| exposure | insulation | glazing | window area |
|---|---|---|---|
| South | 4 cm | clear glass | 15 % |
| East/West | 6 cm | double glazing | 15 % |
| North | 4 cm | double glazing | 15 % |

results that are much closer to the normal practice in building construction
In other cases, designers may prefer the insulation thickness and/or glazing type to be the same for the whole building, or the choice of glazing may depend on architectural reasons. Such additional constraints can be easily taken into account for example, imposing solar reflecting glass for the office building, the following optimal solutions will be found for n = 5 years:

| exposure | insulation | glazing | window area |
|---|---|---|---|
| South | 6 cm | solar reflecting | 15 % |
| East/West | 6 cm | solar reflecting | 15 % |
| North | 6 cm | solar reflecting | 15 % |

## CONCLUSIONS

The optimization of the building envelope, in terms of thermal insulation and solar collection, is often carried out referring to energy performance only. Instead, the economic aspects of the problem should not be neglected and for this purpose a simple method has been described in this paper. The resulting solutions are strictly dependent on the basic hypotheses concerning both the climatic and the economic situation, but results may be interesting: for example, they often show the convenience of insulation levels higher than usual, but also the limitations inherent in some design tendencies (e.g. to "zero energy" houses) become very evident

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# PREDICTION OF INDOOR AIR MOVEMENT OF NATURALLY VENTILATED CLASSROOMS IN SCHOOLS IN MALAYSIA

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## ABSTRACT

This paper presents the results of experiments conducted in a boundary layer wind tunnel on an architectural model of a typical naturally ventilated classroom. Indoor air velocity were measured inside the classroom model for 7 wind directions (0°, 15°, 30°, 45°, 60°, 75°, 90°) using the mean speed coefficient method. For each of the classroom configuration tested, a total of 15 measurements were taken inside the model and the average velocity coefficient and the coefficient of spatial variation were computed. Correlations and regressions of the experimental data collected resulted in the development of a preliminary empirical model which provides a simple but important tool that can predict wind induced indoor air movement in naturally ventilated classrooms for various wind directions as is needed for the assessment of the indoor thermal comfort conditions.

## KEYWORDS

Natural ventilation; velocity coefficients; thermal comfort

## INTRODUCTION

Incorporating natural ventilation in enhancing thermal comfort is a good passive design strategy to conserve energy in warm climates. While it is impossible to be comfortable throughout the day by depending solely on it, a good naturally ventilated designed building can at least reduce or minimise the energy consumed by air-conditioning and mechanical ventilation

All public schools in Malaysia rely on natural ventilation for comfort. Most of the classrooms are fitted with fans to assist in increasing comfort levels. However, in schools where fans are not available, the students will thus have to rely totally on wind driven natural ventilation for comfort. The design of the public schools are standardised by the Government. To date, no

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work has been done to assess the efficiency of the school design in providing the right amount of air movement and air distribution for comfort.

This paper describes tests conducted in a wind tunnel designed to study air movement inside naturally ventilated classrooms. The main focus was on investigating the effect of different wind directions on the internal air velocity and its distribution. The goal was to develop preliminary empirical model equations which can predict interior wind induced air velocity coefficients for various wind directions.

## EXPERIMENTAL SET-UP

The experiments were conducted in a boundary wind tunnel which is 18m long and with a 1m by 1m cross section. It has an axial flow fan driven by an 8.0 HP motor that is controlled by a variable speed control unit. The first 12m of the wind tunnel correspond to the flow processing section in which wooden blocks cover the floor to simulate the flow approaching the model. The model is placed on a turntable immediately downwind of the flow processing section. The model which were made of perspex, resembles a typical classroom that follows the standard design of public schools in Malaysia. Corresponding to a scale of 1:30, the overall dimensions of the model classroom is 250mm by 300mm and 107mm high, which gives a maximum wind tunnel blockage of 3.2%.

Wind velocities were measured directly at 15 equally spaced points in the model classroom (see Fig. 1), using a velocity sensitive thermistor that is compensated for variations in airstream temperature. All interior measurements were taken at a model height of 3.7cm, corresponding to the full scale head height of 1.1m of a seated person. 2 sets of experiments were carried out; case 1 wall comprising all windows as the windward side and case 2 wall comprising doors as the windward side. The log law (Aynsley,et al 1977) was used to describe the vertical profile of the mean windspeed :

$Vz = Vz_1 \ln ( z / z_o ) / \ln ( z_1 / z_o )$ ,
$Vz$ = Mean wind speed at height z above $z_o$ (m/s)
$Vz_1$ = Mean wind speed at some reference height z1 above $z_o$ (m)
$z_o$ = Terrain roughness length (m)

The terrain type chosen for this study was for suburban areas with terrain roughness length of 0.3. Fig. 2 shows both the theoretical and measured boundary layer velocity profile used in this study.

Table 1. Summary of results

| Wind Dir.θ (Degrees) | Case 1: Windows Cv | Case 1: Windows Csv | Case 2: Doors Cv | Case 2: Doors Csv |
|---|---|---|---|---|
| 0 | 0.1591 | 0.0937 | 0.1459 | 0.1238 |
| 15 | 0.1576 | 0.0726 | 0.1509 | 0.1545 |
| 30 | 0.1585 | 0.0840 | 0.1699 | 0.2044 |
| 45 | 0.1634 | 0.1049 | 0.1660 | 0.2070 |
| 60 | 0.1450 | 0.1881 | 0.1272 | 0.1122 |
| 75 | 0.0747 | 0.1249 | 0.0903 | 0.1056 |
| 90 | 0.0584 | 0.0486 | 0.0593 | 0.0467 |

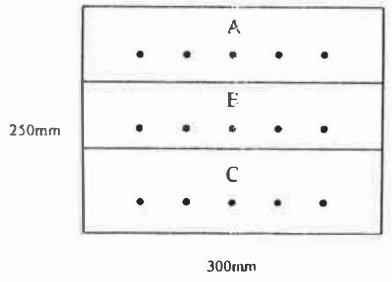

Fig. 1 : Sensor positions

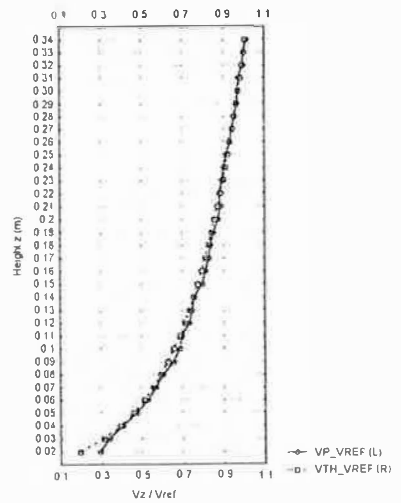

Fig 2 MEAN VELOCITY PROFILE

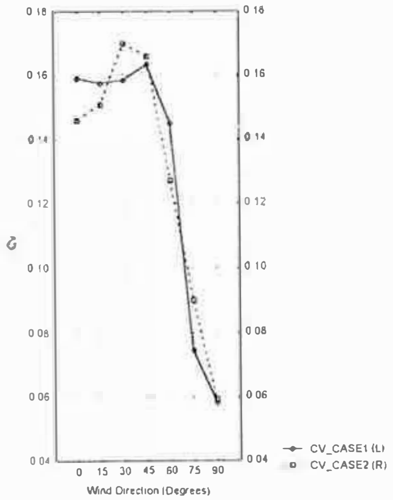

Fig 3 GRAPH OF Cv AGAINST WIND DIRECTION

## RESULTS

The mean windspeed coefficient method was used to assess the natural airflow (Aynsley et al 1977). The coefficient, Cv, is the ratio of the mean windspeed at a point inside the room to the mean windspeed at a specified reference height. In this study the reference height was taken to be 10m (0.33m model scale). The relative spatial uniformity , Csv, gives the overall spread of the local indoor velocity distributions ( Ernest et al. 1991). Table 1 shows a brief summary of the values of Cv and Csv inside the model for the various wind incidences. Overall, the values of the Cv inside the classroom is rather low. Also, there is not much difference in the values of Cv between both cases. This is probably due to the low ratio of outlet to inlet size as the wall porosity of cases 1 and 2 are 15.6% and 18.4% respectively

### Prediction of mean velocity coefficient with wind incidence

The maximum mean velocity coefficient occurred at wind direction 45° and 30° for cases 1 and 2 respectively, while the minimum occurred at wind incidence 90° for both cases. Thus, oblique wind incidences increase the percentage of air movement within the room. Fig. 3 shows the variation of Cv with wind incidence for both cases. Based on the multiple regression analysis conducted on the data collected, the following model equation was found to be able to predict the values of Cv in the classroom :

$$Cv = A ( Vr - Vi ) + B ( Vr - Vi ) \cos \theta + D \qquad (1)$$

Vr = Mean outdoor reference velocity (m/s)
Vi = Mean indoor velocity (m/s)
θ = Wind direction (0° ≤ θ ≤ 90°)

The values of the coefficients are :

A = -0.27189, B = 0.0041, D = 0.80467 ; Correlation ($R^2$) = 0.995 ( Case 1)
A = -0.34532, B = 0.0004, D = 0.9898 ; Correlation ($R^2$) = 0.992 ( Case 2)

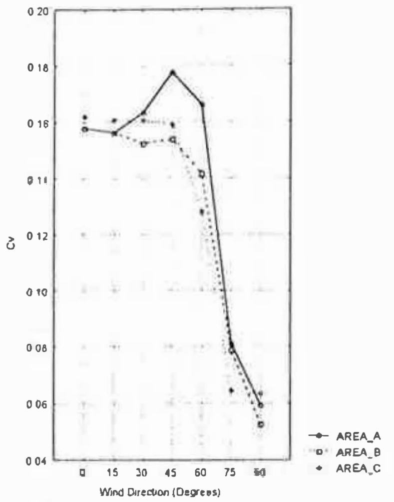

Fig 4a Cv DISTRIBUTION IN SPACES IN ROOM (CASE 1)

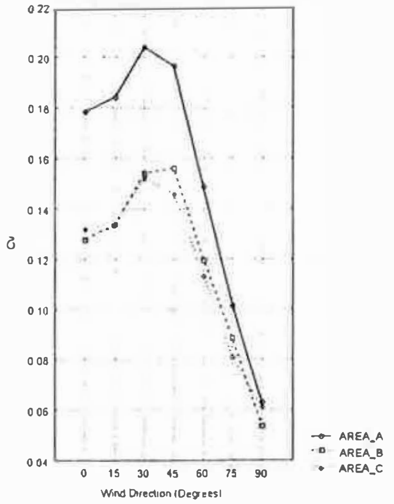

Fig 4b Cv DISTRIBUTION IN SPACES IN ROOM (CASE 2)

Room Air Distribution

Figures 4a and 4b show the mean windspeed coefficient distribution for spaces A,B,C as described in Fig.1. Space A represents the windward side for both cases. Generally, the value of Cv was found to be slightly greater on the windward side for case 2 for all wind incidences. Also, there seems to be a greater difference in the values of Cv between space A and space B (middle of classroom) for case 2. Again this is probably accounted by the higher inlet size. As the velocity distribution in the space becomes more varied, the value of the coefficient of spatial variation, Csv increases. When the Csv value is high, the difference between the maximum and minimum values of air velocity in the room is high, showing a greater spatial unevenness of the interior velocity distribution. A rather uniform flow seems to occur at wind direction 90° for both cases

## CONCLUSION

The wind tunnel measurements done in this study was able to develop a preliminary model equation which can predict the indoor air motion inside a typical classroom as a function of wind direction. It has also enabled the study of the overall velocity distribution inside the classroom. Ongoing research is looking at classrooms in 3-storey blocks as well. The results of all these experiments will be compared with those conducted in actual field studies. A critical analysis of both the experimental and field study should result in a final model equation that can provide architectural guidelines for the design and arrangement of naturally ventilated classrooms.

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# CONCEPTS AND DIFFERENCES BETWEEN BIOCLIMATIC ARCHITECTURE FOR EUROPE AND FOR THE TROPICS

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## ABSTRACT

The purpose of this paper is to deal with environment conscious design traditionally regarded from an European perspective, from the point of view of a tropical country. The reflections started from the conceptual approach made by Rafael Serra (Serra, 1997) about architecture for the day and for the night, set in an European context, and the adequacy and applicability of these concepts to the tropics. From the beginning, it was evident that there are differences between the two points of view. As the European point of view is normally taught in Latin American universities without very much discussion, the aim of this paper is to reflect about the differences in the concepts and on the consequences of their application for the integration between design and climate in a tropical environment

## KEYWORDS

European vs. tropical architecture; bioclimatic architecture; architecture day and night; concepts for tropical architecture, energy and architecture

## ARCHITECTURE BY DAY AND BY NIGHT AND HISTORY

From the begining of their history until the Middle Ages, cold country inhabitants, trying to proctect themselves from the hostile climate, constructed buildings similar to caves, with a small entrance door and no windows, or only small ones for communication, with heavy walls to insulate and keep the warmth. At night, with all the openings closed for protection. With every slit, loophole or crack blocked to avoid the frozen wind, and with no lights outside, there was no "architecture by night". The European architecture, which began in the Middle Ages, could only express its symbolic reality by daytime, under daylight. Contrasts of light and shadows from daylighting enhance the architectural details, defining with more or less intensity, the volumes, with their elaborate profiles and shapes. Windows didn't show the indoor, which remained as an ensemble of grey shadows. At night, buildings were no more than badly defined shapes, without any symbolic expression. As a consequence, the architecture that must build structures which show symbolic and sufficient reasons for power, could only show them in the daytime