ENVIRONMENTALLY FRIENDLY CITIES, Proceedings of PLEA'98, Lisbon, Portugal, June 1998
Pages 393-396 © 1998 James & James Science Publishers Ltd

Air flow through louvered windows in small rooms

FERNANDO OLIVEIRA AND LEONARDO BITTENCOURT*

Universidade Federal de Alagoas –Depto. de Arquitetura e Urbanismo /CTEC
Campus A C. Simões - Tabuleiro do Martins, CEP 57072-979 Maceió-AL, Brasil
Phone: (+5582) 972 8727/973 2539 Fax: (+5582) 214 1625
E-Mail: prol@nornet.com.br E-mail: lsb@dcc.ufal.br

Abstract

In equatorial warm humid climates, ventilation has been largely adopted as a major strategy for natural passive cooling. In those climates the use porous elements are common to allow for permanent ventilation as temperature rarely drops below 20°C. Nevertheless, the performance of many building components has not been thoroughly determined, making it difficult to predict buildings performance as ventilation rates, estimated in most simulation codes are often based on apertures typologies from temperate and cold regions. This paper is the result of an experimental assessment carried out at the Universidade Federal de Alagoas, comparing the airflow velocity inside two identical rooms. The rooms were shaped and sized similar to a typical local bedroom (2.80 x 3.50m), having the same window area as inlet and a door as outlet, both placed in the centre of external walls of the test rooms. In one of the rooms the aperture would have a permanently open window, while in the other one there was a window with horizontal slates. Air speed near the windows were measured to obtain the resistance to the airflow produced by horizontal slates (with and without mosquito screens), under different wind speed and directions. Results shows that the resistance to the airflow may vary significantly as a function of wind speed and direction.

INTRODUCTION

Around the equatorial belt, climates are predominately warm and humid. In such climates, daily and seasonal temperature fluctuations are small and vapour pressure levels are high. Air temperature is normally below skin temperature and a partially cloud sky is typical, yielding an appreciable amount of diffuse radiation and very bright skies. In these climatic regions shading is essential and cooling is the main target of building design. Heating is never required. Thermal comfort in buildings has relied basically on cross ventilation and the avoidance of heat gains [1], [2], [3].

Air movement reduces the effective temperature due to evaporation of sweat from skin and to convective exchanges between the air stream and the body [4]. Hence, the upper limit of the comfort zone can be extended as a function of air speed [5], [6]. An elevation of about 2.5°C on the preferred temperature (under still air conditions) was observed when Scandinavian subjects were exposed to an air speed of 0.8 m/s and 50% of relativity humidity [7]. This cooling effect, however, has been reported as being higher in other situations [1], [8]. There are indications that air motion can produce comfort at air temperatures above 30°C at acceptable air velocities [1], [3], [9], [10].

The nuisance due to draught caused by turbulent air flow with relatively low air speeds may be true for individuals living in cold and temperate climates who are not used to continuous air movement [11], but does not seem to reflect the reality of hot and warm regions. On the contrary, in such regions ventilation is one of the most important factors that determine human comfort [12] and looks like the simplest cooling strategy [2], [8], [13]. In conjunction with solar shielding, ventilation seems to be the most suitable strategy for this sort of context [14], where air temperature is always below skin temperature and other cooling processes present drawbacks. In this context, the different characteristics of windows acquire special importance, as most of times the air flows inside buildings through its apertures.

Nevertheless, most of the available software used to simulate thermal comfort in buildings deal with ventilation aspects in a simplistic way. Part of this is caused by the lack of information regarding ventilation performance presented by typical openings used in the tropics, particularly the porous components like louvered windows and mosquito screens.

This paper aims to show that significant variation in the air flow may be found when different windows are used. It suggests that an adaptation in the air flow rates (demanded by the programs) may be necessary when using a software that is not able to estimate the variation in the air flow produced by the different porous components, largely used in the tropics. An empirical assessment is carried out to identify the difference in ventilation performance between an open window and a louvered window in low-rise buildings with small rooms.

METHODOLOGY

The assessment is based on data obtained from readings on two test cells built at the Universidade Federal de Alagoas, located in the city of Maceió, Brazil. It consists of two ground floor rooms, each one with an aperture measuring 0.80m x 1.10m (typical local window size) as shown in Figure 1 and 2. The first aperture was kept free from obstruction as a completely open window would be, and is named Model 0 (M0). In the second aperture a louvered window with horizontal slates was placed, named Model 1 (M1), Figure 3. The performance of both apertures were measured under different wind speed and direction. The same procedure was repeated using a mosquito screen on the internal surface of the louvered window, in this case named as Model 2 (M2).

The facade containing the apertures were designed to face East as the predominant winds come from the eastern quadrant. To properly discern wind directions in the field measurements a device was especially manufactured. It comprises a vertical metal axis fixed in the ground and having a circular ring on the top, marked every 22°30". Woollen strings were fixed along the vertical axis in such a way that, even when the wind was blowing with low speed, these strings aligned with the wind direction, Figure 4.

Ventilation readings were taken from one external and one internal point in each test cell. Internal readings were taken at 1.50m height and 0.50m away from the window plane. External readings were taken at the same height and 6.00m windward from the construction, Figure 2.

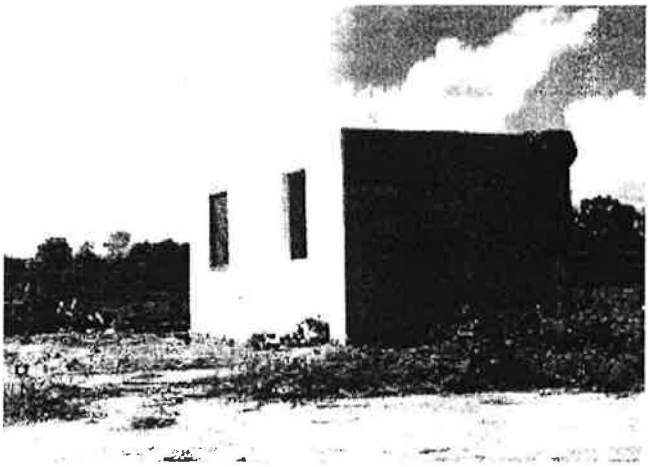

Figure 1. Photograph of test cells.

Time averaged readings were taken to minimise errors due to wind turbulent velocity variation. In addition, internal readings were taken some seconds after the external ones to make sure that they would reflect the actual reduction on the speed read 6.75m away from the internal reading points. Measurements were only taken when the wind direction presented itself as reasonably stable, in direction and speed, to reduce the margin of error.

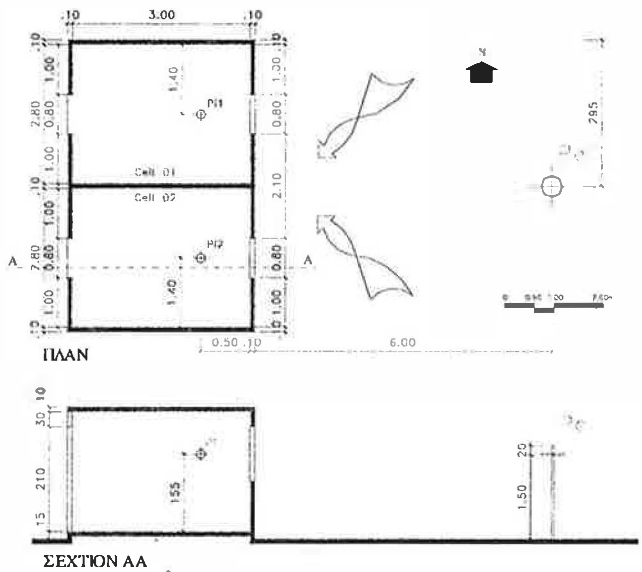

Figure 2. Test cells used for the experiment

The influence of different wind speed and incident direction on the internal velocity was assessed. Direction were grouped in sectors of about 22°30" each (90°, 67°, 45°, 22° and perpendicular to the window- 0°).

The open window (Model 0) was considered as a reference to which the louvered window would be compared.

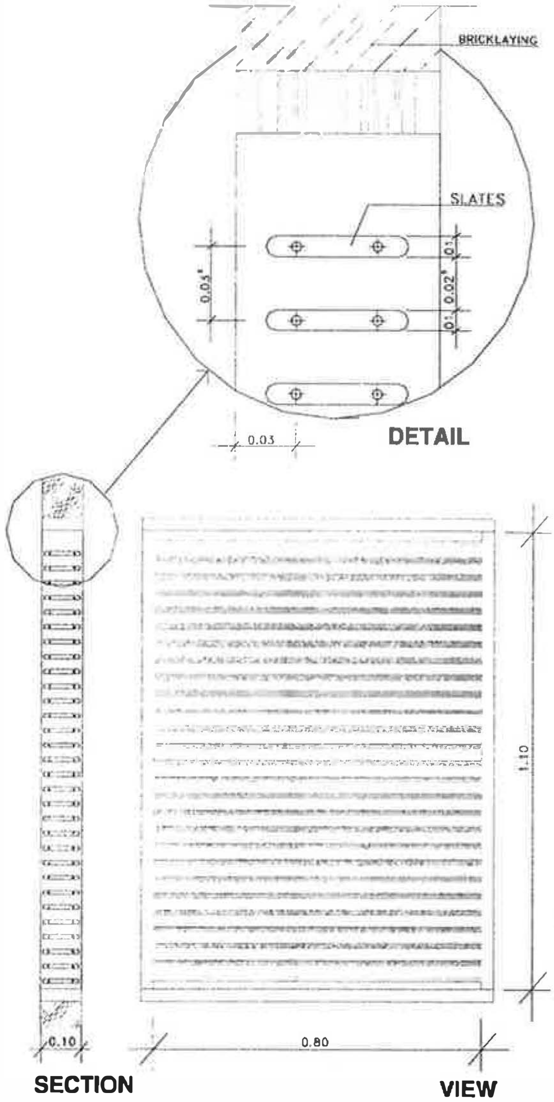

Figure 3. The assessed louvered window

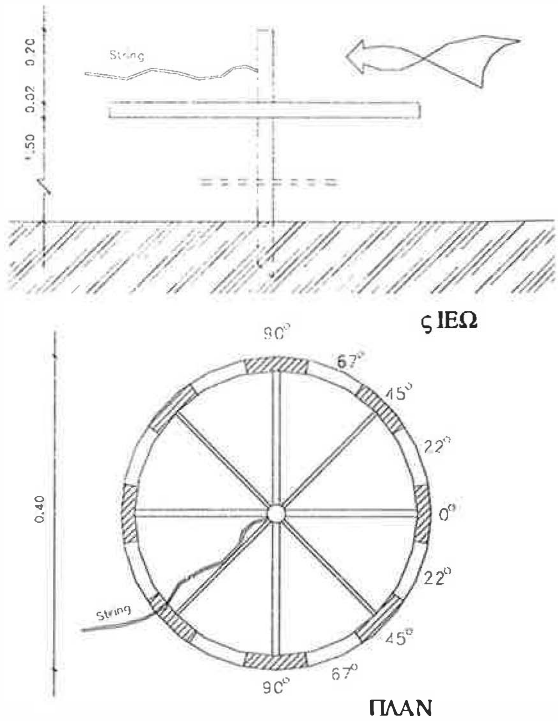

Figure 4. Device to identify wind direction

RESULTS

Findings are presented as the air-stream velocity drop after it has passed through the louvered window. It is expressed as a percentage representing the ratio between average internal air velocity (Vi) and average external wind speed (Ve), for different wind angles of incidence.

Figure 5 presents a logarithm best fit line for the readings obtained from the cell with the open window, considering the effect of the wind speed and direction in the airflow resistance (Vi/Ve).

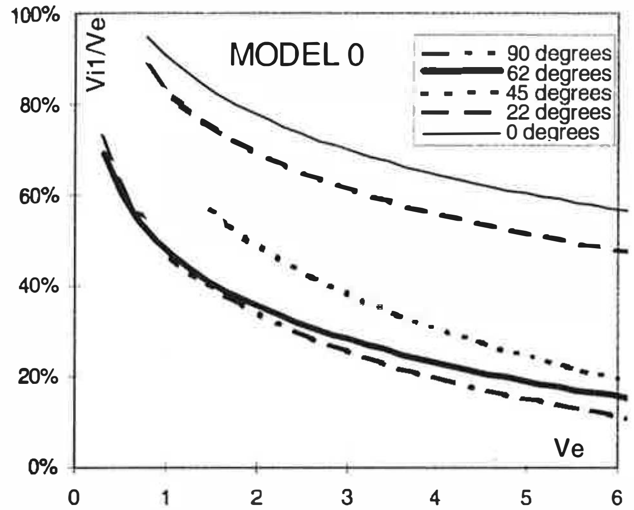

Figure 5. Air flow resistance for the open window as a function of window speed.

Figure 6 presents linear regressions of the data obtained from different wind incidence angles, comparing the air velocity drop for the louvered window as a function of the velocity drop for the open window (M0). It compares the resistance offered by the louvered window to the one presented by the open window.

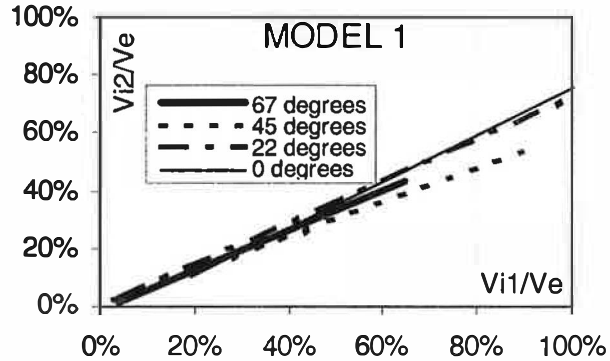

Figure 6. Comparison of air flow resistance for the open window and the louvered one.

Figure 7 displays the results for the case where a mosquito screen is added to the louvered window.

DISCUSSION

Results displayed in Figure 5 suggest that the air flow resistance increases as a function of wind speed. It also shows that the wind incidence angle affects significantly the flow resistance, particularly at higher wind speed.

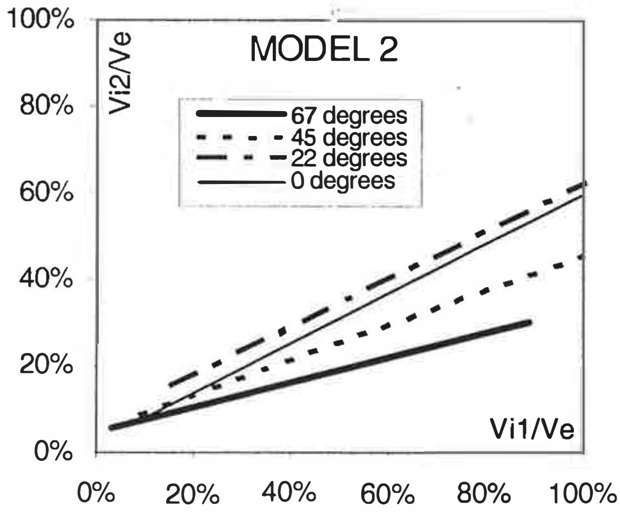

Figure 7. Comparison of air flow resistance for the open window and the louvered window with mosquito screen.

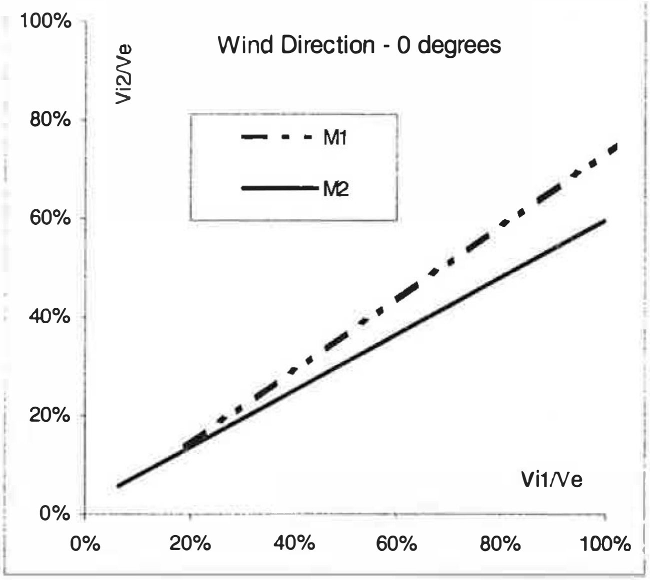

Figure 8. Performance difference between model1 and 2 for wind flow normal to the window plan.

Figure 6 shows that the airflow resistance through the louvered window is about 70% of the one found for the open window.

Figure 7 indicates that, with mosquito screen, the louvered window presents and flow around 60% of the one found for the open window, considering wind incidence close to the normal to the window (0° and 22°). For oblique wind incidence (45° and 67°) the flow is reduced to about 40%. This difference in performance of Model 1 and Model 2 concerning the wind incidence angle is illustrated in Figures 8 and 9.

CONCLUSION

The findings here presented indicates that there is need for further research aiming to identify the ventilation performance of window types peculiar to the tropics. It also suggests that the use of inappropriate values of air change rates in thermal simulation codes may cause inaccuracy, particularly where porous components are used as is the case of most warm humid regions.

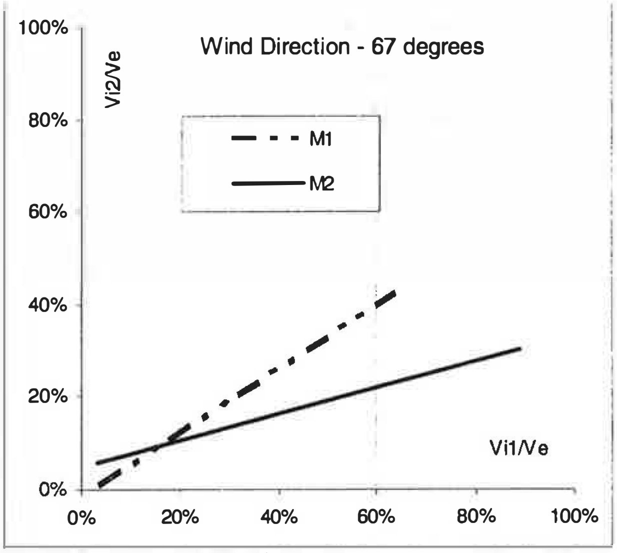

Figure 9. Performance difference between model1 and 2 for wind flow oblique to the window plan.

ACKNOWLEDGEMENTS

The authors would like to thank you the valuable help from the members of the Programa Especial de Treinamento em Arquitetura – PET/ARQ – from the Universidade Federal de Alagoas, Brazil.

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