

## CONCEPTUAL IMPLEMENTATION OF NATURAL VENTILATION STRATEGY

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### ABSTRACT

The necessity of focus on more large integration of passive concepts for indoor climate conditioning is today a reality. Through this study, a contribution to fill the lack of useful design guidelines for natural ventilation is proposed, in order to develop the passive ventilation systems implementation. Besides a methodological approach, the paper proposes conceptual tools. The implementation of a natural ventilation strategy includes the envelope building design, the indoor spaces layout and the component sizing. This study explores an architectural classification of ventilation systems. The ventilation system involvement is underlined through evaluation of ventilation efficiency concerning two natural ventilation systems using ducts.

### INTRODUCTION

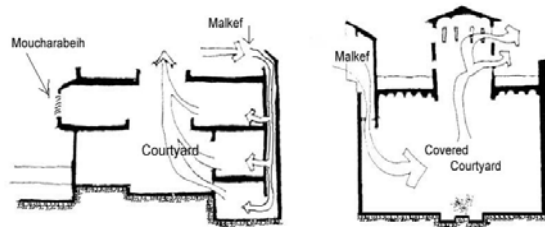
The generalisation of natural ventilation use depends on wining architect's trust in this technique by proposing simple designing tools. Indeed, the evolution of the indoor environment requirement: thermal comfort, air quality, ... throws the natural ventilation technique back into question in favour of the mechanical ventilation. Generalised after the oil crisis, the mechanical ventilation allows theoretically both to reply to indoor environment regulation and to avoid heat losses.

In the brief period of the past decade, the European developments have proceeded through a number of distinct generations of naturally ventilated buildings. Through the consciousness initiated by the scientific research of the building trade energy consumption, the natural ventilation is updated. The natural ventilation concepts in evolution today, resulted from the traditional architecture. However, the innovation consists on the integration of the control notion in the ventilation strategy (airflow control, air velocity, air rate and temperatures).

#### **Natural ventilation, a new idea ?**

From architectural point of view, it is easy to make the parallel between the natural ventilation strategies in past and the contemporary architecture. A short overview on the main natural ventilation devices

around the Mediterranean basin permits to spot three main natural ventilation strategies. The courtyard house is the product of a sophisticated historical process of unconscious "climatic design". The "Patio house"(fig.1) is a typology in which all living areas distributed around the courtyard benefit by the courtyard air circulation at low speed. Designed to limit the indoor conditions fluctuations, large openings are turned toward the courtyard.



*Figure 1 Combination of natural ventilation devices in traditional Arab house "Malkef, Courtyard" (Architectural scientific journal n°4, 1988)*

The "Malkef" or the wind catcher, however, appears as the most important device that serves the ventilation. The collected air, above the roof, is led by a chimney sheltered from the solar radiation (to prevent the air warm up) and distributed on the various floors. The wind catcher is naturally selective because it does not function only thanks to the winds but also thanks to the difference in temperature between the wind and the interior ambient air. Indeed, when the interior air is fresher than the surrounding air, it causes a pressure; witch prevents the wind from penetrating in the sensor to go down to the ground floor from the dwelling.

The most interesting opening is the "Moucharabeih" (fig.2) which is a kind of lathing opening finely braided. The small openings allow taking advantage of ventilation. In many places, porous jars placed in front of the window cool the air as it flows inside by provoking the evaporation of the water.

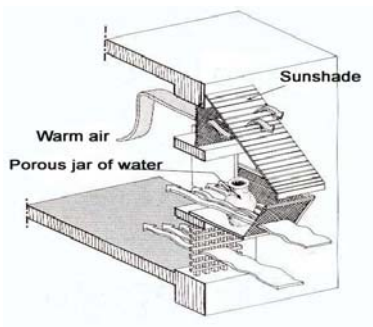


Figure 2 "Moucharabieh" operating system (Izard, 1979)

### Architectural analysis

These natural ventilation systems ensue from a long intercultural and revolutionary "trial and error" process. Until now, the main drawback in using natural ventilation is the limited possibilities for the airflow control. The natural ventilation barriers concern the airflow regulation. The technologies evolution brings new elements, which permit to evolve the natural ventilation techniques.

In general, the literature classifies the natural ventilation strategies in three categories:

- Single side ventilation
- Cross ventilation
- Stack effect

The development of the green building design obliges to go further in the direction of the architectural innovation. An awakening has been supported by the European projects that explore new processes in favour of the energy saving and the environment protection. The natural ventilation systems examination reveals that the ventilation strategy is, generally, based on the devices design. In contrast, the previous classification is not sufficient to characterize ventilation systems.

The basis elements of natural ventilation systems are:

- An appropriate building form, which is sited and shaped furthering the access of outdoor air.
- An appropriate choice of natural ventilation devices in accordance with the climatic outdoor conditions sited and shaped to take advantage of prevailing winds and/or to take advantage of buoyancy forces.
- Appropriately, sized inlet and outlet openings to admit and to exhaust sufficient air to achieve the natural ventilation objective.

The purpose of this study is to complete the lack of useful design guidelines. We propose a methodological approach composed of a topomorphological analysis, which permits to establish a

typological devices classification besides the topological spaces analysis.

### Natural ventilation devices

An overview of naturally ventilated buildings permits to identify the main natural ventilation devices. The study of the ventilation strategy in each example emphasizes the importance of the design approach. The adoption of a natural ventilation strategy must be accompanied by a specific design of the building. The natural ventilation strategy depends on the envelope building design and the indoor spaces layout. The morphological analysis (Mansouri et al., 2002) consists in the acquaintance of the spaces organisation logics. Taking the diversity of building designs into account as the specific character of the spaces arrangement requires the development of a method based initially on geometrical principles. This part of the study aims at developing a classification of these devices according to the morphological aspects (Larochelle et al., 2000).

### Transition space:

This strategy of ventilation is based on the use of distribution space such as the atrium or the stairwell atrium in the case of the "Administration building of Würzburg" (fig.3). Besides its function of distribution, the atrium permits the ventilation of the spaces it serves. Beyond the natural ventilation, the transition space is a place of relaxation and regrouping, which plays an important role in the organisation of the circulation.

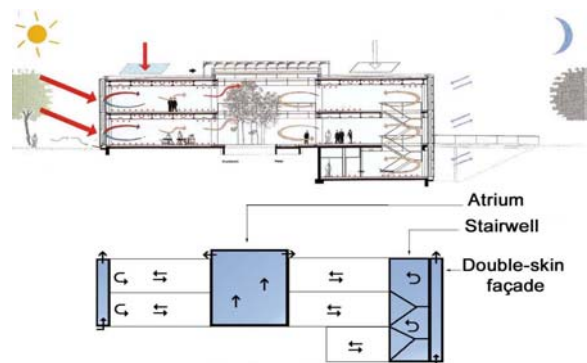


Figure 3 The atrium is also one of the key elements of the natural ventilation strategy (Architecture review "DETAIL" n°3 1997).

As it was underlined before, ventilation strategy by transition space affects the building design. Therefore, the organization of the spaces depends on the positioning of the transition space. The ventilation strategy is based on the transition spaces organisation according to the position, the number and the connection of the transition spaces. Three principal organisations are possible (fig.4):

- Distant structure: the building ventilation is distributed on different transition spaces.
- Adjacency structure: the building ventilation system includes more than one transition space. The contact between the transition spaces increases generally the air circulation.
- Overlapping structure: the transition spaces are partially superposed. Therefore, the ventilation strategy influences all the building spaces organization.

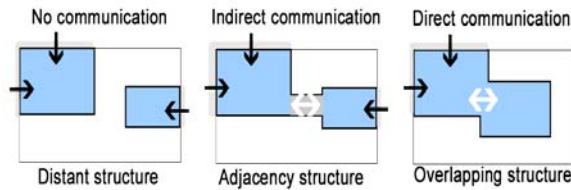


Figure 4 Transition spaces layout configurations

**Stack devices:**

The most common system is the chimney formal aspect, which differs from a building to another. The stack natural ventilation devices are not integrated in the building framework. Therefore, they don't influence the space organization of the building. It is the reason why the constraints related to the positioning of this system are unimportant. We can see in the following example of the "BRE Building" (fig.5) that the superposition of the spaces permits to ventilate them by a unique stack chimney in the front of the building.

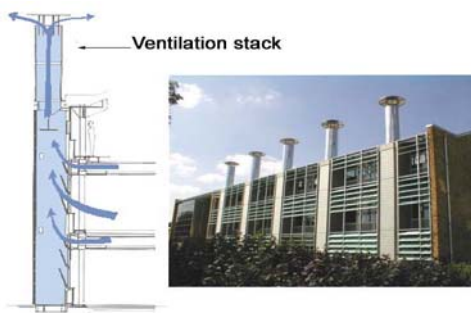


Figure 5 Ventilation stacks are incorporated in the south facade of the building (Feilden Clegg Bradley architects 2001. Personal communication).

Widely spread in Europe, the chimney is taken back under different shapes. However, this system can be considered as a wind catcher according to his design. On topological point of view, the building design is independent of the natural ventilation strategy. Actually, a stack device ventilates each space. That is, several spaces fitting are possible according to the building function (fig.6):

- An adjacency structure: each space is ventilated individually.

- An overlapping structure: all spaces are partially superposed. However, each space has a specific ventilation strategy.
- A fitting structure: similar designing spaces are superposed.

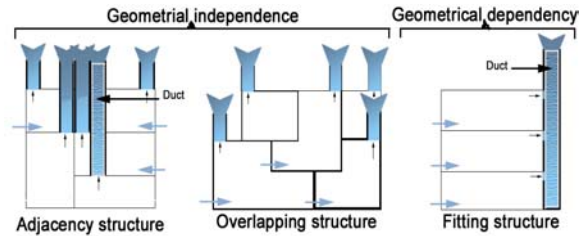


Figure 6 Stack devices : Spaces layout configurations

**Ventilation shaft:**

The ventilation shafts are integrated in the building envelope. Consequently, most of them participate to the constructive structure of the building. In another way, the building design depends on the ventilation requirements. For example, in the case of the "Craning Crescent Center building" (fig.7), the spaces positioning and their organization are actually conditioned by the natural ventilation requirements. The size of the ventilation shafts and the spaces location depend on the ventilation strategy.

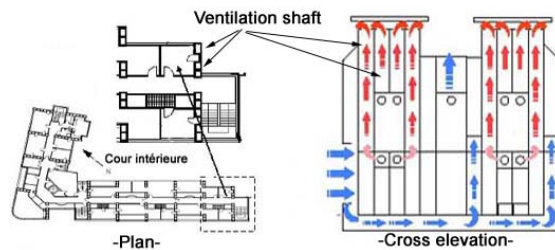


Figure 7 Natural ventilation strategy was developed using diaphragm cross walls (European NatVent™ Project CD Rome, 1988)

The building spatial organisation is widely dependent on the ventilation system. In the same times, the ventilation system requirements condition the building envelope design. From architectural point of view, two solutions of spaces layout are possible (fig.8):

- An adjacency structure: each space contains separately the ventilation shafts.
- A fitting structure: the spaces are ventilated using one single duct and the slate air is rejected by another common duct.

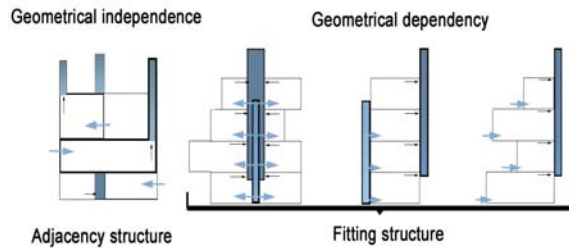


Figure 8 Ventilation shaft: Spaces layout configurations

### Front opening:

Several techniques of ventilation are developed around the "Double-skin Facade". The ventilation is based on the design of the openings. This natural ventilation strategy is especially developed in the moderate climate countries. The most famous example is the "Commerzbank" designed by Norman Foster (fig.9). The offices on the outer faces get their air directly from the exterior through the breathing outer section, which has two layers of fixed sheet of glass. The inner one is a double glazed opening that can be opened inside at the tops. The external air gets in the facade cavity by the outdoor glass mouths.

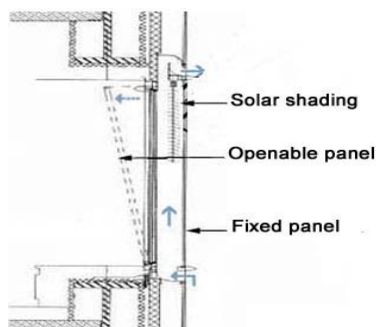


Figure 9 Commerzbank offices ventilation by front openings (Fosters and Partners 2001, personal communication).

The ventilation of the spaces is essentially based on the building external envelope design and the opening allocation on the façade. The natural ventilation control requirements are achieved by using two strategies. These last concern the linkage between the ventilated spaces and the outdoor. Two principal layouts can be adopted (fig.10):

- External adjacency: in this case, the ventilated spaces are partially subjected to the building envelope, in contact with the outdoor.
- Internal adjacency: the building spaces are ventilated through a transition space that creates the contact with the outdoor.

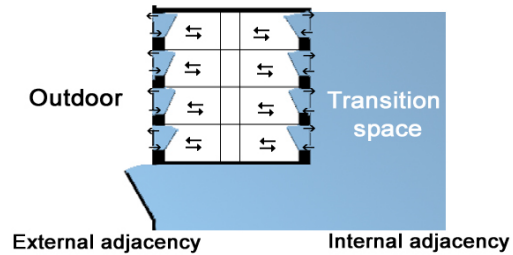


Figure 10 Front opening: Spaces layout configurations

The implementation of a natural ventilation strategy depends on the choice of natural ventilation system. The study of two different configurations of natural ventilation system composed both of ducts permits to underline the airflow rates variations stemmed from the devices form variation.

### METHODOLOGICAL APPROACH IN THE DEFINITION OF DESIGN GUIDELINES

The efficacy of a natural ventilation strategy is essentially conditioned by the sizing of components on which the airflow control depends. The indoor environment conditioning is submitted to strict regulation. Concerning, ventilation too, the architects must be in conformity with the comfort standard. The integration of natural ventilation devices acts on the building layout, therefore the devices sizing is important for the architect.

The technology improvement displays the advantages of natural ventilation and, at the same time, gives the means to master the airflow and to control the indoor environment. Advanced research, in particular concerning the numerical simulation of the natural phenomena, permits to fulfil the indoor environment quality requirements at least energy cost. In the last decade, the use of natural ventilation in European commercial office buildings has received much attention. An increase of the naturally ventilated building has been noted essentially under moderate climates. The architects propose an important number of innovative solutions to prevent natural ventilation disadvantages.

The interior layout of the building becomes crucial, as well as his physical location. The designer must consider fluctuations of outdoor environment characteristics: temperature, humidity, wind speed and direction... After the identification of the natural ventilation purpose, the design of naturally ventilated building implies to integrate and to follow accurate design guidelines at the different stages of the design process. These guidelines are related to:

- Site design aspects: location and orientation of buildings as well as landscaping.



- Building design aspects essentially related to the spatial distribution.

### Study of natural ventilation system using duct

The last part of this paper is devoted to the study of designing guidelines related to the shaft ventilation systems. The computing simulation using the coupled programs COMIS (Feustel H et al , 1990) and TRNSYS (Klein S.A et al , 1994) permits to define the devices behaviour. In this paper, a thermo-aerodynamic analysis is carried out to characterise the role of the duct systems structures. The project set out to evaluate the duct performances in real conditions of outdoor climate, essentially wind effect. Therefore, we take the weather data of "La Rochelle" in France as reference. The multizone dynamic analysis program COMIS-TRNSYS supports modelling of coupled thermal airflow interactions and building ventilation system. The modelling studies are used to evaluate:

- Indoor air temperature during natural ventilation system operation
- Air changes in terms of times histories.

These statistics have been devised to provide design guidelines for preliminary considerations. To facilitate preliminary design considerations, the ventilation capacities of duct are evaluated both in accordance to the duct length and the duct diameter in the specified site. The total length of the duct is uncloded between 3 m and 12 m.

The scope of the modelling studies is a building. This last is a multizone model constituted by three zones. The ventilation system is constituted by ducts that are disposed on a horizontal position for the air inlet and on vertical position for the air exhaust (fig.11). We have chosen to put the zones one above the other. The zones are similar concerning the volumes (3m x 3m x 3m) and the materials (Outdoor wall: k-Wert= 0.296 W/m2K, Floor: k-Wert= 3.061 W/m2K.).

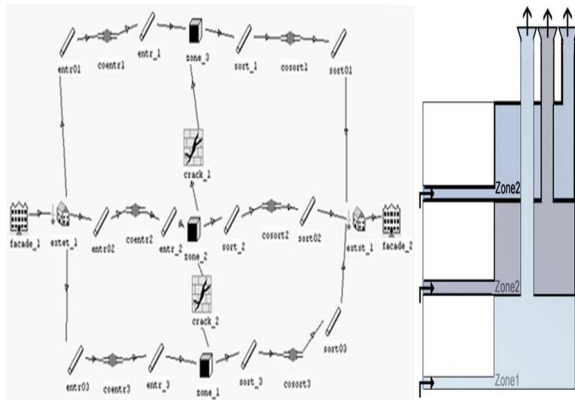
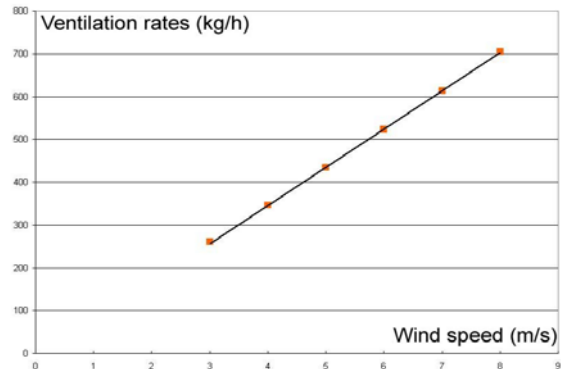


Figure 11 Schema of the building and the Comis model under Lisibat Interface.

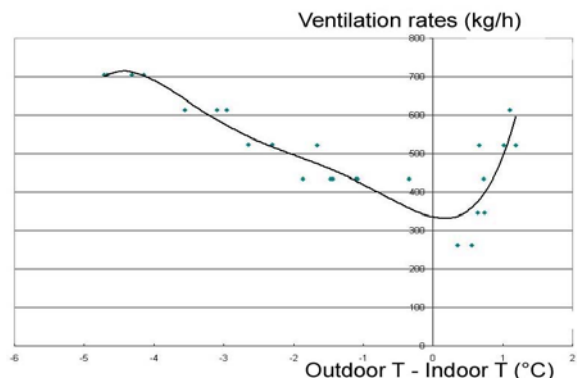
### Computed results analysis:

This section presents and discusses the implications of computed results for both the length and the diameter of the ducts. The computed results concern a simplified single-zone. As expected, the simplified single-zone model permits to study the duct behaviour. The total duct length varies from 3 m to 12 m.



Graph 1 Computed results of Wind speed (m/s) and ventilation rates (kg/h) (21 March diameter of 0.2m and length 10 m)

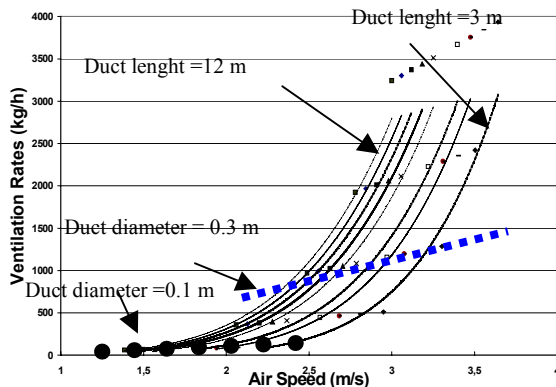
As expected, the results tabulated above clearly reveal an increase of the ventilation flow rates following the wind speed. The ventilation rates increase is more noticeable for larger diameter. Indeed, as noted in graph.1 there is a relation between the diameter and the ventilation rates. This last increases in a significant way when the diameter is larger. To evaluate the indoor temperature evolution compared to the flow rate evolution, the results obtained for the period between (1 – 15) July are reported in graph.2.



Graph 2 The ventilation rates evolution according to the outdoor and indoor difference temperature

The impact of the outdoor temperature variation can be observed on the indoor temperature. The slight variation of indoor temperature is probably due to the important building thermal mass. The temperature attenuation is important.

The simulations, in the second step, permit to assess the evolution of air inlet speed following the diameter increase (graph.3).



Graph 3 Air inlet speed in the duct according to the diameter variation (0.1m to 0.5m) and length variation (3m-12m).

As expected, the ventilation rates increase in the same time as the diameter, however, the results tabulated above reveal the decrease of ventilation rates with the increase of the duct length. The schema gives indications about the means of airflow rates following the length and the diameter variations. The study purpose is not to substitute for the mathematical models but to give large information about the duct performance in the specified site.

### Comparison between two configurations

Following the duct characterization, we propose to study two different configurations of building integrating a natural ventilation system based on ducts. According to the precedent classification proposed in this paper, we study the two following configurations:

- An adjacency structure: each space contains separately the ventilation shafts (fig.12)
- A fitting structure: the spaces are ventilated using one single duct and the slate air is rejected by another common duct (fig.12).

Situated in the same site, the collected information about the duct performance informs about the duct sizing. Nevertheless, the comparison is not total because the stack effect is not the same, i.e. the lengths of the vertical ducts are not the same. These results give information about the order of magnitude of ventilation rates that correspond to the building requirements and the number of possibilities is reduced for the designer. The first configuration called "Adjacency structure" (fig.12) is composed by three zones disposed one above the other. Each one is ventilated by a system composed of a duct with a diameter of 0.1 m and a length of 10 m. Considering the results obtained in the previous study the duct diameter of 0.1 m should be suitable for the most

unfavourable case, i.e. the first zone. This last is ventilated by a system composed by two ducts with a total length of 18 m. According to the ventilation rules, the ventilation rates should be at the minimum equal to 27 kg/h, so the air inlet speed should be greater than 0.79 m/s. The air inlet is located in the bottom of each zone and connected to the duct by an elbow duct fitting. The air outlet is located on the top of each zone connected also by an elbow to the duct. The length of the air outlet duct differs from one zone to other as shown in fig.12.

The second analysis concerns the configuration called "Fitting structure" (fig.12). The same characteristics of building are chosen concerning the zones volume and the materials. The zones are ventilated by only one duct with a diameter of 0.3 m and a length of 10 m. Each zone is connected to the air inlet duct by an elbow in the bottom of the ventilated space. The air exhaust is conveyed in a duct with a diameter of 0.3 m and a total length of 8m. According to the results presented above, to achieve the ventilation requirements i.e. 81 kg/h a diameter of 0.3 m for this system is satisfactory. Indeed the air speed into the duct must be greater than 0.26 m/s if we consider the unfavourable case of the second zone with a total duct length of 24 m. Each zone is connected to the air outlet duct by an elbow in the top of the zone.

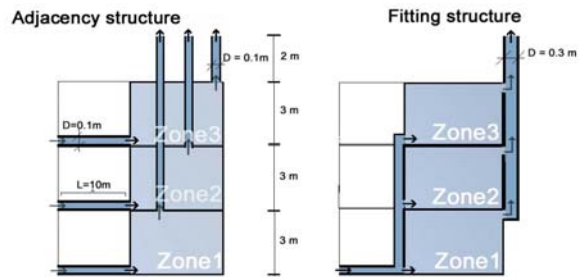


Figure 12 Ventilation strategy configurations

### Computed results analysis:

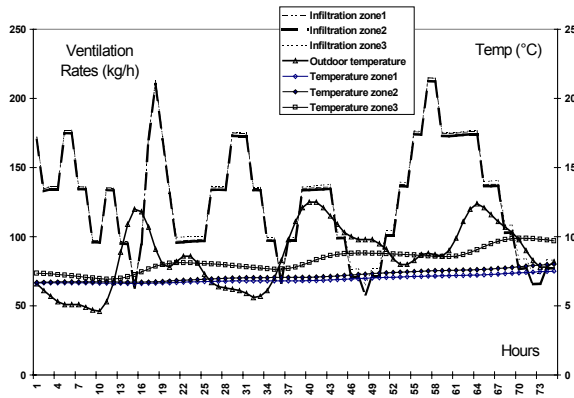
This section presents and discusses the building behaviour for both proposed configurations. The COMIS program allows implementing, based on the "Numerical data for air infiltration and natural ventilation" (Orme et al., 1998), the pressure coefficient on both the opposed faces of the building. The chosen buildings are surrounded by obstructions equivalent to half the height of the building.

To evaluate the indoor temperature in each zone and the airflow rates, thermal airflow interaction is computed using the programs COMIS TRNSYS. The buildings are submitted to the same outdoor conditions. The used materials are identical. The simulation process follows three steps:

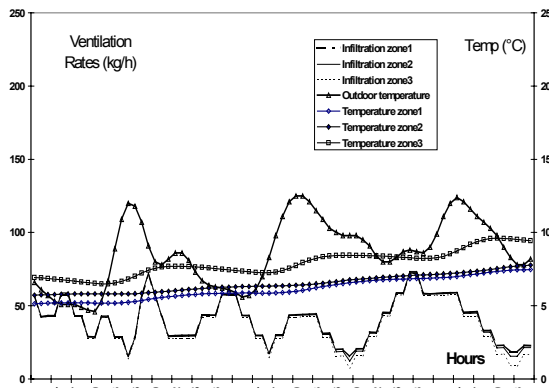
- Each thermal zone is described in PREBID by the specification of the used material, the zones orientations and connections

- The description of the natural ventilation system in COMIS by the definition of the zones and the ventilation components.
- Finally Iisibat interface allows establishing the connections between the programs COMIS and TRNSYS

The results obtained for the period from 10 to 13 March are reported in the graphs 4 and 5 for the two configurations.



Graph 4 Ventilation rates (kg/h) and temperature (°C) variations for the "Fitting structure" (for the period of 10-13 March)

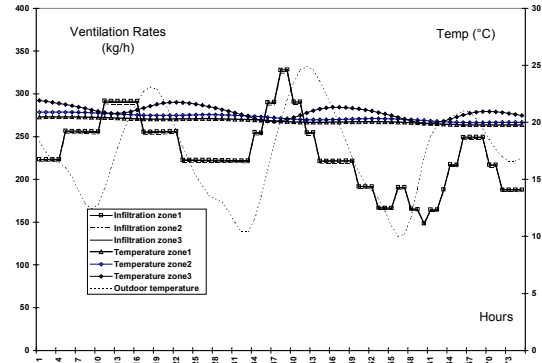


Graph 5 Ventilation rates (kg/h) and temperatures (°C) variations for the "Adjacency structure" (for the period of 10-13 March)

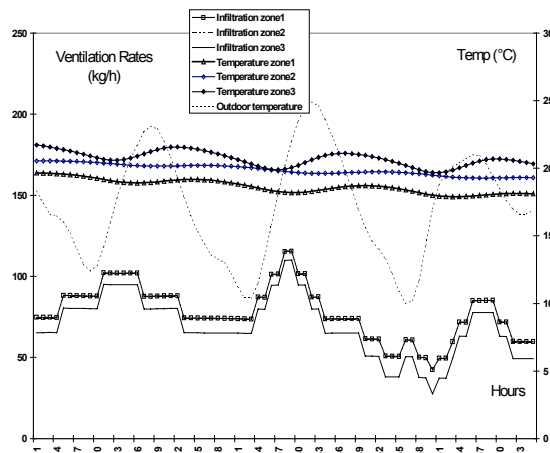
The comparison between the "Adjacent structure" and "Fitting structure" reveals that the airflow rates in the second case are more important. The airflow rates raise in a range between 55 kg/h and 210 kg/h (graph.4) however with the second system the decrease is significant (graph.5). Indeed, with the second configuration the airflow rates increase from 7 kg to 71 kg/h. Concerning the temperatures, the slight variation on indoor temperature in the first zone and the second zone is probably due to the important building thermal mass. In contrast, in the third zone, which is more exposed on the building top, the temperature variation is more important. The airflow impact on the temperature variation noted on

both configurations is bringing closer to the outdoor air temperature. However, the temperature difference between the two configurations is minor.

Next, the same simulations are conducted for three summer days from 14 to 16 September.



Graph 6 Ventilation rates (kg/h) and temperatures (°C) variations for the "Fitting structure" (for the period of 14-16 September)



Graph 7 Ventilation rate (kg/h) and temperature (°C) variations for the "Adjacency structure" (for the period of 14-16 September)

As expected, the ventilation rates are more important in the fitting structure. In the same time, the indoor temperature variation for the third zone is more sensible to the outdoor temperature variation. However, the ventilation rates are fewer because of the slight stack effect due to the low chimney for the third zone. The increase of the ventilation rates result in an increasing of the indoor temperature as showed in graph 6 and 7. There is a time lag between the indoor temperature increasing and the outdoor temperature variation.

In comparison to the "Adjacent structure" the ventilation rates are multiplied by 3 for the "Fitting structure" at certain times. The important ventilation rates increasing disturb the thermal comfort. The duct size for the first configuration is larger than we need to meet the ventilation requirements. The duct sizing

in that case is not proportioned to the spaces volume. In the second configuration, the duct sizing is closer to the ideal solution. However, the ventilation rates in the winter are frequently below the ventilation regulation 27 kg/h for each zone. The duct sizing, in the first configuration, was underestimating. In contrast, in the second case the duct diameter was overestimate. On the architectural point of view it appears that the "Fitting structure is more interesting. Indeed, with a unique duct with a diameter lower than 0.3 m the system fulfil the ventilation requirement. However in the second case of "Adjacent structure", the diameter should be larger than 0.1 m. Considering that the system is composed by three ducts, it is more interesting to have only one duct particularly if we consider the spaces congestion and the complicated structure. Accordingly, we can suppose that it is not necessary to increase the duct diameter proportionally to the number of zones. In the same time, on the architectural point of view, the fitting structure is more interesting even if the adjacency structure permits more independence in spaces organisation.

The carried out study, on the duct operation according to the length and the diameter variation, gives an order of magnitude about the ventilation rates evolution according to the air speed obtained in the duct. However, the results cannot be generalized. The duct performance is related to the specified site.

More simulations should be computed for both configurations to find the ideal solution. The carried out study shows the difficulty of the natural ventilation component sizing. More design guidelines should be established for orientate the architect about the order of magnitude of airflow rates.

### CONCLUSION:

Face up to the request of architects as regards of design tools to fulfil the users demand for comfort quality; it is significant to envisage adapted tools to the designers who are confronted with real buildings. The new European directives, in favour of energy saving and environmental protection must find an echo near the architects on whom rests the responsibility to convey these new concepts. The study presented here is a proposal of a methodological approach, which is close to the architects and their concerns. In this paper, the main design process is highlighted. It is defined in three phases and directed towards the architects. On the architectural aspect, a devices classification is proposed. The topo-morphological analysis underlined the main devices organization related to the spatial layout of the building. This approach contributes to guide the designer in the general spatial organisation that imposes the integration of natural ventilation strategy.

The methodological approach presented in this study aims at define a process resulting on general design guidelines. The carried out study, applied to the duct behaviour is an example of the architect request. Simulations using the coupled programs COMIS and TRNSYS allow characterising the effect of a duct according to the system structure. The complexity of the components and the important number of variable characteristics impose to go further in the computed analysis to define design guidelines. In the same time, the multiplicity of natural ventilation system should be considered.

The method proposed in this article open up new prospects for natural ventilation systems. Our purpose is to give to the designer the sufficient conceptual elements to meet indoor environment quality: thermal comfort and air quality.

### ACKNOWLEDGEMENTS

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