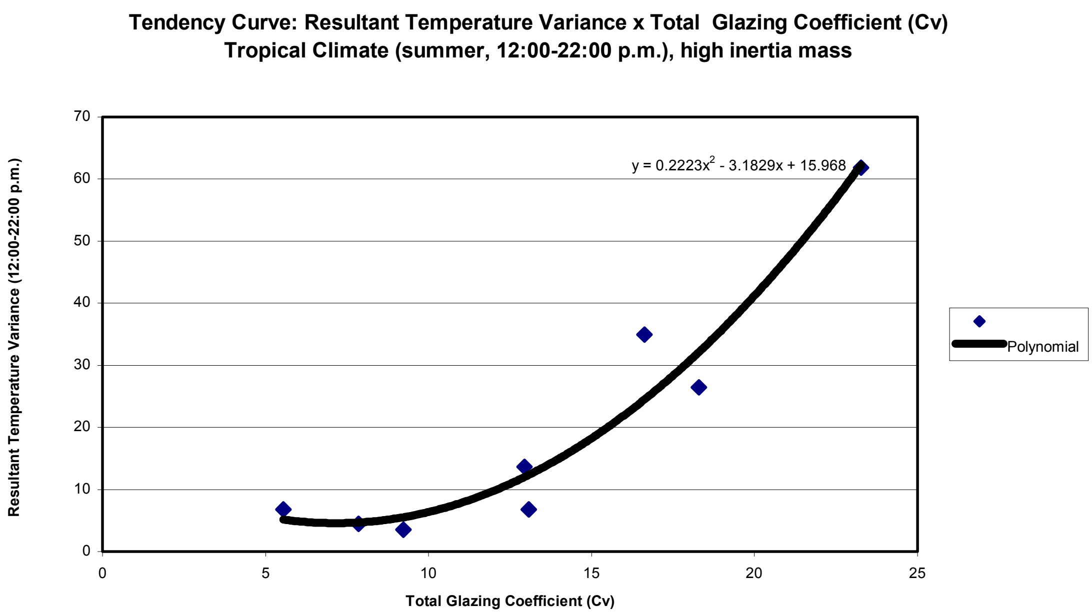

Figure 2 Comparison between the resultant temperature variances and total glazing coefficient, taking the high inertia mass of opaque envelope.

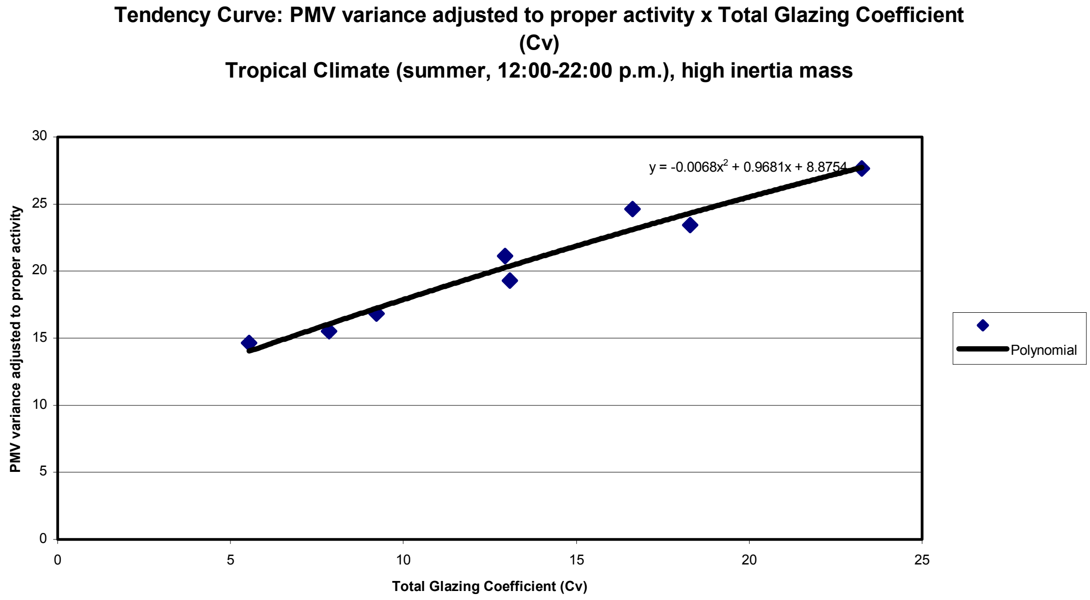

Figure 3 Comparison between the PMV variances adjusted to proper activity and total glazing coefficient, taking the high inertia mass of opaque envelope.

CONCLUSION AND COMMENTS

In non-air-conditioned buildings in warm climates, the variation of renewable air (volume per hour) can provide a thermal comfort sensation, considering the increase of the night natural ventilation and the variation of renewable air during a discomfort sequence (Queiroz and Bastos, 2002b).

Observing the numerical results and the tendency curves, the PMV adjusted for expectancy may predict a general criterion of quality, applied in the earliest phases of the design building. The tendency curves have demonstrated that the PMV adjusted for expectation is proportional to the performance of the solar transmitted coefficient of glazed envelope (see Figure 4). The best thermal performance of indoor quality was in agreement with the high inertia mass designed for the opaque envelope.

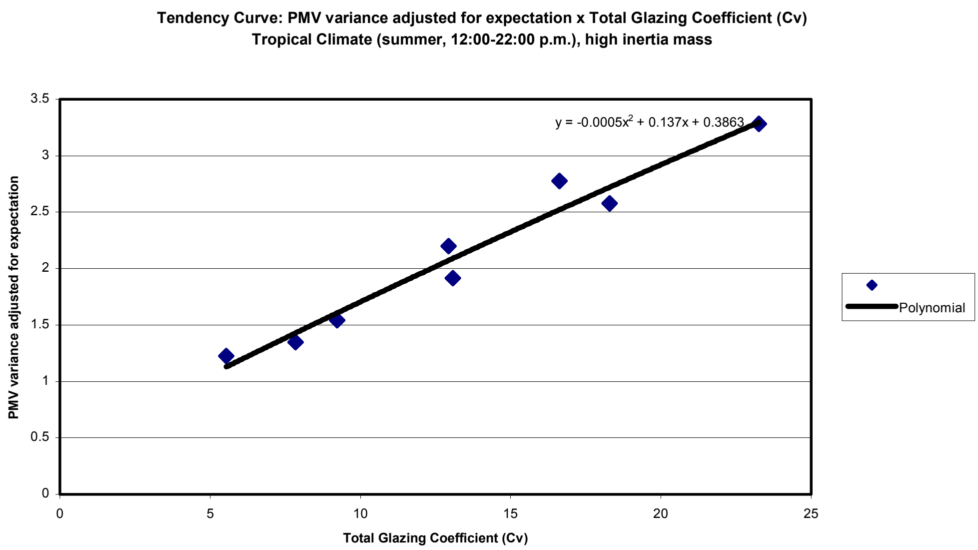

Figure 4 Comparison between the PMV variances adjusted for expectation and total glazing coefficient, taking the high inertia mass of opaque envelope.

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