NATURAL VENTILATION IN RESIDENTIAL ARCHITECTURE IN VIETNAM

Thông gió đối lưu trong kiến trúc nhà ở tại Việt Nam

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Abstract: Natural ventilation, particularly buoyancy-driven ventilation, plays a pivotal role in optimizing indoor microclimates and safeguarding human health within the hot-humid context of Vietnam. Unlike ventilation driven by aerodynamic pressure (direct wind), buoyancy-driven ventilation—often referred to as the stack effect—operates on thermal pressure differentials to facilitate a continuous upward airflow. In architectural practice, this mechanism is widely implemented through double-skin façades or the strategic integration of atria and light-wells in residential design. A profound understanding of these physical principles, coupled with flexible application, appropriate material selection, and advanced simulation technologies, is essential to creating sustainable living environments that remain in harmony with the natural ecosystem.

Tóm tắt: Thông gió tự nhiên, đặc biệt là thông gió đối lưu, đóng vai trò then chốt trong việc tối ưu hóa vi khí hậu và bảo vệ sức khỏe con người tại vùng khí hậu nóng ẩm Việt Nam. Khác với cơ chế thông gió nhờ áp lực khí động (gió thổi trực tiếp), thông gió đối lưu — hay còn gọi là hiệu ứng ống khói — vận hành dựa trên sự chênh lệch áp lực nhiệt để tạo ra dòng luân chuyển không khí liên tục từ thấp lên cao. Trong thực tiễn kiến trúc, giải pháp này được ứng dụng rộng rãi thông qua thiết kế mặt đứng hai lớp hoặc tổ chức không gian thông tầng trong nhà ở. Việc thấu hiểu bản chất vật lý và vận dụng linh hoạt các cơ chế này, kết hợp cùng vật liệu phù hợp và công nghệ mô phỏng hiện đại, chính là chìa khóa để kiến tạo nên những không gian sống bền vững, hài hòa với thiên nhiên.

Từ khóa: thông gió, đối lưu, khí hậu nóng ẩm, mặt đứng hai lớp, thông tầng.

Keywords: ventilation, convection, hot-humid climate, double-skin façade, atrium.

Received: 10/2/2026; Revised:20/2/2026; Accepted: 11/5/2026.

I. INTRODUCTION

1.1. The Role of Natural Ventilation in Residential Architecture in Vietnam

In tropical humid climates such as those in Vietnam, natural ventilation plays a particularly important role in ensuring thermal comfort and protecting the health of building occupants. Natural ventilation helps dissipate excess heat accumulated within buildings, reduce the surface temperatures of structural components and occupants, while also minimizing relative humidity and eliminating unpleasant odors. In addition, natural ventilation contributes significantly to environmental improvement by enhancing air circulation and removing pollutants such as CO_2, odors, mold spores, and microorganisms, thereby creating a healthier and more comfortable indoor environment.

Moreover, natural ventilation supports moisture evaporation and reduces indoor humidity levels, which is especially important under the hot and humid climatic conditions of Vietnam.

Table 1. Human Response to Indoor Air Velocity [1]

Air Velocity (m/s)	**Human Response**
0 – 0.05	Feeling of stagnant air
0.05 – 0.25	Slight sensation of airflow
0.25 – 0.50	Pleasant airflow sensation; thermal sensation decreases by approximately 1.1 – 1.7°C
0.50 – 1.00	Stronger airflow sensation; generally still comfortable; thermal sensation decreases by approximately 2.2 – 2.8°C
1.00 – 1.50	Strong airflow; some individuals may experience discomfort; thermal sensation decreases by approximately 2.8 – 3.9°C
Above 1.50	Significant reduction in working comfort due to excessive airflow; thermal sensation decreases by more than 2.8 – 3.9°C

Specifically, according to the book Architecture and Climatic Physics by Prof. Dr.Sc. Phạm Ngọc Đăng and Dr. Phạm Hà Hải [2], the amount of heat dissipated by the human body through convection is determined as follows:

$q_{đl} = \alpha.\ v0,3\ (35 - tk)$ [2]

where: α_l: coefficient representing convective heat transfer;

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v: indoor air velocity (m/s);

t_u: indoor air temperature (°C).

In addition, the amount of heat dissipated by the human body through sweat evaporation is expressed as:

q^{mh}_{max} = 29,1.v0,8 (42 - e), (kcal/h) [2]

where:

v: v – indoor air velocity (m/s);

42-e:vapor pressure corresponding to saturated water vapor at skin temperature;

e: partial vapor pressure of water vapor in the surrounding air environment (mmHg).

According to the human physiological characteristics, the amount of heat dissipated through sweat evaporation is proportional to air velocity vvv (m/s). Therefore, increasing indoor air velocity enhances heat dissipation and improves human thermal comfort. According to Table 1, it can be observed that ventilation contributes to cooling the human body effectively, thereby increasing comfort levels. In practice, this can be readily achieved through natural ventilation or mechanical ventilation systems.

1.2. Na tural Ventilation Mechanisms

In architectural and building design, two fundamental principles of natural ventilation are commonly applied, namely wind-driven ventilation and buoyancy-driven ventilation. According to the book Architecture and Climatic Physics by GS.TSKH. Phạm Ngọc Đăng and TS. Phạm Hà Hải, these principles are governed by wind pressure and thermal pressure, respectively.

Specifically, the formula for wind pressure is expressed as:

P_g = 0,612 υn2 [2]

where:

PgP_gPg: wind pressure (Pa);

vvv: wind velocity (m/s).

Under normal climatic conditions, when wind speed is high, pressure differences are typically generated on the surfaces of buildings exposed directly to the wind. This pressure difference creates airflow movement and promotes natural ventilation.

In English, convection refers to the transport mechanism in which a fluid (such as gas or liquid) moves due to differences in density between regions. This phenomenon commonly occurs in fluids subjected to heating, such as boiling water, heated air, and hot water systems, and plays a crucial role in natural ventilation.

For residential buildings, natural ventilation is often achieved by creating openings, ventilation slots, or windows. When air within a room is heated, its density decreases, causing it to rise and escape through upper openings, while cooler outdoor air enters through lower openings. This process forms a continuous airflow cycle. If a windward opening is created simultaneously, pressure differences generated by the wind can further enhance the airflow rate. In such cases, cool air enters through lower openings, absorbs heat from indoor spaces, rises, and exits through upper openings. This mechanism is also known as cross ventilation.

Figure 1. Illustration of cross ventilation driven by wind pressure

The formula for buoyancy-driven ventilation (thermal pressure ventilation) is given as:

P_t=0,043.H.(t_n-t_{ra}),"kg/" "m" ^{2} [2]

where:

H: vertical distance between the air inlet and outlet openings (m);

t_n: indoor air temperature (°C);

t_{ra}: outdoor air temperature (°C).

It can be observed from the equation that the coefficient 0.043 is relatively small, indicating that the pressure generated by buoyancy-driven ventilation is generally much lower than wind pressure generated by wind-driven ventilation. Consequently, buoyancy-driven ventilation is mainly used to create airflow circulation and remove stale indoor air. This principle is particularly effective when combined with ventilation ducts, vertical ventilation shafts, rooftop ventilation chimneys, or strategically positioned internal openings in regions characterized by hot and humid climates.

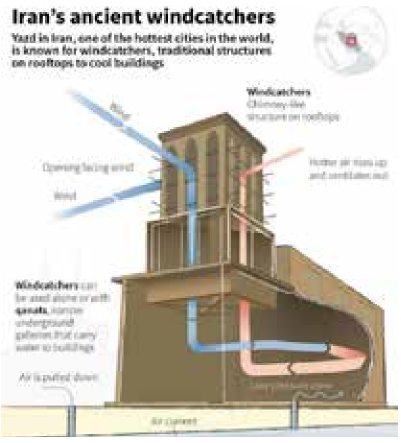


Figure 2. Wind-catcher in Persian Architecture [3]

Therefore, under the hot and humid climatic conditions of Vietnam, buoyancy-driven ventilation has significant practical applications in residential architecture. Specifically, it is frequently integrated with courtyards, ventilation shafts, and stairwells to enhance cooling performance and improve indoor thermal comfort.

II. RESEARCH MATERIALS ON CONVECTIVE VENTILATION APPLICATIONS IN VIETNAM'S HOUSING DESIGN

2.1. Utilization of Double-Skin Façades

Double-skin façades are typically considered a "large cavity" system, consisting of two façade layers separated by an air gap. This cavity may be naturally ventilated or mechanically ventilated. The air cavity between the two façade layers acts as an insulating layer that minimizes heat transfer while also facilitating effective natural ventilation. In the context of contemporary architecture, the concept of "using multilayer skins for climate-responsive buildings" has become increasingly widespread.

According to the classification proposed by Oesterle et al. [4], double-skin façades are generally categorized into four principal systems: the Box Window System, the Buffer System, the Extract Air System, and the Twin-Face System.

The Twin-Face System differs significantly from the other three systems in terms of ventilation strategy and solar heat reduction performance for the building envelope.

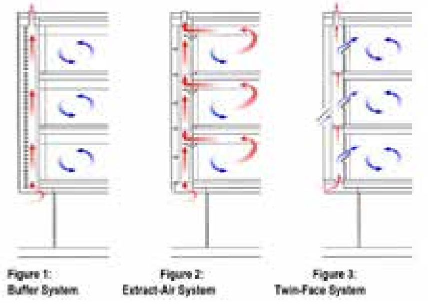
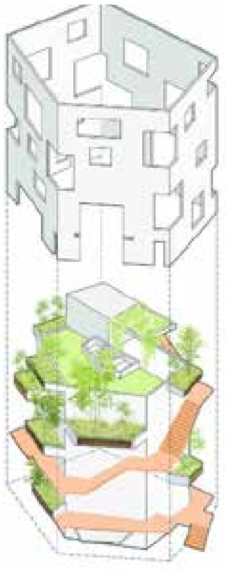


Figure 3. Description of the three double-skin façade systems by Werner Lang and Thomas Herzog [4]

Accordingly, the cavity width between the two façade layers typically ranges from approximately 150 mm to 900 mm, depending on the building scale and functional requirements. When this cavity is naturally ventilated, indoor air rises due to thermal buoyancy and exits through upper openings, while cooler outdoor air enters through lower openings. This process creates a continuous airflow circulation within the cavity. Simultaneously, solar radiation absorbed by the outer façade layer is partially dissipated through ventilation before reaching the inner façade layer and indoor space, thereby reducing heat gain inside the building. Furthermore, visual transparency ("view") is maintained due to the use of transparent glazing systems.

Bát Tràng House



Hạ Long Villa

Figure 4. Application of convection ventilation in facade design by Architect Vo Trong Nghia

This solution is extensively implemented in residential designs that prioritize vernacular characteristics and align with trends of tropicalization, aiming for optimal adaptation to Vietnam's distinctive hot-humid climate. In the Ha Long Villa project [5], architect Vo Trong Nghia utilized a structure comprising two nested pentagonal volumes to create an intermediary buffer space. This semi-outdoor area serves not only as a thermal insulation layer for the interior mass but also as a versatile environment—enabling the residents to cultivate gardens, engage with the urban context, and conduct daily activities or relaxation within a space that maintains a profound connection with nature.

A representative example is the Bat Trang House [6], designed by architect Võ Trọng Nghĩa, which has become a notable inspiration for sustainable residential architecture in tropical climates. The building incorporates a double façade system with a cavity approximately 1000 mm wide, combined with vegetation and permeable brick layers. This cavity operates as a natural ventilation system, enabling continuous airflow and effectively reducing the heat absorbed by the outer façade before it reaches the interior spaces. In particular, the outer façade layer is constructed using perforated brickwork, which blocks direct solar radiation while still allowing cross ventilation and diffused natural lighting to penetrate into the indoor environment.

2.2. Ventilation Solutions in Residential Buildings

In practice, to achieve effective natural ventilation for residential buildings, architects often incorporate cross ventilation strategies to dissipate indoor heat. In addition, architects frequently design voids or atriums to enhance vertical airflow circulation.

Figure 5. Anh House / Sanuki + Nishizawa Architects [7]

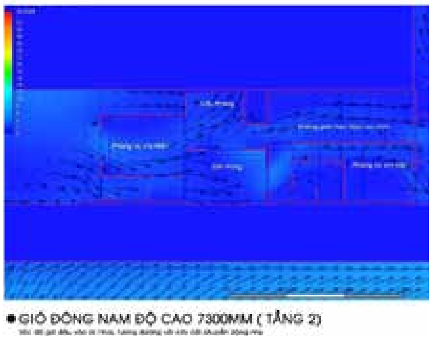


Figure 6. CFD simulation illustrating airflow movement prediction. Through this approach, architects can evaluate multiple design alternatives, adjust opening dimensions and positions, and optimize natural ventilation performance, thereby minimizing solar heat gain [8].

These design solutions create transitional buffer spaces, enabling wind to enter and circulate naturally throughout the building. Specifically, voids, courtyards, ventilation shafts, or open staircases promote vertical airflow movement and improve thermal comfort in hot and humid climates. Particularly in tube houses, which are commonly found in Vietnam, integrating continuous ventilation systems, ventilation openings, cavities, and courtyards helps dissipate accumulated heat, regulate humidity, and facilitate natural airflow circulation, thereby creating a healthier living environment while reducing dependence on mechanical air-conditioning systems.

III. RESULTS AND DISCUSSION

In the context of increasingly polluted living environments and the growing complexity of climate change, applying natural ventilation strategies in residential architecture not only helps reduce operational and energy costs but also contributes positively to environmental protection.

Renowned architect Norman Foster once posed the question: *"Why should we equip buildings with complex mechanical systems when they can naturally adapt to climate conditions?"* This perspective is particularly relevant for tropical humid climates such as those in Vietnam, where abundant wind resources can be effectively utilized to reduce indoor temperatures and improve thermal comfort.

Through the analyses presented above, it can be affirmed that natural ventilation, especially buoyancy-driven ventilation, plays an essential role in improving thermal comfort and enhancing living quality in Vietnamese residential architecture. The application of these solutions is not merely a technical approach but also an architectural strategy that integrates climatic adaptation with sustainable development.

To maximize the effectiveness of buoyancy-driven ventilation, building design should be thoroughly analyzed using simulation methods such as Computational Fluid Dynamics (CFD) or experimental studies corresponding to specific building typologies. From these analyses, architects can identify appropriate design strategies and provide scientifically grounded solutions suitable for regional climatic conditions and residential culture, while also contributing to environmental protection.

In addition, research on façade materials with low thermal absorption and high thermal insulation capacity should be further promoted to improve the effectiveness of double-skin façade systems. Furthermore, architects may propose integrated ventilation solutions that combine natural ventilation with greenery, water features, and transitional semi-open spaces to reduce solar heat gain. These solutions not only help buildings maximize natural airflow utilization but also minimize dependence on mechanical cooling systems.

The effective use of local materials and the application of passive thermal techniques and climatic engineering strategies are key factors in creating harmonious living environments between humans, architecture, and nature.

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