

COMBINED CFD-MEAN ENERGY BALANCE METHOD TO THERMAL COMFORT ASSESSMENT OF BUILDINGS IN A WARM TROPICAL CLIMATE

Stéphane Sanquer¹, Mohamed Abdesselam², Fabien Picgirard³

¹Meteodyn, Nouméa, New Caledonia, France

²Solener, Lille, France

³Ademe, La Réunion, France

ABSTRACT

The paper presents combined approaches dedicated to assess the thermal comfort in a tropical climate. UrbaWind, an automatic computational fluid dynamics code, was developed to model the wind in urban environments. A module was recently added to assess the buildings's natural cross ventilation. The simple thermal method Batipei, allows computing the mean overheating inside the building by considering the envelope thermal behaviours, the outdoor thermal conditions and the mass flow rate.

Finally, an architectural case of urban renovation of old buildings in La Reunion Island is presented as an example of the using of the combined approaches.

INTRODUCTION

Background

In the context of reducing the energy consumption in buildings for the overseas territories located in warm tropical climate, The French energy agency (ADEME) needed rules and tools for existing buildings adapting them to such climates, different from the European temperate climate. In the French territory "La Reunion", 17% of the housing is air conditioned. This rate has doubled over the last five years. In this context, the local agency proposes an alternative way to improve the comfort with bioclimatic approaches. Architects, designers and property developers especially in low-rent buildings should know immediately if the buildings could be made thermally comfortable without cooling. Thermal assessments of buildings are intricate and detailed in urban areas located on or near complex terrain. They need to carry out their surveys with simple, easy-to-use methods. Hence, ADEME (La Réunion agency) developed a method BATIPEI devoted to evaluating the indoor thermal comfort in warm tropical climates by taking into account the external climatic parameters, the internal heat gains and the air change rate of the room. This method will determine buildings or apartments that need air conditioning and those that could be naturally ventilated according to the local climatology.

The natural ventilation of a building is driven by the combined forces of wind and thermal buoyancy.

However, when openings are large enough and the air change rate is high enough, the indoor temperature is quite homogeneous, and except for tall volumes, the natural ventilation is mainly driven by the wind forces. So for the natural ventilation assessment in tropical warm climates, the thermal forces are generally assumed as negligible compared to the wind driven forces. The assessment of the cross-ventilation efficiency is completed by considering the wind speed levels inside the buildings, and the flow-rates through the openings or generally the air change rate of the volume (ACH).

The cross wind flow rate depends on the size of the opening, on their aerodynamic efficiency namely their aerodynamic discharge coefficients, on the pressure coefficients on the building envelope and on the reference wind velocity upstream the building. Aynsley *et al.* (1977) gave an analytic expression useful for a single ventilated volume with two openings, but as soon as the number of openings is greater or the internal volume is divided in sub volumes, a resolution for non-linear system has to be used.

All of these characteristics are fundamental and depend on the external wind pressure at the openings. The pressure on the envelope of the building can be defined with tables (Liddament 1986, Clarke. J et al. 1990, Eurocode) or by using parametric models based on the analysis of results from wind tunnel tests (Grosso 1992). These tables or correlations are potentially inapplicable when buildings are irregular and different from the simple shape or when they are flanked by others buildings in a complex urban area with canyons and corner. In these configurations, the wind fluctuates strongly and the pressure coefficients and the wind-driven natural airflows could be evaluated with some difficulty. These external wind pressures should be evaluated either from wind tunnel tests (Kandola, 1990) or from computational fluid dynamics (CFD) simulations (Ayad 1999, Fahssis et al. 2010). Analytic method such as the Aynsley method could not be used for complex flat layout where pressure loss occurs. Network aerodynamic tools that include the pressure loss depending on the internal porosity are necessary to assess the air change rate in such layout. UrbaWind, a CFD software dedicated to modelling the urban

climatology, was upgraded to deliver the mass flow rate to assess the cross ventilation efficiency (Sanquer et al., 2011).

The thermal comfort inside naturally ventilated buildings depends on the indoor temperature, the air humidity and the velocity in the occupied zone. Givoni defined comfort curves (Krüger et al., 2010) as areas in the wet air diagram that depend on the indoor velocity. This diagram allows designers to know if an indoor situation defined with velocity, temperature and humidity is comfortable.. The figure 1 shows that when indoor velocity is close to unity, the comfort area (continuous black line) is larger than in a lower velocity (no indoor motion in dotted line, velocity=0.5 m/s in dashed line). Points in the diagram were determined by dynamic simulations (Garde R., 2006). Some are in the comfort domain bounded by polygonal curves (comfortable situations) whereas the others remain outside the area (too warm and wet or too cold) indicating uncomfortable indoor climates.

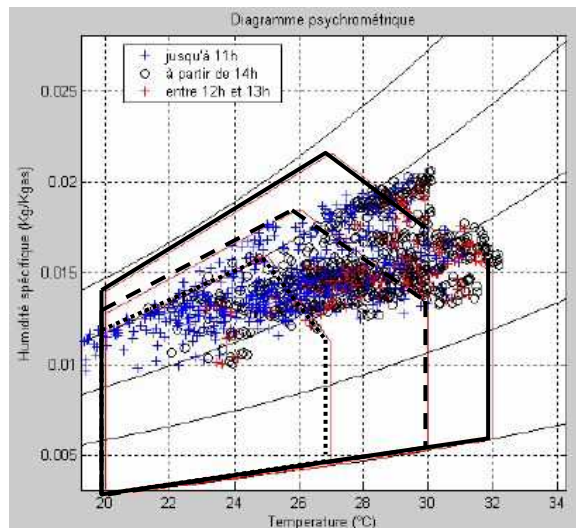


Figure 1 : Thermal dynamic simulation in an office at La Réunion Island during the summer (Garde R., 2006)

A thermally comfortable building which is well designed for a tropical climate is described as having:

- An indoor mean temperature close to the outdoor temperature. That means the designers properly managed the heat balance : solar radiation flux, internal heat gains, heat extraction with the ventilation
- A maximum temperature smaller than the acceptable comfort temperature according to the humidity and the indoor air velocity, depending on air motion dynamics.

The indoor temperature depends on the air change rate and the thermal characteristics of the building's envelope (conductance, specific heat). Dynamic Thermal Modelling is developed with absolute precision to simulate the instantaneous physical behaviours of a building, while delivering much data.

Knowledge of building heat transfer and airflow is required to use the software and to assess the thermal efficiency of the buildings. Developments and improvements of the thermal behaviours of the buildings are not simple. Variations of any input parameter give whole variations of the thermal equilibrium of the building. Models complexity and many interactions avoid the explicit knowledge of the thermal mechanisms. The contribution of various parts of the building into the energy balance should be clearly highlighted to allow users to find improvements in the comfort level. Unfortunately, Dynamic Thermal Modelling can be expensive and time consuming, and cannot be used for smaller projects or for the initial step of creating a proposal where budgets are limited. Such a simple approach cannot be based on dynamic responses of the building but rather on average energy balance equation.

Therefore, new simple model, firstly pedagogical, based on an average method, was developed for warm tropical climates by Abdesselam (1997). The effects of each heat gain and loss were evaluated on the temperature of the room. Indoor overheating in comparison with the outdoor temperature is computed. The comfort criteria is targeted in a place where the temperature criteria keeps the indoor climate comfortable.

Purposes

The first objective of this report is to present a method of assessment for the indoor thermal comfort in a warm tropical climate. The method is composed of two separate tools: an aerodynamic model that estimates the air exchange through the building walls, roof and openings, and a thermal model that computes the indoor temperature.

The aerodynamic tool is a CFD-Network software named "UrbaWind which performs calculation of the outdoor wind combined with a macroscopic network method for the evaluation of the mass flow rates through the openings. Results depend on the external wind conditions, taking into account the local wind climatology.

The thermal tool named BATIPEI is a simple thermal method, which computes the mean overheating inside the building. The inputs of the tool are the building's thermal characteristics, the outdoor thermal conditions, including temperature and solar radiations and the mass flow rate delivered by aerodynamic tools.

The second part of this article addresses the urban renovation of old buildings overheated during the summer at the city of Saint-Denis (La reunion Island) carried out with this method. The main objective for the apartments' owners is to define new thermal behaviours of buildings in order to improve indoor thermal comfort and to minimize air conditioning.

NUMERICAL APPROACHES

Aerodynamic Tool

The CFD method of UrbaWind consists of solving the Reynolds-Averaged Navier-Stokes equations on an unstructured rectangular grid with automatic refinement of the mesh near obstacles. The CFD tool delivers the tri-dimensional mean velocity field and the mean pressure for each point in the domain.

When the airflow is steady and the fluid incompressible, the mean equations for the mean velocity components \bar{u}_i contains unknown quantities, the turbulent fluxes that can be solved by a one-equation model. The transport equation for the turbulent kinetic energy k contains a dissipation term ε deduced from the mixing-length theory.

$$\frac{\partial}{\partial x_i} \left[\rho \bar{u}_i k - \left(\frac{\mu_T}{\sigma_k} \right) \frac{\partial k}{\partial x_i} \right] = \mu_T \left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i} \right) \frac{\partial \bar{u}_j}{\partial x_i} - \varepsilon \quad (1)$$

The turbulence viscosity μ_T is considered as the product of a length scale with a speed scale, which are both characteristic lengths of the turbulent fluctuations.

$$\mu_T = \rho k^{1/2} L_T \quad (2)$$

$$\text{and } \varepsilon = C_\mu \frac{k^{3/2}}{L_T} \text{ and } C_\mu = 0.09 \quad (3)$$

The turbulent length scale L_T varies linearly with the distance at the nearest wall (ground and buildings).

This methodology, along with the use of a very efficient multi-grid coupled solver allows for a fast convergence for every kind of geometry.

Boundary conditions are automatically generated. The mean velocity profile at the computation domain inlet is determined by the logarithmic law in the surface layer, and by the Ekman function. A 'Blasius'-type ground law is implemented to model frictions (velocity components and turbulent kinetic energy) at the surfaces (ground and buildings).

Typically CFD computation domains cover an area of maximum 1000 m x 1000 m, taking into account the effects of neighbouring buildings. The mesh refinement at an obstacle can reach 5 cm. If needed, it is possible to also compute the flow inside the building, but this can be time consuming and expensive.

For the simple thermal assessment in such applications, computing the indoor domains is not necessary. For rooms with more than two openings, a network approach delivers the mass flow rate crossing each opening (Fhassi *et al.*, 2010). The internal pressure is not known and the flow rate through openings are solved by an iterative process. Firstly, the indoor pressure P_i is initialized as the average of the outer surface pressures P_k at the opening k , weighted by the square of the free aerodynamic area A_k . The values of the P_k are obtained by the CFD calculation with UrbaWind.

Then, after several steps, the computation is achieved. At the iteration n , the flow rates at each opening k are computed by:

$$|Q_k^n| = A_k \sqrt{2|P_k - P_i^n|/\rho} \quad (4)$$

The outflow rates are updated by solving an equation (5) with a Newton-Raphson iterative method.

$$\sum_k Q_k^n = 0 \quad (5)$$

The internal pressure at step $n+1$ is updated and the flow rates are adjusted with the new internal pressure. The iteration stops when convergence is achieved. In the case of a flat with several rooms, the free aerodynamic area of the opening k is replaced by an equivalent aerodynamic surface, taking into account the door aerodynamic surface A_{door} of the secondary room (Sanquer *et al.*, 2011).

$$A_k^{eq} = 1 / \sqrt{\frac{1}{A_k^2} + \frac{1}{A_{door}^2}} \quad (6)$$

Thermal tool

The maximum temperature T_{max} and the mean overheating depend on thermal inertia of the buildings. To assess simply the comfort, one solution consists of replacing the requirement on T_{max} with a requirement on ΔT , the mean daily overheating. Abdesselam (1997) developed a new method named BATIPEI for the French tropical island La Réunion. As soon as the air change rate is high enough (more than 10 vol/h) and the temperature daily range is moderate (6 °C) as in such a warm tropical climate, the contribution of the thermal inertia in the evaluation of the indoor temperature and of the comfort level is relatively low. During the development of the method, it was shown that whatever the thermal inertia, comfort was achieved for such a oceanic tropical climate with a mean overheating ΔT that didn't exceed 2°C. The influence of inertia is lower than half a degree (figure 2) and becomes a second order parameter compared to the ventilation rate in the energy balance equation.

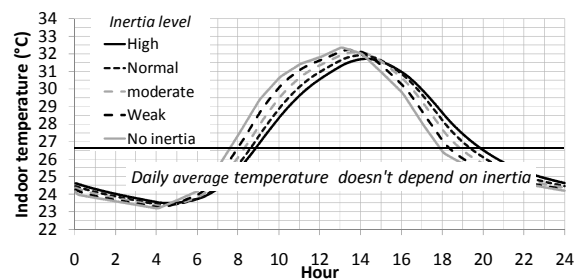


Figure 2 : Indoor temperature for various inertia with an air change rate equal to 15 vol/h

This method was developed as a preliminary and complementary thermal approach for designers, especially for renovated buildings that are overheated during the summer. The mean overheating is relevant thermal criteria and suitable to design the thermal characteristics of buildings because:

- It is a representation of the mean comfort and also of the excess heat that a successful design could eliminate or avoid with static parameters (convective transfer, absorption and shade coefficients, air change rate).
- It can be computed with an analytic approach allowing separating the origin of the overheating. Such a method becomes useful to assess the natural ventilated buildings with a simple tool made of Excel © worksheets.

The main aspects of the method consist in clarifying the gains and losses of enthalpy with a balance equation in a periodic and stationary regime. This energy balance written on a daily cycle separates:

- The sun radiation gains received by the room indoor air from the wall by conduction (E_{sun}), transmitted directly through the openings (E_o), and the internal gains (E_{int})
- The losses given to the environment by conduction through the envelope (E_c) or with the air change rate (E_{ach}).

The energy loaded by the buildings during a daily cycle is zero. The dynamic parameters disappear in the balance equation. Hence,

$$E_{sun} + E_o + E_{int} = E_c + E_{ach} \quad (7)$$

In stationary periodic regime, the conductive and ventilation terms can be written during a sequence of equivalent warm days as follows:

$$E_c = \int^T \sum_j U_j A_j (T_i - T_o) dt \quad (8)$$

$$E_{ach} = \int^T C_a ACH V (T_i - T_o) dt \quad (9)$$

With j the wall index, T the period duration, U_j the wall conductance, A_j the wall j area, T , and T_o the indoor and outdoor temperatures, C_a the specific heat of air, ACH the Air Change Rate, V the room volume. The analysis is based with mean values namely the mean overheating of the room ΔT_S and the mean conductance of the room U_m .

The energy loss can be determined by the mean daily overheating as follows:

$$E_c + E_{ach} = (U_m A + C_a ACH V) \Delta T_S T \quad (10)$$

The energy gains can be written after calculations as follows:

$$E_w = \sum_j \frac{A_j E_{wj} U_j}{h_{oj}} \quad (11)$$

$$E_o = \sum_j A_j \left(\sum_i E_{soi} \right) \left(1 - \frac{U_j}{h_{ij}} \right) \quad (12)$$

E_{wj} is the sun radiation energy absorbed by the wall j with an area of A_j . E_{soi} is the sun radiation energy crossing the opening i up to the wall j . h_{oj} and h_{ij} are the convective heat transfer coefficients of the outdoor and indoor walls.

The mean overheating of the air volume depends on the sun radiation contribution and can be written by introducing a term depending on the air change rate and another that corresponds to the mean overheating without ventilation.

$$\Delta T_S = R_C (U_m, D) \times \Delta T_S (D = 0) \quad (13)$$

Where D is specific mass flow rate: $D = ACH V/A$

$$\Delta T_S (D = 0) = \frac{1}{U_m A} \left[\sum_j A_j \frac{U_j E_{wj}}{h_{oj} T} + \sum_j A_j \left(\sum_i \frac{E_{soi}}{T} \right) \left(1 - \frac{U_j}{h_{ij}} \right) \right] \quad (14)$$

This is the temperature reached by the air volume without ventilation, namely the overheating when all of the energy gains are extracted with the conduction through the walls and the roof. This term depends only on the characteristics of the opaque and glazed faces and characterize:

- The building performances considering the sun protection. In fact, the terms E_{wj}/T and E_{soi}/T are the mean daily fluxes absorbed and transmitted through the walls and openings depending on the solar characteristics of the faces (colors, sun screen...) and the mean daily solar radiations,
- The repartition of the conductance according to solar exposure of the various faces

In theory, the optimized layout corresponds when the lowest conductance namely the best insulated faces are the most exposed faces to the sun radiation. The R_C parameter defined the ratio of energy evacuated with the conduction as:

$$R_C (U_m, D) = \frac{U_m}{U_m + C_a D} \quad (15)$$

The curves of R_C versus the building conductance show on figure 2:

- The more insulated the building is (low value of U_m), the more efficient the air change rate is.
- For medium sized isolated buildings ($2 < U_m < 4$), the mean overheating is reduced about 2/3 as soon as ACH is in the range 10 to 20 volumes an hour.

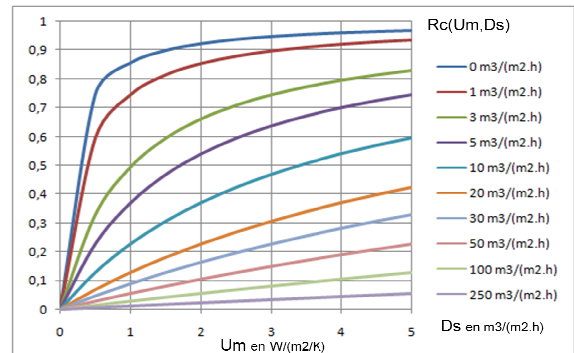


Figure 2 : Contribution of conduction to extraction of heat for various values of air change rate

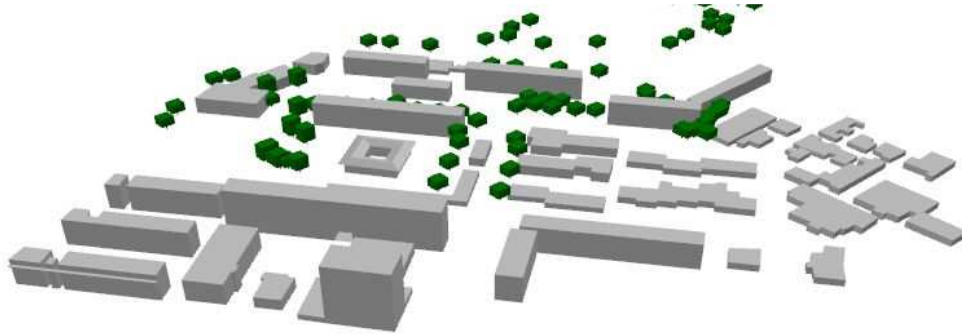


Figure 5 : Block geometry model in UrbaWind

EXAMPLE OF NATURAL VENTILATION AND THERMAL ASSESSMENT OF BUILDINGS IN AN URBAN AREA

At the Réunion Island, trade winds are moderate on the north side of the island. The climatology characteristics estimated at 40 m above the ground at the site is shown on figure 3. The average velocity is close to 3.5 m/s at 40 m. So according the log-law profile, the mean velocity is expected to be close to 2 m/s at 10 metres above the ground and the buildings may be naturally ventilated at this point.

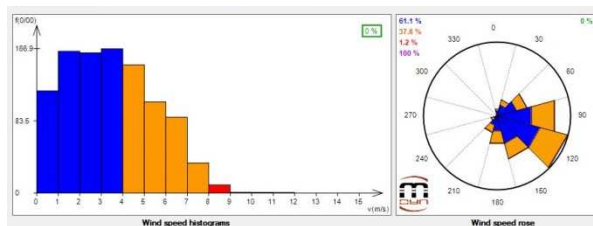


Figure 3 : Climatology of the site (h=40 m)

Due to the neighbouring buildings, the wind should be computed, and the mass flow rates entering the flat, should be assessed.



Figure 4 : "Chateau Morange" block at Saint-Denis (La Réunion Island)

The layout of the "Chateau Morange" block, which is located close to the north coast of La Réunion island at Saint-Denis, is shown on Figure 4. The project consists of the construction of new buildings (red

ones), of and the demolition (blue ones) or renovation of (white ones) the existing buildings.

Figure 5 shows the layout with the CFD software Urbawind where the neighbouring buildings and trees were also defined.

The computational domain covered 500 m by 500 m area and 100 m in height. The horizontal and vertical refinement for the cells close to the walls, the ground and all the result points are defined at 1 meter giving a total number of 1 million cells. The wind flow simulations were conducted for each wind incidence from 0° to 330° with a step of 45°. The time of computation was 1 hour for each run.

Figure 6 shows an example of the mean speed up factor field for trade winds and their direction in this area ("Alizés" trade winds flow in the sector 120°). The speed up factor is defined as the ratio of the mean speed at the result points to the reference mean velocity measured close to the computational domain entrance at 100 meters above the ground.

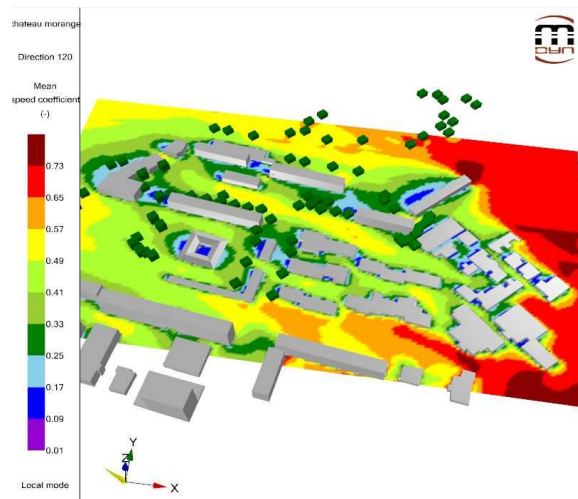


Figure 6 : Speed up factor field at 2 above the ground (wind direction 120°)

Figure 7 shows an example of a mean pressure coefficient on buildings of interest. The pressure coefficient is defined as the ratio of the mean pressure on the building walls to the reference dynamic pressure of the incoming wind measured

close to the computational domain entrance at 10 meters above the ground.

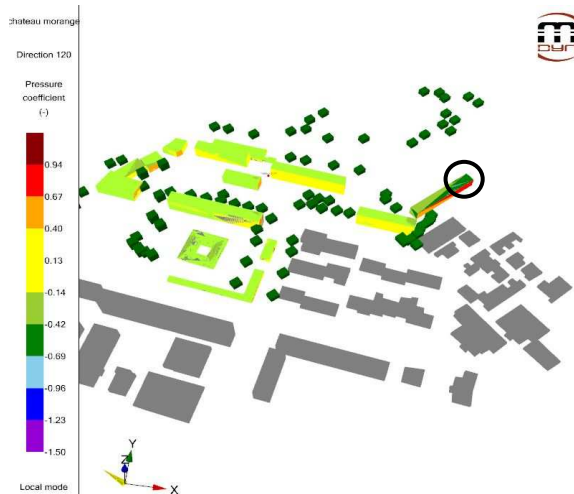


Figure 7: mean pressure coefficient on the buildings walls (wind direction 120°)

For each wind direction giving a pressure field on the outside walls, the flow rate was evaluated following the macroscopic method described previously for an apartment located at the top level of the building shown with a circle on figure 7. This apartment was chosen because of its exposition to the sun radiation, (roof and east sidewall) making it the worst case with the most expensive cost to renovate.

The flat is a medium sized flat with a main room and two bedrooms as shown on figure 8. The surface and volume of the space are respectively 65 m² and 160 m³.

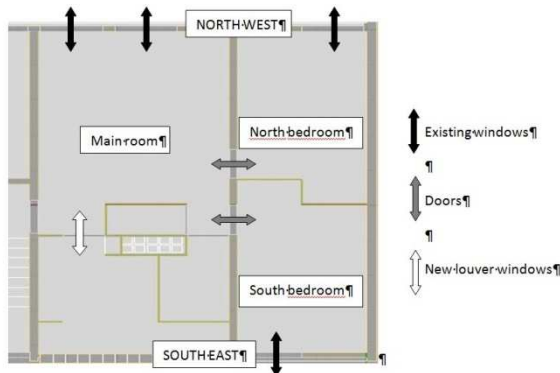


Figure 8 : mean pressure coefficient on the buildings walls (wind direction 120°)

Before renovation, three windows (1.2x1.2m) are fitted on the north side and one window on the south side. To increase the cross ventilation rate, two renovations were made: enlarging the doors in order to increase the indoor permeability, and adding another window on the south side (a louver on the balcony wall with an area of 1m² or 2 m²). The bedroom doors were expected to be opened but a configuration with closed doors and a jalousie window (0.5 m²) above the door was tested.

The ventilation was estimated according to the climate around the block by taking into account the occurrence of both the velocity and incidence (Figure 9).

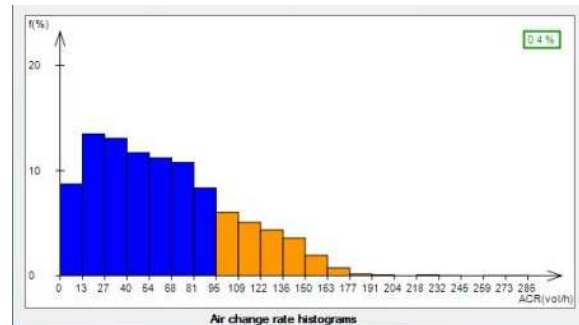


Figure 9: Air change rate distribution (yearly data)

The yearly average Air Change Rate <ACH> and other criteria are shown in table 1 for six configurations before (the first line) and after renovations (the five following lines).

P(ACH<15) is the probability for ACH to not exceed 15 vol/h. A minimum air change rate ACH(P<0.05) is defined as follows : ACH is lower than this value 5% of the time (18 days a year). These statistics are useful when evaluating the efficiency of a cross ventilation configuration and to assess the thermal behavior of the apartment as presented in the following section of the article.

Table 1 : Statistics of Air Change Rate

CASES	<ACH>	P (ACH<15)	ACH (P<0.05)
North : 3 windows South: 1 window Doors : opened	65 Vol/h	0.11	9 Vol/h
North : 3 windows South: 1 window Doors : enlarged	90 Vol/h	0.06	13 Vol/h
North : 3 windows South: 2 windows (1.4 m ² + 1 m ²) Doors : opened	105 Vol/h	0.05	15 Vol/h
North : 3 windows South: 2 windows (1.4 m ² + 2 m ²) Doors : opened	140 Vol/h	0.03	19 Vol/h
North : 3 windows South: 2 windows (1.4 m ² + 1 m ²) Doors : closed (louver 0.5 m ² above the door)	80 Vol/h	0.09	10 Vol/h
North : 3 windows South: 2 windows (1.4 m ² + 2 m ²) Doors : closed (louver 0.5 m ² above the door)	115 Vol/h	0.05	15 Vol/h

Compared to the example referenced, the new configurations with a second south window (1m²)

improved up to 40% of the average value $\langle \text{ACH} \rangle$ and 65% for the lower value of ACH. By enlarging the second window to 2 m² this allowed double the the amount of cross ventilation in the apartment.

Increasing the internal porosity is an efficient way to improve the cross ventilation. The ratio of north wall to south wall porosity is too large before the renovation. The flow of air has to go through the south bedroom to cross ventilate the flat. Opening up the south wall of the main room should be recommended. More over, to open the wall above the bedroom doors with a small louver maintains air circulation even when the door is closed.

Following the aerodynamic assessment, designers should check to ensure the air change rate is high enough to allow the extraction of heat. The temperature variation at Saint-Denis is shown on figure 10. January and February are the most difficult periods to achieve the indoor thermal comfort. The average daily temperature can rise up to 30°C. According to the Givoni's Diagram (figure 1), overheating of the indoor air should not exceed 2°C in this area in order to not exceed 32°C inside the buildings.

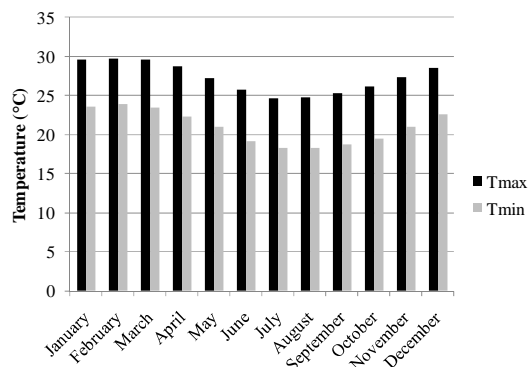


Figure 10 : mean of the extreme temperature at Saint-Denis (from Meteo France)

The apartment is located on the top of the building and is exposed to sun radiation. The heat flux with the apartment on the floor below was neglected. The walls and ceiling are made of concrete with an internal layer of wall plaster. The northeast windows are opened and sun screens reduce the sun radiation by about 30%. The external walls are clear and the solar absorption coefficient is 0.4.

The computation of the mean thermal balance was carried out with the method BATIPEI previously described. The fluxes associated with the highest solar radiation at Saint-Denis (Austral summer) are used as input data in the simulation as shown in figure 11.

The computation was carried out by writing the surface of the walls, roofs and openings area, and their thermal coefficients (convective transfer, absorption and shade coefficients) in tables for each apartment. The mass flow rate defined as an input was calculated with UrbaWind. Nevertheless, further computations were carried out by varying the ACH

in order to evaluate sensibility of the system to the air exchange rate.

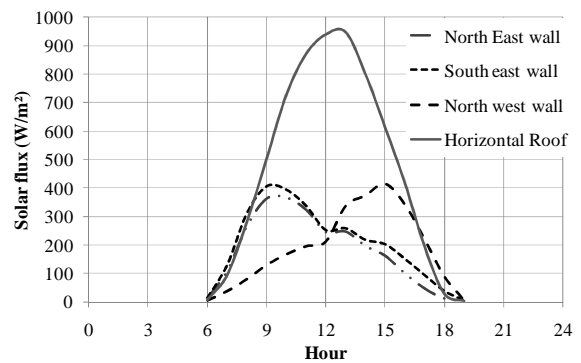


Figure 11 : Solar fluxes on the roof and the flat walls (Austral summer)

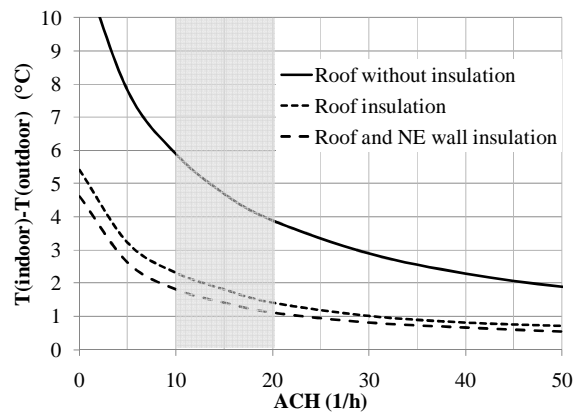


Figure 12 : Overheating temperature versus the air change rate for reference layout and improved layouts with insulation.

Without additional insulation, the convective transfer coefficient $U_{\text{wall}}=U_{\text{ceiling}}=2.8 \text{ W/m}^2/\text{K}$. As shown on figures 12, the mean overheating is in the range [4-6] °C for ACH in the range [10-20] volume/hour exceeding the “2°C” limit. The main part of the heat transfer is associated to the roof (70%) as shown on figure 13.

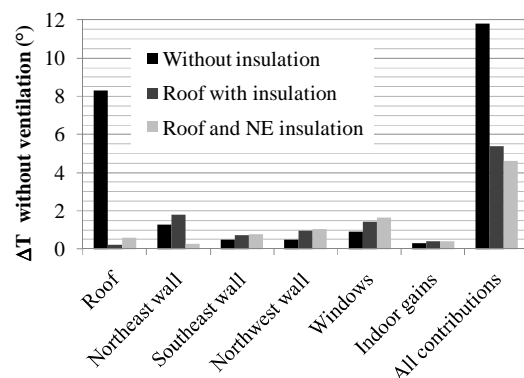


Figure 13 : Overheating temperature for every building part without ventilation.

Hence, the external treatment of the roof with a mineral wool (thickness= 0.1m, thermal conductivity $\lambda=0.04 \text{ W/m/K}$) was necessary. The overheating became close to 2°C with ACH between 10 to 20

Vol/h. The overheating is mainly due to the sun exposure of the northeast wall and can be reduced with an additional outside insulation, for instance with a thin polyurethane layer about 20 mm.

Finally, the overheating is lower than 2°C for the range of ACH expected to be reached during summer. Note for the summer months, statistically speaking, ACH is lower than 10 volume/hour 5 hours per month and lower than 20 volume/hour 17 hours per month. In other words, the mean overheating of the renovated flat could only exceed 1°C one day a summer month and 2°C for only a few hours.

CONCLUSION

The indoor thermal comfort in a tropical climate of naturally ventilated buildings depends both on the thermal behaviours of the buildings and the air exchange through the openings. Natural ventilation is less effective in urban environments and is not easily designed because of the complexity of wind velocity behaviours. Hence air exchanges across the buildings' openings are functions of the wind speed in the urban areas, of the building shape and on the efficiency of the openings. Designers and architects alike, need tools to swiftly validate the cooling strategy for the building design. The openings (positions, dimensions and efficiency) and the thermal definition of the envelope (insulation layer, sunscreen, windows glass...) need to be defined with simple tools that give results which are easily understood.

That being said, this article presented a method to assess the indoor thermal comfort in a warm tropical climate. The method is made of two separate aerodynamic and thermal tools. First, the assessment is carried out from an aerodynamic point of view. Air Change Rates are evaluated for each apartment from the buildings in this project. Statistics of ventilation rate are then extracted from the local climatology. The second step consists of computing the thermal response of a building to the climatic parameters: wind, temperature, humidity and solar radiation. Mean overheating inside the building is calculated and compared with the maximum indoor temperature acceptable according to the comfort criteria, for instance with the Givoni's diagram.

Finally, a case of urban renovation of an older building at the city of Saint-Denis (La Réunion Island), is presented here as an example of the use of combined approaches devoted to designers. The tools allow upgrading the strategy of cross ventilation by introducing new openings in order to obtain an air change rate high enough to allow heat extraction. The envelope is also upgraded according to the thermal tool resulting in the improvement of the insulation of the roof and of external sidewall source of heating flux.

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