



HVAC - Natural Ventilation Practices and Principles

An Online Continuing Education Course for Engineers

Course Number: HV-3011

Credit: 3 Hours / 3 PDH / 3 CPD

HVAC – Natural Ventilation Practices and Principles

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INTRODUCTION

Natural ventilation, as the name implies, is a system using natural forces to supply fresh air for comfort and heat dissipation. As an alternative to mechanical (fan-forced) ventilation, this approach relies on the natural forces of wind and buoyancy to deliver fresh air to indoor spaces. Natural ventilation may be divided into two categories:

1. **Controlled natural ventilation** is intentional displacement of air through specified openings such as windows, doors, and ventilators. It is usually controlled to some extent by the occupant.
2. **Uncontrolled ventilation (Infiltration)** is the random flow of air through unintentional infiltration through cracks, gaps or crevices in the building structure. It is less desirable and can be controlled only by plugging the gaps.

Natural ventilation has several benefits: low running cost, zero energy consumption, low maintenance and probably lower initial cost. It is regarded as healthier and the way it connects with outside is seen as a psychological benefit. The effectiveness of natural ventilation is determined by the prevailing outdoor conditions – microclimate (wind speed, temperature, humidity and surrounding topography) and the building itself (orientation, number of windows or openings, size and location).

The alternative to natural ventilation is mechanical ventilation, which uses one or more electrical fans or blowers to move air in and out. The primary advantage of this approach is the consistency and controllability of the rate of ventilation. Other advantages include the opportunities for air filtration and possible heat recovery. The disadvantages are the capital costs, the running costs, the noise, and continuous maintenance.

We will focus on Natural Ventilation in this course.

The design of natural ventilation system necessitates knowledge of the mechanism of air flow through buildings and also of factors which have a bearing on air flow patterns indoors. In this course we will define and discuss three essential aspects of natural ventilation:

1. **Natural Driving Forces.** The first aspect is the natural forces utilized to drive the ventilation. The driving forces can be wind, buoyancy or a combination of both.
2. **Natural Ventilation Principles.** The second aspect is the ventilation principle used to exploit the natural driving forces to ventilate a space. This can be done by single-sided ventilation, cross ventilation, or stack ventilation.
3. **Architectural Elements.** The third aspect is the characteristic architectural elements used to enhance natural ventilation. The most important characteristic elements are wind towers, wind scoops, chimneys, double facades, atria, and embedded ducts.

SECTION 1: NATURAL DRIVING FORCES

Natural ventilation is provided from two sources: thermal buoyancy and wind.

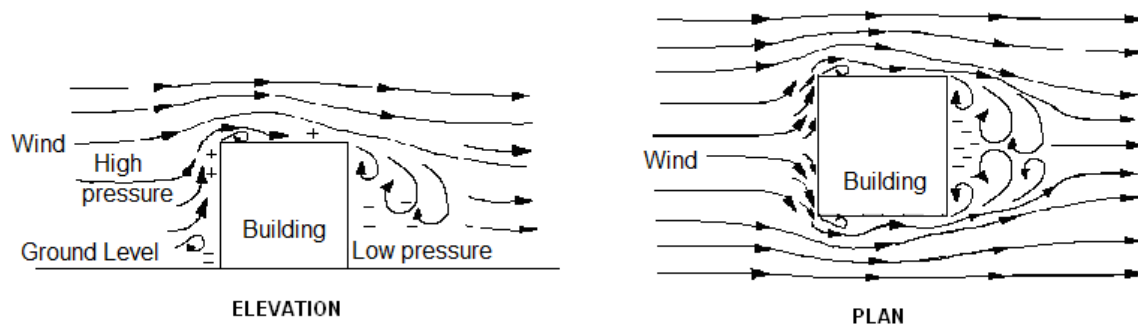
1. **Wind** - The air moves from higher (positive) pressure regions to the lower (negative) pressures regions. This phenomenon is based on Bernoulli's principle, which uses pressure differences to move air. The pressures generated by natural wind are typically - 0.004 to 0.14 inches of water column (in- wc).
2. **Buoyancy** - The warm air is less dense than cool air so it rises and creates a difference in pressure which in turn induces air movement. This phenomenon is called "the thermal buoyancy" and is sometimes referred to as "the stack effect". The pressures generated by buoyancy are quite low ranging - 0.001 to 0.01 inches of water column (in- wc).

The magnitude and pattern of natural air movement through a building depends on the strength and direction of these natural driving forces and the resistance of the flow path. Stack ventilation, can operate when no wind pressure is available. (The absence of wind can occur at certain times, due to its variability, or in certain sites, due to blocking effect of other buildings or vegetation). It can also operate in deep plan buildings where the distance from openings in the perimeter, and the presence of partitions, make wind-driven cross ventilation impractical.

The design of natural ventilation system often relies on both these driving forces. The dominating natural driving force has consequences for the shape and layout of the building.

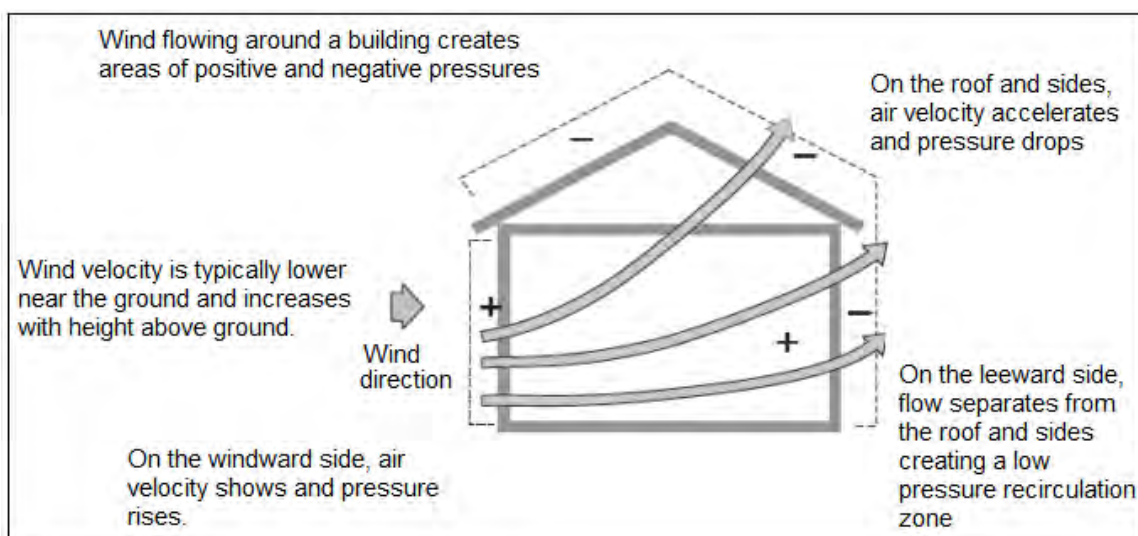
Wind Effect

Natural ventilation is induced by differences in air pressure across the building. When wind strikes a building, a region of higher pressure is created on windward wall and a negative pressure on the leeward side of the building façade. A pressure gradient is thereby created across the building in the direction of the incident wind. This pressure gradient around a building in turn creates a negative pressure area inside the building that encourages air to move through the building and via its openings. The air moves through from the opening in the positive pressure façade to the opening in the negative pressure one.



Detail of Airflow Around a Building

Wind effect uses Bernoulli's principle of fluid dynamics, which states that at higher speeds the static pressure decreases and at lower speeds the static pressure increases. The air speed on the windward side of the building reduces as it collides with the building, resulting in an increased pressure. Conversely, the air speed on the top and the leeward sides of the building increases, resulting in reduced pressure. A pressure differential is thus created between windward and leeward walls. The effective pressure difference tends to be greatest (about 1.4 times the dynamic pressure at eaves level for typical rectangular buildings), when wall openings are about 15% to 20% of wall area. This means that the average wind speed through wall openings has the potential to be 18% higher than the local wind speed. Without any openings the wind pressure difference is about 1.1 times the dynamic pressure at eaves level. With a 60% wall opening or more, the wind pressure difference between windward and leeward surfaces remains constant around 1.0 times the dynamic pressure at eaves level.



The magnitude of the wind pressure (P) is proportional to the velocity pressure, and is given by:

$$\Delta P = 0.013 \frac{\rho V^2}{2} (c_{p-ww} - c_{p-lw})$$

Where

- ΔP = pressure difference from ambient in in. wc.
- V = Time-averaged approach wind velocity in mph
- ρ = Air density in lb_m/ft^3
- C_{p-ww} = Wind pressure coefficient
- C_{p-lw} = Wind pressure coefficient

The value of C_p depends on the shape of the building, orientation of the building etc. Analytical values are available for many shapes, although these values have been measured experimentally.

$$C_{p-ww} = +0.65$$

$$C_{p-lw} = -0.65$$

Example: Consider a building with a wind velocity of 20 mph, orientation of the wind is perpendicular to the building facade. Calculate the wind pressure difference through these values have been measured experimentally.

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Solution

Density of air at 70°F is

$$C_{p-ww} = +0.65$$

$$C_{p-lw} = -0.65$$

$$\Delta P = 0.013 (c_{p-ww} - c_{p-lw}) \frac{\rho V^2}{2}$$

$$\Delta P @ 0 \text{ mph} = 0 \text{ in-wc}$$

$$\Delta P @ 5 \text{ mph} = 0.015 \text{ in-wc}$$

$$\Delta P @ 10 \text{ mph} = 0.06 \text{ in-wc}$$

$$\Delta P @ 20 \text{ mph} = 0.25 \text{ in-wc}$$

Ventilation Calculation from Wind Effect

The rate of wind driven airflow across any opening in the building façade can be calculated by using the empirical power law:

$$Q = C_d \cdot A \cdot V$$

