THE GUIDE

NATURAL VENTILATION

genatis
Gestion des Energies Naturelles //

INDEX

THE GUIDE TO NATURAL VENTILATION

PREFACE

by Jacques GANDEMER

Genatis companies offer facade and roof openings for natural ventilation. The latter are in aerodynamic interaction with the building in question, itself under the influence of its immediate environment and the specific characteristics of the winds on the site.

The proper functioning of these natural ventilation solutions depends on appropriate consideration of:

- *Their dimensions*
- *Their location*
- *Their own aeraulic architecture, but also on the internal aeraulics of the building.*

The objective is to maximize the efficiency of natural ventilation, air intake and extraction, in all climatic and environmental situations. The energy performance of the premises as well as the quality of the indoor air and the thermal comfort of the occupants will, in fact, be improved.
We have undertaken, in close collaboration with the Eiffel Aerodynamics Laboratory and Genatis, scientific work for the efficient development and technical development of openings. For this approach, we made extensive use of physical modeling in the wind tunnel. »

Few words about...

JACQUES GANDEMER

Aerodynamic Engineer and Doctor in Theoretical Fluid Mechanics and Aerodynamics. A specialist in architecture and urban planning, he is in demand in these fields on a global scale. From 1988, he held the position of head of the Aerodynamics and Climatic Environment department at the Center Scientifique et Technique du Bâtiment, in Nantes. Then from 2001 to 2007 that of Director of the Climatology, Aerodynamics, Pollution and Purification Department.
Between 1999 and 2015, he developed around forty industrial programs including 17 invention patents and 28 commercial exploitation protocols in application in the fields of industrial Aeraulics, Thermal, Air Quality.

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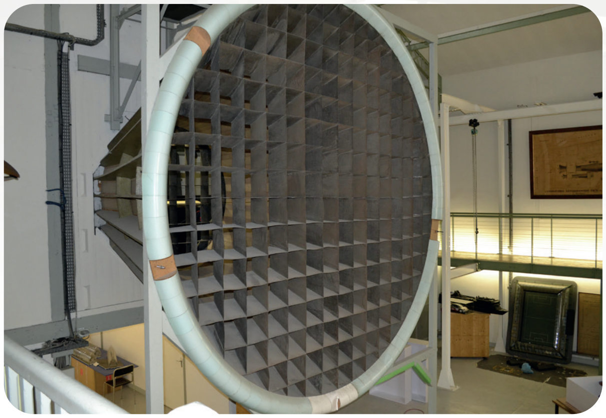
THE EIFFEL WIND TUNNEL

EIFFEL Aerodynamic Laboratory was designed by Gustave Eiffel at the foot of his famous Tower in 1909. It was then relocated in 1912 to Auteuil and is now classified as a Historic Monument.

Drawing on its experience, Eiffel Aerodynamics conducts studies and tests in the service of Automotive Engineering, Construction, the Environment and Aeraulics. The Eiffel Laboratory has long been offering numerous studies on natural ventilation in buildings. Its approach is based on two key steps:

A theoretical study containing all the data and technical constraints to propose a ventilation system concept, the sizing of the air inlets and outlets and the definition of the internal aeraulic circuits.

Validation on a model in a wind tunnel to optimize the location of air inlets and outlets in the presence of wind. Velocity and pressure measurements can complete visualizations for a better understanding of aeraulic mechanisms. The optimization takes into account the possible interaction with the environment (topography, buildings, etc.).



01. OBJECTIVES & INTRODUCTION

THE PURPOSE OF VENTILATION IS TO ENSURE INDOOR AIR QUALITY, THERMAL DISCHARGE AND TO CONTRIBUTE TO SUMMER THERMAL COMFORT.

INDOOR AIR QUALITY

This is to ensure a renewal of hygienic air and to guarantee a better quality of indoor air and thus protect the health of the occupants and the building.
In fact, indoor air can be 8 times more polluted than outdoor air.
In question, a significant concentration of:

- **Chemical pollutants:** COV[1] or COSV[2], tobacco smoke, pesticides, carbon monoxide, CO2 ...
- **Biological pollutants:** molds, humidity, allergens, pollens, bacteria (ex: legionella, virus...)
- **Physical pollutants:** radon, fine particles, dust, fibers (asbestos, mineral fibres, etc.)
- **Other pollutants** related to occupants and their activities.


Indoor pollutants

[1]: Volatile Organic Compounds
[2]: Semi-Volatile Organic Compounds

IN EFFECT, INDOOR AIR CAN BE 8 TIMES MORE POLLUTED THAN THE OUTSIDE AIR.

SUMMER COMFORT

Natural ventilation affects summer thermal comfort and the well-being of occupants.

On the one hand, it allows the extraction of thermal loads, in other words **thermal discharge:**

- **Internal thermal loads:** emitted by the occupants, their activities and the equipment (computers, lighting, machines, etc.);
- **External thermal loads:** due to solar radiation.

On the other hand, if a dynamic of internal natural air currents is reached, **with a flow speed of 0.5 to 1.5 m/s,** and that it sweeps the areas of activity and stays of the occupants (between the admissions and extractions) then **the perceived temperature will be lowered by 4 to 5°C** compared to the interior ambient temperature.
While the **regulatory hygienic air renewal** in France is of a **few volumes/hour** (0.5 vol/h in residential, 2 to 3 vol/h for schools, etc.), much higher renewal rates are necessary for thermal relief (8-10 vol/h) or ventilation for hygrothermal comfort (8-10 vol/h with additional air blowers or 30-120 vol/h with natural ventilation alone).

Indeed, in general (depending on the thermal insulation, the activity of the occupants, etc.), **the thermal loads are evacuated** correctly for air renewal rates of **8 to 10 volumes/hour mini** (then T °int=T°ext).
However, **beyond 26°C outside,** the thermal discharge is not sufficient and the indoor ambient temperature becomes uncomfortable (because T°int=T°ext≥26°C). It is then recommended to integrate air blowers (speed generators of the order of 1m/s) or to increase the air renewal rate (**from 30-120 vol/h**) in order to ensure the thermal comfort of the occupant thanks to the lowering of the perceived temperature.

02.
GENERAL PRINCIPLES

NATURAL VENTILATION IS GOVERNED BY TWO PHYSICAL PRINCIPLES:

- **THE THERMAL DRAFT**
- **THE AERODYNAMIC PUMP**

THERMAL DRAFT

The thermal draft or **«chimney effect»** is managed by natural convection. **Hot air, which is less dense than cool air tends to rise** and extract itself naturally at the top (via an opening in the roof) provided that it can benefit from a flow of cool air at the intake equivalent to the potential outgoing airflow. In addition, the hot air being possibly stale, **its replacement by fresh and new air** also has a positive effect on the quality of indoor air by allowing the extraction of pollutants. This mechanism can only be established **if the indoor temperature is higher than the outdoor temperature.**

The dynamic pressure of the thermal draft is directly proportional to the height of the **«chimney column»** air extraction column and to the temperature difference between the incoming air (outside) in the lower part and the extracted air (inside) at the highest level.

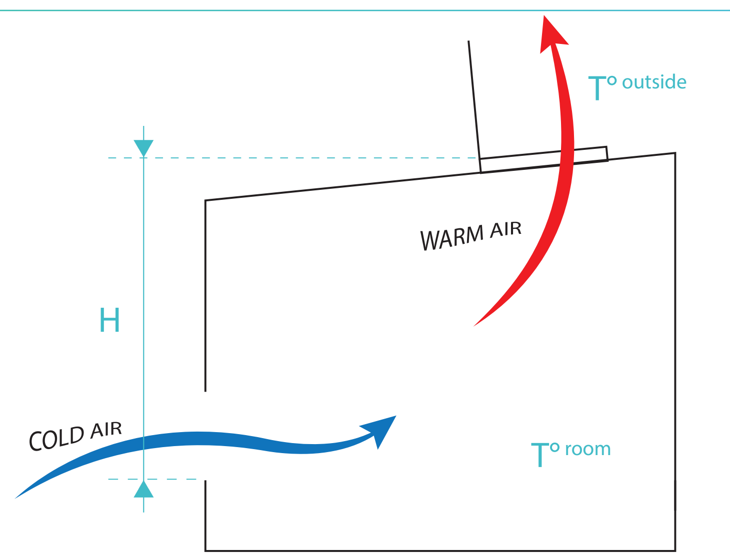
The thermal draft is only significant and constitutes an extraction potential only in very tall buildings (minimum 10m). In addition, the thermal **stratification** in a "column" (ex: in a stairwell) usually **does not exceed 1°C per meter.** However, the thermal draft or «thermal pump» is efficient only temporarily, the time to evacuate the overheating initially stored. **The flow drops very quickly,** because the **difference** between the indoor ambient **temperature** and the outdoor temperature **decreases.**

The case of smoke extraction operation is quite different insofar as the smoke is hot (even very hot) compared to the outside, and can be fed continuously by the fire. Under these conditions, the thermal draft is powerful. It is typically the thermal operation of the domestic fireplace which, in order to operate and ensure combustion (maintenance of the hot source), needs an appropriate intake air flow.

IF THE INDOOR TEMPERATURE OF THE BUILDING IS EQUAL (OR LOWER) TO THE OUTDOOR TEMPERATURE, THE THERMAL DRAFT PHENOMENON CAN NO LONGER EXIST.

If the indoor temperature of the building is equal (or lower) to the outdoor temperature, the thermal draft phenomenon can no longer exist.

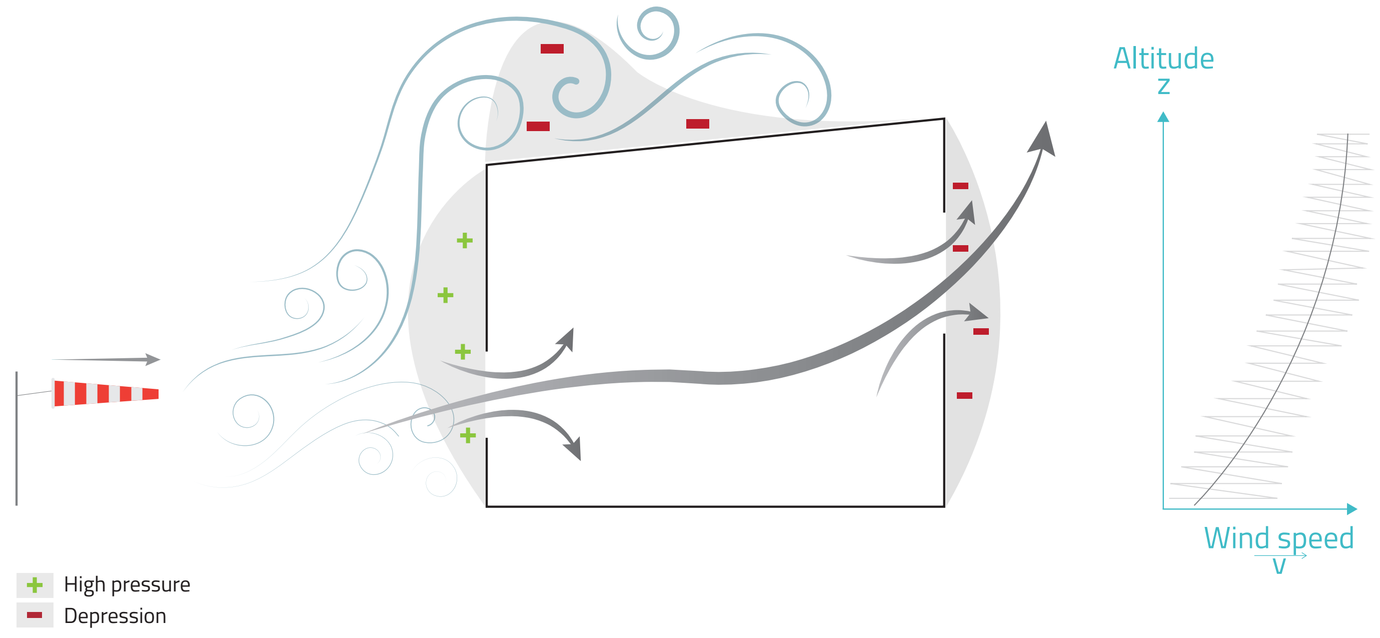
In the summer period, for complete thermal relief and even more so for the thermal comfort of activity spaces, **natural ventilation** driven **solely** by **thermal draft cannot be sufficient.** On the other hand, natural **aerodynamic mechanisms** can make it possible to **achieve the expected ventilation objectives,** subject to adequate weather conditions and architecture (Cf. Aerodynamic pump p10).



Principle of thermal draft

THE AERODYNAMIC PUMP

Wind is the engine of natural ventilation. When it strikes the building, bypassing it from above and from the sides, it develops pressure fields of different signs on the facades and the roof.



Pressure fields developed by the wind on the building

We speak of **overpressures** when we are **facing the wind,** and of **depressions** at the level of the **break-offs and in the wake.** The openings in the facade and in the roof make it possible to connect, from the inside, zones of different pressures by creating "balancing flows" called ventilation.

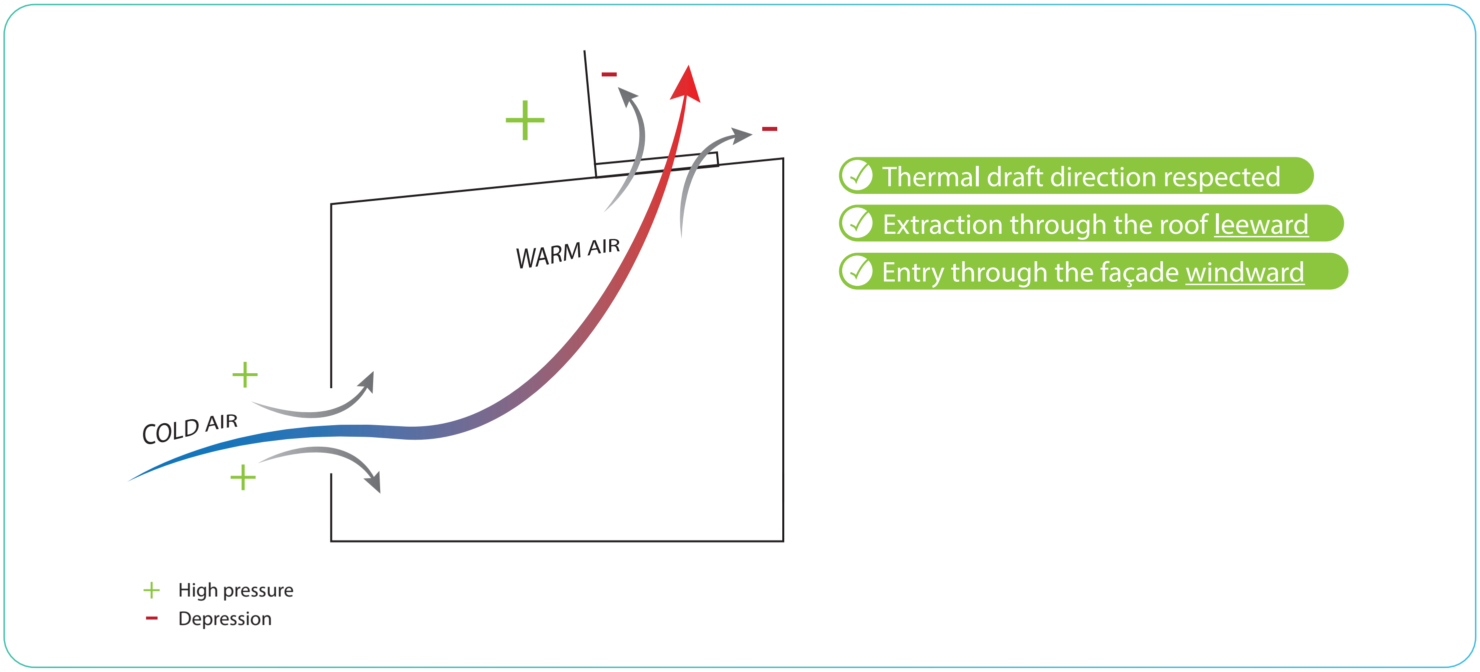
The **external pressure fields** are a function of the **incidence of the wind, the geometry of the building** and its proportions, as well as the **aerodynamic interactions with the immediate environment** of the building (effects of guidance, masks, etc.) due to obstacles peripherals such as other buildings, forests... Internal ventilation flows are governed by the external pressure fields, but also depend on **the specific characteristics of the openings in the facade and in the roof.** Indeed, the location, dimensions, distribution and type of these openings define the pressure drops which are specific to them, in other words their **intrinsic aerodynamic performance.** A fortiori, the aerodynamic efficiency in natural ventilation of an opening will increase its performance in smoke extraction. Furthermore, the **internal architecture** (obstacles, partitions, furniture, etc.) determines the path of the internal currents (direct or indirect).

All of these characteristics govern the air renewal rate and the internal irrigation dynamics. T**he wind is a powerful engine for ventilation but it is by nature fluctuating and unstable.** Therefore, wind-induced external pressure fields and associated balancing flows are also temporally induced:

- **The wind speed can fluctuate** from 50% to 150% (over a period of 3-4 seconds) compared to its average value (calculated over a period of 10 min);
- Average speed increases with altitude;
- **The incidence of the wind** (that is to say its direction) **can oscillate** instantaneously from 15° to 30°;
- The average directions (over a period of 10 min) can also vary slowly depending on the general daily climatic context.

CONCLUSION

These two physical principles can be combined and thus ensure optimal natural ventilation. Indeed, an adequate orientation of the building equipped with correctly positioned and dimensioned openings allows the creation of an effective internal ventilation. A judicious location of the openings on the building results in **air intakes in the lower part** and **extractions via openings in the upper part,** or better, **in the roof** (zone where the depression is always maximum on an obstacle). Thus, irrigation currents develop and follow the same trajectory as the air displacement induced by thermal draft.



Principle of thermal draft combined with the aerodynamic pump

In addition, **efficient natural ventilation** is directly linked to the ventilation performance of the openings (the objective is to minimize pressure drops).

The renewal air volumes are governed by the smallest of the potential flow rates (inlet or outlet). Also, it is always necessary to privilege the extraction (more stable than the admission) and to ensure a **ratio between the surfaces of entry and exit** such as:

Usable extraction area ≥ Usable air inlet area

Remember that when the thermal discharge is reached (no more interior overheating), the interior and exterior temperatures are identical. However, to have a perceived temperature lower than the ambient temperature (**up to -5°C**), it is necessary to use air blowers if the transit speed does not reach 1m/s.

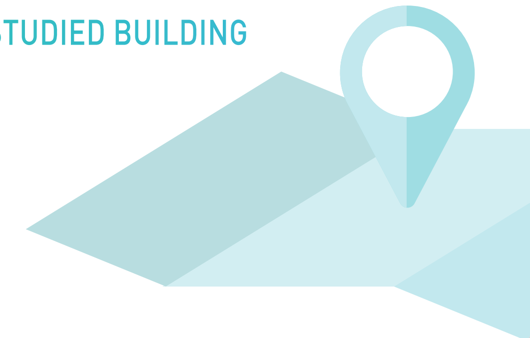
03.

STUDIES & RECOMMENDATIONS

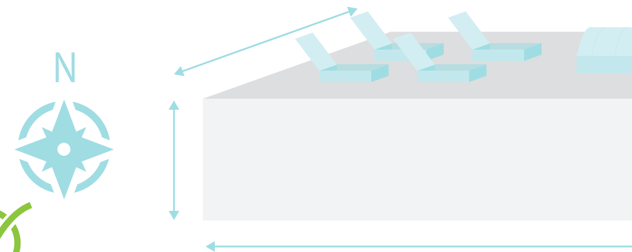
ELEMENTS NECESSARY FOR THE STUDY OF A PROJECT

To study and size a project, it is essential to take into account the following elements since they will have a major impact on the performance of natural ventilation:

GPS COORDINATES (OR ADDRESS) OF THE STUDIED BUILDING

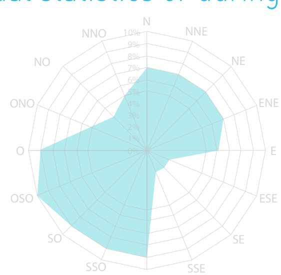


ORIENTATION AND EXTERNAL ARCHITECTURE OF THE BUILDING



PREVAILING WINDS ON THE SITE

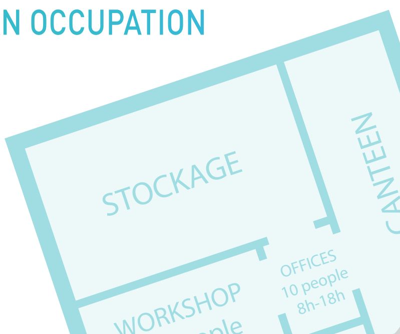
(Speed and direction - annual statistics or during the summer period)



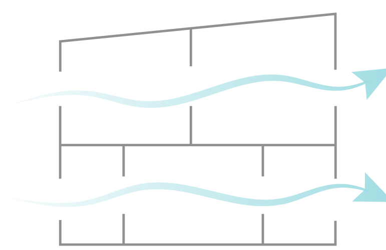
BUILT ENVIRONMENT PERIPHERAL

(Mask effect, especially in the direction of the prevailing winds)

BUILDING ACTIVITY & AREAS OF HUMAN OCCUPATION

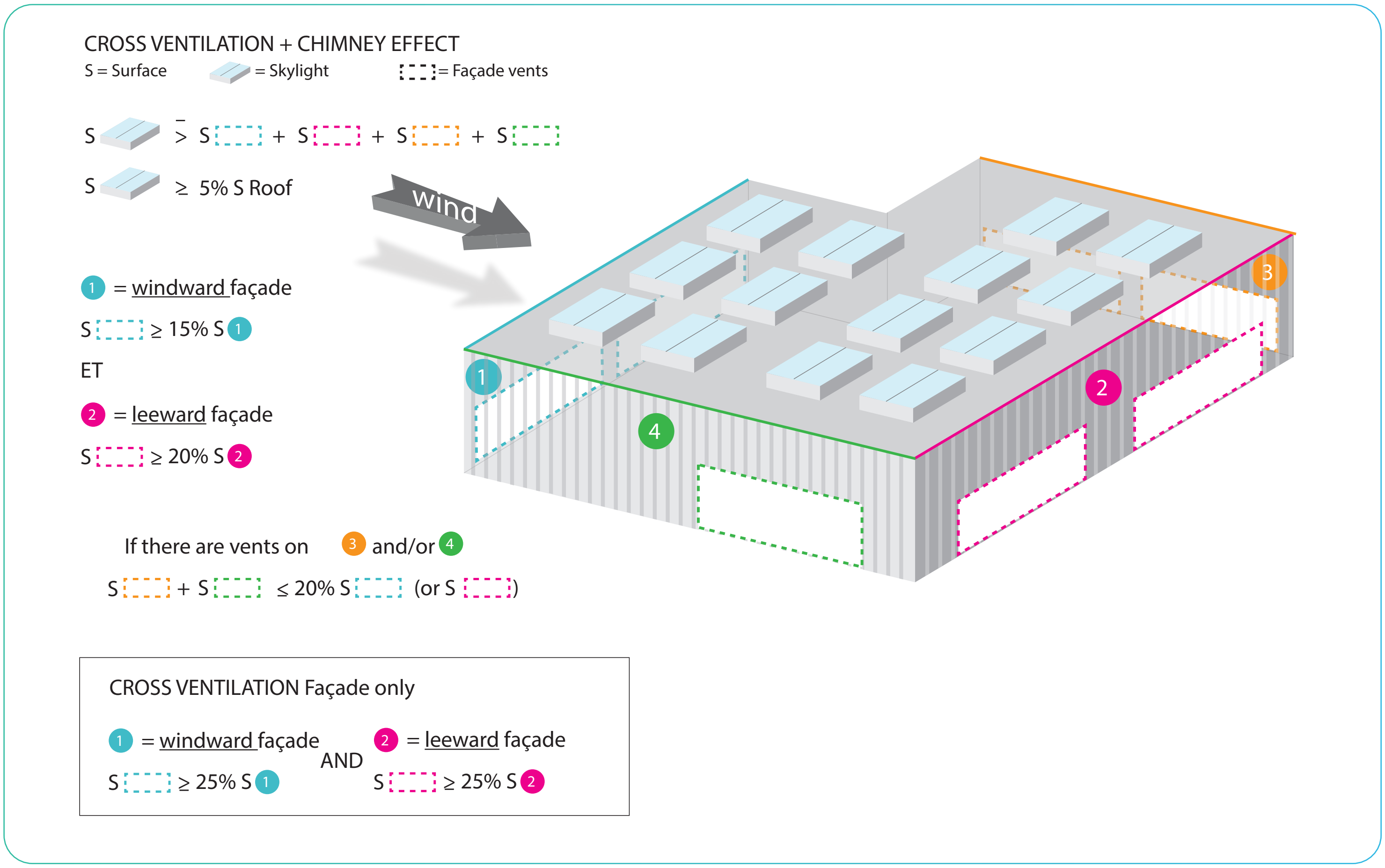


ARCHITECTURE AND INTERNAL AIR BARRIERS



Before undertaking the practical evaluation of the roof and facade surfaces necessary for efficient air renewal, it is necessary to have a reflection, on the one hand, on the **prevailing winds** of the site and, on the other part, on the **aerodynamic interactions of the building with its environment** (immediate in particular).

After this climatic, architectural and environmental analysis, a few rules should be applied to maximize the effectiveness of the natural ventilation strategy:



On the façade:

- The front openings will be positioned facing the prevailing wind. The presence of openings on the **windward** (**1** on the diagram) and **leeward** (**2** on the diagram) facades is essential. These openings can be supplemented by openings on the other facades (**3** and **4** on the diagram);
- **The openings** will be located on **two opposite faces** than on two adjacent faces. The internal flow will then be more sweeping;
- **Openings on the largest surfaces** of the building, rather than on the gable, will be preferred. While weighing the principle taking into account the location of the building in its environment;
- **The openings** will be, if possible, **at least 5 meters away from the corners of the building** to avoid pneumatic short-circuit effects;

- Direct aeraulic paths will be developed in order to sweep the interior of the building thanks to **cross-flows from the bottom to the top**, by favoring the passage on activity zones;

- In through ventilation (entrances and exits in facades only): the openings of the facade to the wind (**1** on the diagram) will represent **at least 25% of the surface of the facade.** Ditto for the leeward facade (**2** on the diagram);

- In through ventilation with chimney effect (air inlets on the facade and air outlets on the roof): the openings will represent **5% of the roof surface.** The overall surface of the openings of the windward facade (**1** on the diagram) must be at least equal to **15% of the surface of this facade.** The overall surface of the openings of the windward facade(**2** on the diagram) must be at least equal to **20% of the surface of this facade.**

On the roof:

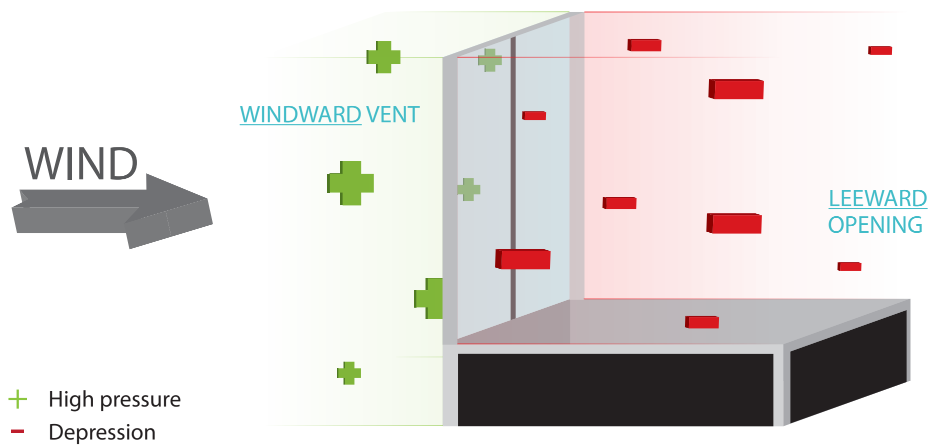
- The homogeneous orthogonal grid will be the preferred configuration, while respecting a free distance of 3 meters from the acroterion on the entire periphery of the building. It will be necessary to have at least **1 opening of 5m² for 100m²** of roof;

- In through ventilation with chimney effect (air inlets on the facade and air outlets on the roof: The openings will represent -in the roof- **at least 5%** of the surface of the roof;

- When possible, the implementation of a waterproof windbreak emerging at least 1m above the acroterion on the entire periphery of the building will reinforce the low pressure areas on the roof.

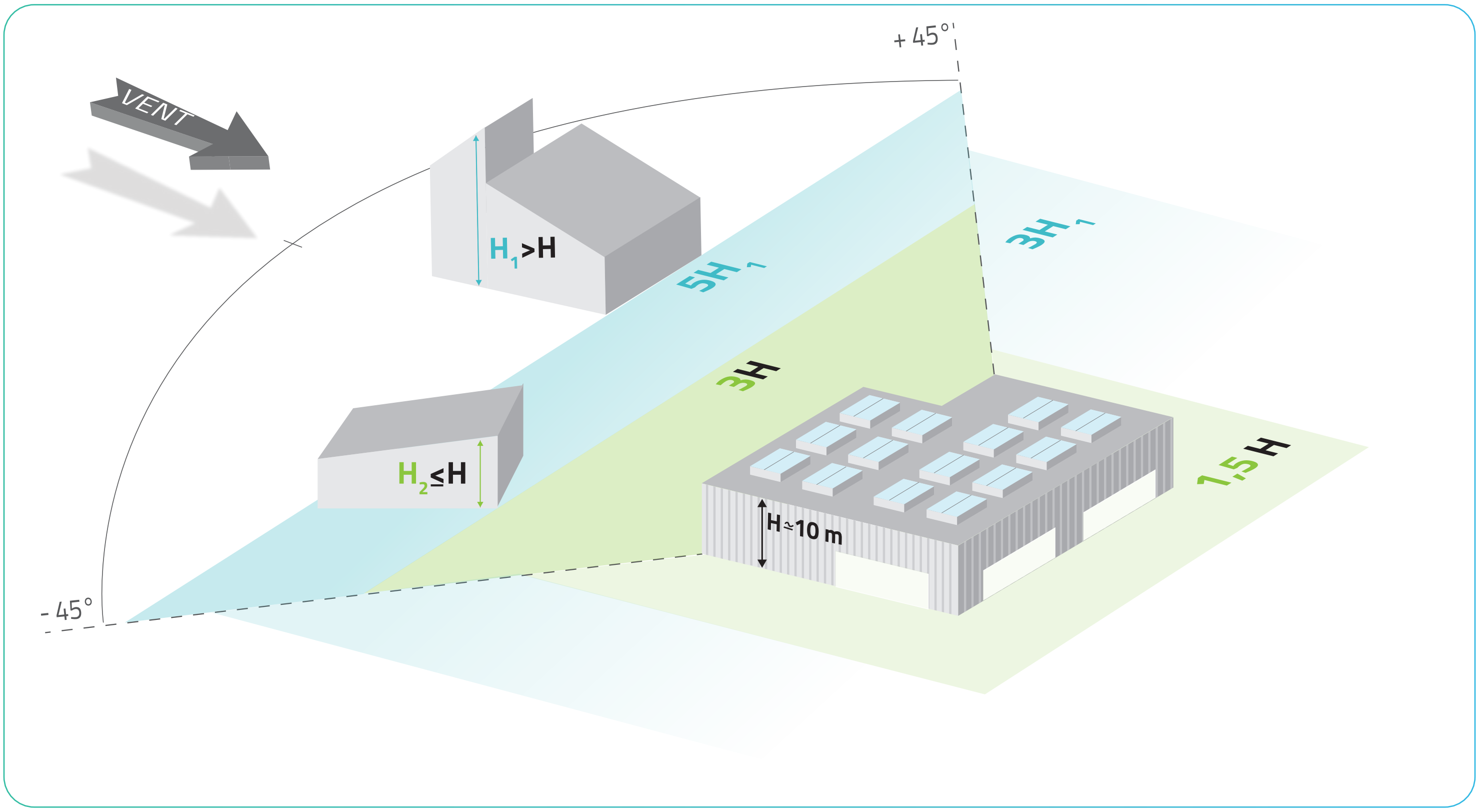
- The surface of the openings on the facade will be, at least, equal to the surface of the openings on the roof;

- To reinforce the extraction, it will have to be oriented so that the opening is **under the prevailing winds:**



Orientation of the sash in relation to the prevailing winds

Nevertheless, the **«mask effect»** of surrounding obstacles can reduce the **performance of the aerodynamic pump by up to 50%.** To avoid this environmental effect, it is essential to respect the existence of «breathing» spaces on the outskirts of the building:



Principle of the "mask effect" around a building

• For the wind to be able to develop a sufficient external pressure field on the building to drive natural ventilation, **minimum distances must be respected between the obstacles and the building under study** of height **H**, located downstream.

- **Case of a building of height** H_1, higher than our building: a minimum distance of **5**H_1 following the trajectory of the prevailing wind and **3**H_1 for the other wind directions must be respected between the two buildings.

- **Case of a building of height** H_2, less high or of equivalent height to our building: a minimum distance of **3H** following the trajectory of the dominant wind and **1,5H** for the other wind directions must be respected between the two buildings.

• To consider a building **independent of its environment,** it must be separated from any other obstacle by a **minimum distance of 10 times the height of the tallest building.**

In addition to natural ventilation...

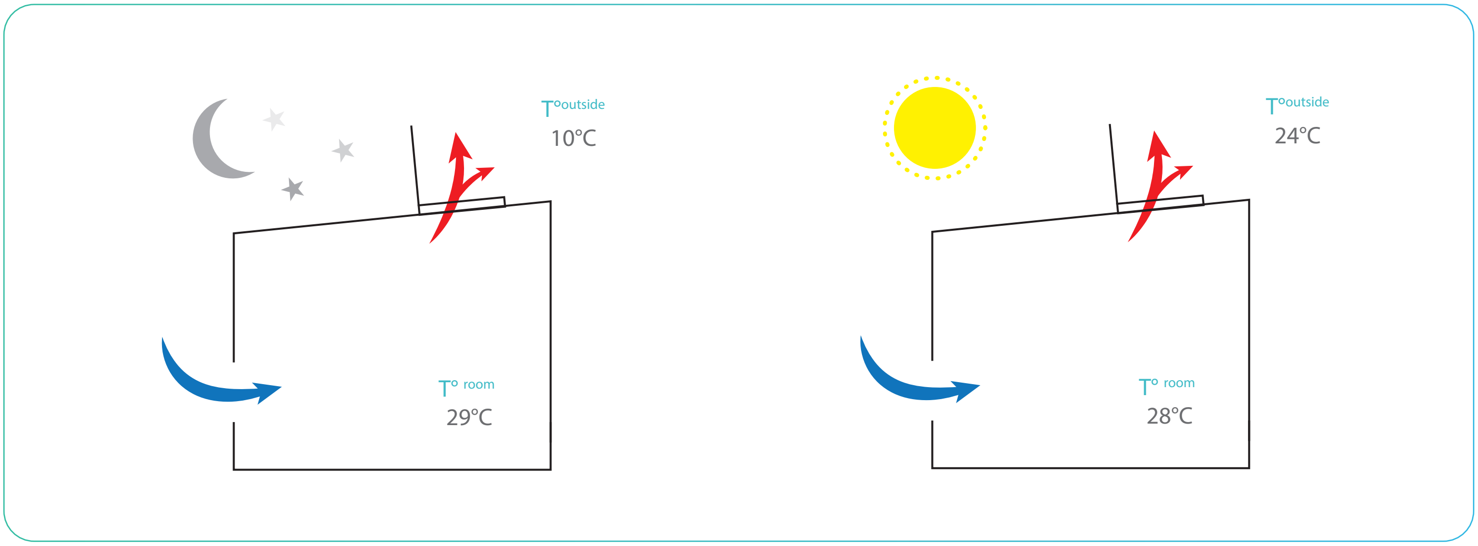
GENATIS OFFERS YOU:

NATURAL VENTILATION & CONTROL

Ventilation can be optimized and automated by piloting, day «Free Cooling» and night «Night Cooling». Indeed, the various equipment allowing control (probes, sensors and automatons) play an important role in the management of openings, taking into account the various natural elements (rain, outside and inside temperatures, CO2 levels), without human intervention necessary. **This ensures that the building is ventilated when appropriate.**

Controlled ventilation at night, when unoccupied, makes it possible in particular to take advantage of outside temperatures that are much lower than those we experience during the day. This makes it possible to evacuate the heat and stale air accumulated during the day and to store a «fresh capital» in the masses of the building. At the start of the activity in the building, this "fresh capital" will be returned in terms of fresh radiation and it is only when the interior temperature reaches or exceeds 26°C that the natural ventilation mechanism will be launched. Reaching the set temperature will allow better comfort for the occupants when starting the activity in the building.
When premises are occupied, controlled natural ventilation relies on outside air to create a perceived temperature lower than the ambient temperature to improve indoor air quality, depending on climatic conditions, to improve health , comfort and productivity of the occupants.

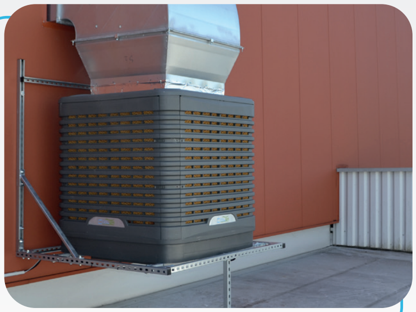
Control plays a major role in the efficiency of ventilation, and thus contributes both to summer comfort and to indoor air quality.



Principles of « Night Cooling » and « Free Cooling »

NATURAL VENTILATION & ADIABATIC COOLING

The combination of natural ventilation and an evaporative cooling solution (adiabatic) makes it possible **to cool the outside air before diffusing it inside the building.** This hybrid ventilation solution promotes the entry of new and healthy air while ensuring the extraction of stale and hot air through roof openings.



NATURAL VENTILATION AND CEILING FANS

If the thermal discharge is naturally ensured but the natural ventilation alone does not make it possible to achieve sufficiently dynamic internal balancing currents (wind speed less than 3m/s), it will be possible to obtain the thermal comfort of the occupants and lower the temperature. felt thanks to air blowers.

NATURAL VENTILATION AND SHADE

Sunshades and facade cladding blades **limit solar inputs** and must be combined with natural ventilation in order to contribute to the summer comfort of the occupants.

Learn more about natural energy management:

Via this reference work, it is a question of transmitting to all the actors of the construction of the levers of reflection and the answers favoring the development of their projects and achievements, from the study to the exploitation of the building.

In parallel with the future Environmental Regulation 2020 (RE2020), the «Positive Energy and Carbon Reduction (E+C-)» prefiguration reference system, this white paper allows its reader to deepen their knowledge and make their choices, in a ethical and environmental respect, as the solutions highlighted are often natural and respond to simple foundations in terms of energy sobriety and management of buildings as a whole.

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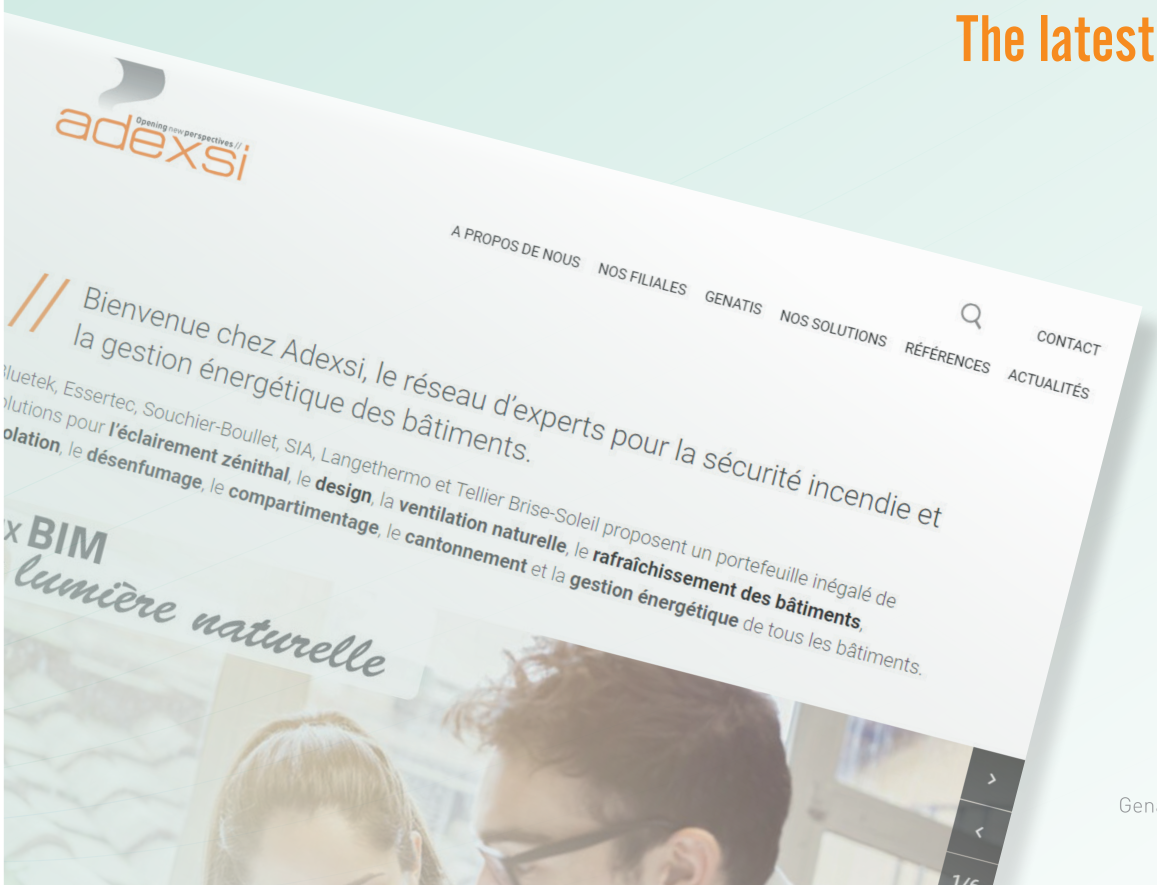

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