SOLUTIONS FOR ENHANCING NATURAL VENTILATION IN ARCHITECTURAL BUILDINGS AND THEIR PRACTICAL PERFORMANCE

MỘT SỐ GIẢI PHÁP TĂNG CƯỜNG THÔNG GIÓ TỰ NHIÊN TRONG CÔNG TRÌNH KIẾN TRÚC VÀ HIỆU QUẢ THỰC TẾ CỦA CHÚNG

Arch. Hoang Minh Hung [1]

Abstract: Recent studies have increasingly highlighted the significant role of natural ventilation in improving indoor air quality, thermal comfort, and reducing building energy consumption. This paper provides a systematic review of strategies for enhancing natural ventilation in architectural buildings, providing a foundation for designers to apply in future practice.

Keywords: Cross ventilation, Double skin facade, Natural ventilation, Solar chimney

Tóm tắt: Những nghiên cứu gần đây đã chỉ ra vai trò quan trọng của thông gió tự nhiên trong việc cải thiện chất lượng không khí, mức độ tiện nghi nhiệt, và tiết giảm năng lượng tiêu thụ trong công trình. Bài báo này cung cấp một cách có hệ thống các giải pháp nhằm tăng cường thông gió tự nhiên trong công trình kiến trúc, từ đó tạo nền tảng để các nhà thiết kế áp dụng trong thực tiễn.

Từ khóa: Mặt tiền hai lớp, Ống khói nhiệt mặt trời, Thông gió chéo, Thông gió tự nhiên

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1. INTRODUCTION

In previous studies[1], the authors have pointed out that the application of natural ventilation in buildings has become, and will continue to become, an inevitable trend due to the benefits it offers. However, designing an effective natural ventilation system that maximizes these benefits requires considerable professional expertise and design experience.

In urban environments, natural ventilation may also encounter adverse impacts, such as the deterioration of outdoor air quality, discomfort caused by traffic noise, as well as excessive heat gain or heat loss under extreme weather conditions.

The aim of this paper is to systematically synthesize the design solutions for natural ventilation that have been implemented and to evaluate their practical effectiveness. By doing so, the study seeks to provide designers with a comprehensive framework that can support a holistic approach and facilitate the integration of natural ventilation strategies into future building designs.

2. RESEARCH METHODOLOGY

The primary research method used in this paper is analysis and synthesis. Studies and articles published in journals and scientific databases including Web of Science, ScienceDirect, and Scopus, as well as textbooks and other documents, were collected and synthesized. The following search term were used: "cross ventilation", "natural ventilation", "wind catcher", "cross wind- induced ventilation", and "cross wind- driven flow". The document type was confined to research articles and review articles and the publication year was set to before 2024. The interesting research articles and review articles whose titles and abstracts include the abovementioned keywords were filtered. All articles are then scrutinized based on the research focus, and those which were not directly related to natural ventilation were excluded from the list. After synthesis, the data were classified based on design solutions. In total, 78 studies were reviewed in this paper.

3. RESULT AND DISCUSSION

After synthesizing the data, the paper proposes several key solutions that have been widely applied. These solutions are categorized into two main groups: design solutions and technical solutions.

[1] Hanoi Architectural University
Emai: hunghm@hau.edu.vn

3.1. Design solutions

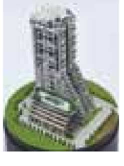
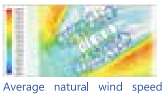
These are design strategies involving the arrangement of floor plans, elevations, or building forms to optimize natural ventilation flows. More specifically, they include determining the position and size of windows and doors, as well as arranging wind-catching elements within the building.

3.1.1. Building form design

Architectural structures exist within a microclimate, and the building form also affects the movement of airflow through it. A well-designed form not only enhances airflow but also improves the quality of natural lighting inside. Buildings with cubic forms are not optimal for natural ventilation, as the recirculation zones they create tend to be stable in size and do not change much. An elongated building form (with its long façade oriented toward the prevailing wind direction) utilizes airflow more effectively than a square form, as it creates larger wind-shadow zones. In addition, for certain types of detached residential buildings, designing building forms with internal voids or courtyards is also an effective solution.

For high-rise buildings with significant wind exposure, large positive pressure zones tend to form on the building surface, which can lead to undesirable effects such as vortices and corner turbulence. Therefore, it is necessary to incorporate openings that help guide airflow in a controlled manner. Table 1 below presents several typical examples of effective building form design and their practical performance.

Table 1. Examples of architectural form designs that enhance natural ventilation

	Building	Building Type	Image	Design Description	Practical Performance of the Solution
1	MBF Tower	High-rise residental building		- Completed in 1994 - Design solution: "porous" façade with multiple openings on vertical surfaces to channel wind into apartments. Ventilation voids are arranged at different heights along vertical cores - The building is oriented at an angle of 20–30° relative to the prevailing wind direction, improving cross-ventilation efficiency	 Average natural wind speed in apartments reaches 1–2 m/s. Ventilation covers most of the apartment area. Indoor microclimate meets thermal comfort conditions
2	The Met	High-rise residental		- Completed in 2005 - Design solution: divided into 6 smaller blocks, with vertical ventilation voids arranged alternately between them - Wind openings and airflow paths are organized rationally, combined with 3 outdoor garden spaces	80% of residents report thermal comfort indoors, 55% of households do not rely on air conditioning. Average wind speed ranges from 0.8–1.5 m/s. At midday, indoor air temperature is several degrees lower than outside at ground level

This solution presents several limitations. First, a portion of the building's usable area is sacrificed to create buffer spaces that guide airflow. Second, the solution requires a relatively large open space surrounding the building to ensure stable natural airflow, avoiding disturbances caused by external obstructions. Third, as a passive strategy, its performance depends on climatic conditions; during certain periods of the year, natural ventilation rates may be sufficient, but the incoming air can carry excessive heat from the outdoor environment, leading to thermal discomfort. Therefore, additional measures are required to reduce the temperature of the incoming airflow before it enters the building.

3.1.2. Floor Plan Layout, Window Position- Size, and Interior Arrangement

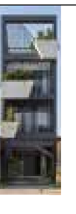
For tube houses—a common building type in large Vietnamese cities- designers have limited options of building form when optimizing natural ventilation. Instead, they rely on the effective arrangement of architectural elements within the floor plan. Research results indicate that appropriate layout planning and window design- including window shape, opening ratio, number of openings, position, type, and orientation- can significantly improve thermal comfort, reduce cooling loads, extend ventilation duration, and enhance indoor air quality [2], [3].When a building is aligned with the prevailing wind direction, its surface obstructs the airflow, creating a positive pressure zone on the windward side, while a negative pressure zone forms on the leeward side.

Openings should therefore be placed at locations where negative and positive pressures reach their highest values, as this creates the strongest airflow through the space. Inlets (entrance openings) play a role in controlling airflow direction, while outlets control airflow velocity. Therefore, inlets should be positioned to guide airflow toward desired areas. Increasing the size of both inlet and outlet openings enhances the average indoor airflow velocity; however, they should have equal widths to ensure effective ventilation.

Openings should be arranged in an offset manner so that airflow can pass through most of the interior space. A window-to-wall ratio of 20%, with a window proportion of 1:2, significantly improves indoor air quality and thermal comfort.

In addition, although the number and shape of furniture do not significantly affect ventilation efficiency, their arrangement does have a notable impact. Placing furniture near corners at inlet or outlet locations can obstruct airflow and create stagnant air zones. Maintaining a distance of 1–1.2 m between furniture and openings is optimal for achieving comfortable indoor airflow conditions.

Table 2 below presents a specific example of optimized floor plan and opening arrangement for natural ventilation in a tube house in Bắc Ninh, Vietnam. By arranging openings appropriately and using the staircase space as a vertical ventilation shaft, airflow can move both horizontally and vertically, ensuring that no interior space becomes "isolated."

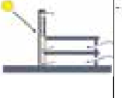
Buiding	Type	Image	Description	Practical Effectiveness
NK House, Bắc Ninh, Việt Nam	Residental House		- Completed in 2020 - Rooms are arranged with large dimensions windows and connected to a central atrium, allowing continuous airflow throughout the spaces - The façade is designed with transitional zones that help reduce the temperature of incoming air before it enters the building	- When the outdoor wind speed reaches 1.5 m/s, indoor wind speeds range from 0.4 m/s (rear bedroom) to 0.9 m/s (front bedroom), with an average of 0.55 m/s - In summer, when the outdoor temperature is 33°C, the perceived indoor temperature ranges from 29–30°C; thermal comfort can be achieved using only fans

This solution is inherently passive and therefore requires complementary measures to reduce the temperature of the incoming airflow during certain periods. In addition, ensuring adequate ventilation across most interior spaces necessitates maintaining open connections, which may compromise privacy in some areas.

3.1.3. Arrangement of Wind Catchers in the Building Layout

More specifically, this solution involves arranging vertical ventilation shaft such as atriums, courtyards, and solar chimneys... These elements create a vertical air pressure difference (stack effect), thereby drawing air upward and generating natural ventilation airflow. To achieve maximum efficiency, the space surrounding the air intake (typically on the ground floor) must have sufficient volume and should not be obstructed by large furniture that could reduce airflow momentum. Additionally, all interior spaces should be connected to the ventilation shaft through openings such as windows. Table 3 below presents several common types of wind catchers and their practical effectiveness.

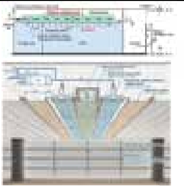
Table 3. Common types of Wind Catchers and Their Performance

		Image	Design Description	Practical Performance of the Solution
1	Atrium		- Suitable for tube houses - Can improve indoor air quality and natural lighting - Should be placed at the center of the floor plan, with an area of about 8–10% of the total floor area	- Can generate stable airflow with velocities ranging from 0.25–0.75 m/s, significantly improving indoor thermal comfort [4]
2	Solar Chimney		- A solution that utilizes solar thermal energy to create a stack effect within vertical air channels - Suitable for regions with high solar radiation, such as southern Vietnam	-Outdoor wind speed has the greatest influence on its performance. Maximum efficiency is achieved when outdoor wind speed is below 0.5 m/s [5]
3	Wind catcher		- A windcatcher is a traditional Persian architectural element found across the Middle East, its use dating back thousands of years. - It provide passive ventilation for indoor spaces. They can also facilitate evaporative cooling with the help of water reservoirs inside buildings. Sometimes, they are pointed into the wind to catch more air	-The use of wind towers can significantly increase airflow within the house, ranging from 0.2 to 0.65 m/s. With precise adjustments to specific parameters, this figure can be further elevated. -It is recommended to utilize four-faced wind towers with a height extending beyond the surrounding airflow disturbance zone, specifically ranging from 7 to 12 meters. The inlet openings should be positioned to directly face the prevailing wind direction, and the opening area should be larger than the outlet area to enhance ventilation flow rates

Solar chimneys and wind catchers are highly effective in hot–dry climates; however, their performance is less effective in hot–humid regions such as Vietnam. Atriums are a commonly used solution in Vietnam, but appropriate shading strategies are required to mitigate solar heat gain.

3.2. Technical Solutions

In many cases, natural ventilation alone cannot meet user's demand, therefore, mechanical systems are employed. Table 4 below summarizes several basic technical devices that are widely used worldwide.

		Image	Description	Practical Effectiveness
1	Fan		- A basic device with simple technology. Easy to operate and maintain, with low maintenance costs	- In a typical house, installing fans can easily achieve indoor thermal comfort. - However, its effective depends on the air temperature
2	Natural ventilation duck system		- A system that guides and distributes natural airflow into buildings, commonly applied in high-rise office buildings - It helps direct airflow into all indoor spaces without causing drafts or discomfort	- Provides stable airflow at around 0.2 m/s throughout the building - Increases the duration of natural ventilation from 55% to 75% of the time - Can maintain indoor airflow temperature between 20–25°C, even when outdoor temperatures drop below 18°C.
3	Double skin ventilation system		- A façade design consisting of two separate layers, spaced approximately 20 cm apart The air cavity between the layers acts as insulation and helps regulate airflow entering the building - Enhances natural ventilation while also providing solar shading, particularly effective in low-latitude regions	- Can increase natural ventilation airflow by approximately 20% to 100% compared to conventional single façades - Air velocity within the cavity ranges from 0.5–2 m/s, significantly improving ventilation performance - Increases the indoor–

This solution is highly effective; however, it requires complex calculations during the design phase, as well as a high level of expertise for operation and maintenance. In addition, the cost of design and installation presents a significant barrier to its widespread adoption.

4. CONCLUSION

This paper has analyzed common solutions to enhance natural ventilation in architectural buildings and their practical effectiveness. To maximize ventilation performance, it is necessary to calculate and apply solutions individually or combine multiple strategies from the conceptual design stage.

In addition, attention should be paid to the temperature and humidity of the incoming airflow, as in certain conditions, excessively high temperature and humidity can cause discomfort, even when natural ventilation is sufficient.

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