Natural ventilation of urban buildings – summary of URBVENT project

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ABSTRACT

The architectural decisions for building that use natural ventilation should be taken in the initial stages of design when little information is available. A new approach is to compare the potential natural ventilation of known buildings in a new site and to adapt the design of the known example. The potential of natural ventilation may be changed by the barriers to its application: reduced wind velocity, higher temperatures, noise and pollution. Simple models, constructed on measurements, give an indication of the influence of these barriers. The dimensions of the openings may be obtained from a database that contains the most common combinations of meteorological conditions, room and opening size, and airflow rates.

1. CLIMATIC SUITABILITY

A lot of attention has been given to model approach design of buildings. The results of the models may be judged and design decision taken. However, in practice the number the initial unknowns is do large that obtaining them becomes too costly and time consuming. Model based design is used only in very few situations.

Much more widely used is the design by examples. Designing by examples simplifies the process of solution searching because it helps to avoid that a fuzzy defined problem becomes an ill defined one.

Although designing by examples is widely used in practice, the research dedicated to this approach is very rare. The evaluation of the degree of suitability of existing examples to a new situation is done by experts based mainly on qualitative reasoning and intuition.

URBVENT project developed two methods to formalize decision taking based on examples. One assesses the climatic suitability and the other one makes a classification of the suitability of a new site in comparison with known sites.

Climatic suitability of natural ventilation is defined as a measure of the energy saved for cooling when ventilation is used. The climate should be taken into account in relation with the building thermal behavior and the anticipated thermal comfort. The thermal behavior of the building may be characterized by the free-running temperature. This is defined as the indoor temperature of the building in thermal balance with the outdoor environment when neither heating nor cooling is used. Furthermore, it is assumed that the free-running temperature is defined for the minimum ventilation rate needed for indoor air quality, which implies that the building is almost airtight. With these assumptions, it may be accepted that, for a given month of the year, the indoor temperature of the mean value of the free-running building is a function of the hour of the day and its dispersion is a function of the building. Based on these assumptions, the probabilistic distribution of degree-hours in function of outdoor temperature may be estimated. The comparison of these distributions gives an indication of the climatic suitability of the natural ventilation (Ghiaus and Allard, 2002; Ghiaus, 2003).

2. NATURAL VENTILATION POTENTIAL

The most influential decisions are taken in the very first stages of urban and building design. The architectural solutions planned during this phase have a major influence on the application of natural ventilation.

To support these decisions, during the URBVENT project it was developed a methodology for assessing the potential of natural ventilation and the design of openings. The natural ventilation potential is the possibility to ensure, at a given urban site, an acceptable indoor air quality by natural ventilation only, provided that the building is appropriately designed. A multicriteria methodology for assessing the natural ventilation potential was developed during the URBVENT project (Germano et al., 2002; Roulet et al., 2002; Germano and Ghiaus, 2003; Germano et al., 2005).

2.1 Driving forces

Natural ventilation is driven by wind and buoyancy. The wind is reduced in the urban environment, especially in the street canyons (Ghiaus and Allard, 2003). Its reduction may be estimated by using the algorithm presented in section 0. The other driving force, the buoyancy, depends on the temperature difference between indoor and outdoor. The outdoor temperature may be significantly higher in urban environment than in the rural adjacent suburbs (see section 0).

2.2 Constraints

Among the barriers to the application of natural ventilation, the urban constraints are pollution and noise. The level of these constraints may be specified quantitatively or qualitatively. The second specification is easier to understand by the non-specialists and can be determined by measurements by subjective answers given to questionnaires.

2.3 Multicriteria analysis

The driving forces and the constraints are integrated in time obtaining wind-time, stack-time, pollution-time and noise-time indicators. Then, a multicritera analysis is performed by using Qualiflex method. The result is a classification of the suitability of natural ventilation in the given site for the buildings considered in the evaluation.

3. WIND VELOCITY IN STREET CANYONS

Wind in street canyons was studied for all types of wind flow outside the canyon (parallel, vertical and oblique to the main axis) and a large range of velocity (0 to 13 m/s) of the undisturbed wind speed. in configurations that are rarely treated in literature: oblique direction of wind and low velocity of undisturbed wind. When the wind speed outside the canyon is between 0.5 m/s and 4 m/s, although the flow inside the street canyon seemed to have chaotic characteristics, extended analysis of the experimental data resulted in two empirical models, one for wind blowing along the canyon and another for the wind blowing perpendicular or oblique to the canyon (Georgakis and Santamouris, 2004; Georgakis and Santamouris, 2005). If the wind speed outside the canyon is higher than 4 m/s, the wind inside the canyon depends on the incidence angle and its velocity is given by simple models already described in the literature (Georgakis and Santamouris, 2003).

4. TEMPERATURE IN URBAN ENVIRONMENT

The temperature distribution in the urban canopy layer is greatly affected by the radiation balance. Solar radiation incident on urban surfaces is absorbed and then transformed into sensible heat. Most of the solar radiation impinges on roofs and on the vertical walls of buildings; only a relatively small part reaches ground level. The heat island effect reveals in higher temperatures in urban area as compared with the surrounding suburbs. But the temperature measured inside the canyon streets was with about 5°C lower than that of the canopy layer, partially compensating the effect of the urban heat island (Georgakis and Santamouris, 2005).

5. NOISE

Noise is intense in street canyons but it is reduced with the height of the buildings. If the sound power is assumed proportional to the number of vehicles per hour, the sound level may be expressed as an expression in which the coefficients may be obtained by regression of the experimental data. Furthermore, if it is accepted that the traffic intensity is correlated to the street width, noise reduction may be expressed as a function of the height above the street. Although the parameters obtained by regression are specific to the experiment conducted in Athens during the URBVENT project, the methodology is applicable to other towns, provided that the specific parameters are estimated or identified experimentally (Nicol et al., 2002; Nicol and Wilson, 2004; Wilson et al., 2005).

6. POLLUTION

Outdoor air pollution is commonly considered as another barrier to natural ventilation since filters cannot be used as in mechanical or air-conditioning systems.

In the joint framework of URBVENT project and the French program PRIMEQUAL, an experimental study of outdoor - indoor pollution transfer was conducted in nine schools. The pollutants studied were ozone, nitrogen dioxide and 15 sizes of particle matter. Three maps were calculated for every pollutant: the I/O ratio, the precision of this estimation and the degree of confidence in the I/O ratio and precision. The ratio of indoor - outdoor concentration was determined as a function of airflow through the facade and of the outdoor concentration. The indoor concentration was smaller inside than outside. Ozone presented the lowest I/O ratio (0.1-0.4). The I/O ratio for nitrogen dioxide was between approximately zero and 0.95. The I/O ratio for particle matter depended on the particle size. The most important variation, 0.25 to 0.70, was measured for particles of small size (0.3-0.4μm); particles of larger size (0.8 - 3μm) represented lower, but comparable, variation of the I/O ratio, 0.3 to 0.7 (Iordache, 2003; Ghiaus et al., 2005).

7. OPTIMAL OPENINGS DESIGN

Natural ventilation of buildings is affected by the urban environment, the building configuration and the type of façade (Georgakis et al., 2004). The airflow through an external opening is strongly dependent upon the wind-induced pressure difference across it. This wind-induced pressure depends on the detailed knowledge of pressure coefficients on each building surface. Reliable pressure coefficient values for complex urban layouts and/or complex façades can only be obtained through wind tunnel studies for each specific case, a technique that is still the rule for such cases today. General studies are thus only possible for cases that do not depend on pressure coefficients: single sided ventilation and cross-ventilation of apartments with openings in a single façade plus a chimney linking them to the roof of the building, in the absence of wind, i.e. stack-induced flow (Almeida et al., 2005).

A database of air-flow rates was calculated for a set of different architectural scenarios for a small room with single-sided ventilated with stack-induced ventilation. For this room, the geometrical dimensions and the weather conditions were varied. The database can be used to find the airflow rate when the geometrical dimensions are given or to find the set of geometrical dimensions that give a required airflow rate. This second situation is far more common in design.

The same two types of database search were implemented by using an artificial neural network.

8. CONCLUSIONS

A method for the assessment of the natural ventilation of an urban site has been developed. The assessment is made firstly by estimating the potential of free-cooling of the site and then by considering the driving forces and constraints of natural ventilation present at the site and by comparing it with other well-known sites. The classification method was validated on eight naturally ventilated building, checking if the prediction of the method fits with the opinion of the occupants of buildings.

Once a site with a good potential is found, the designer's task is to construct a building or to refurbish an existing one in a way that makes the most out of this potential. In other words, both an appropriate site and an appropriate building are necessary conditions for natural ventilation to be applied.

The urban environment presents drawbacks for the application of natural ventilation. The wind, temperature, noise and pollution were studied experimentally. The simple models obtained may be used to estimate the reduction of the potential of natural ventilation due to urban environment.

The design of the facade openings requires an inverse model. The existing tools estimate the airflow rate when the openings dimension and location are given. The approach to inverse the model was to construct a database of simulation results and to find in this database the openings that give the desired airflow. The search in this database was also implemented by using neural-networks.

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