DESIGN SOLUTIONS TO THE IMPROVEMENT OF NATURAL VENTILATION FOR LOW-RISE APARTMENT BUILDINGS IN DANANG CITY

GIẢI PHÁP THIẾT KẾ NHẰM TĂNG CƯỜNG HIỆU QUẢ THÔNG GIÓ TỰ NHIÊN TRONG CHUNG CƯ THẤP TẦNG TẠI THÀNH PHỐ ĐÀ NẴNG

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Abstract - Natural ventilation is an important solution of passive design, which is adapted to the natural conditions of the construction site to create buildings which are convenient for occupants, environmentally friendly, energy savings during its operation and towards a sustainable development in construction projects. However, in some of the buildings, natural ventilation has not been exploied or its effects are not very high. In this article, we study the actual situation and propose some design solutions to enhancing the effect of natural ventilation for low-rise apartment buildings in Danang City, a popular type of shelter in the social housing projects of Danang City.

Key words - natural ventilation, low-rise apartment building, wind driven ventilation, stack ventilation, passive design

Tóm tắt - Thông gió tự nhiên là giải pháp quan trọng của thiết kế thụ động, một giải pháp thiết kế thích ứng với điều kiện tự nhiên của địa điểm xây dựng để tạo nên các công trình tiện nghi cho người sử dụng, thân thiện môi trường và tiết kiệm năng lượng trong quá trình vận hành, đồng thời hướng đến sự phát triển bền vững cho công trình. Tuy nhiên, tại một số công trình kiến trúc, thông gió tự nhiên chưa được quan tâm khai thác hoặc hiệu quả thông gió tự nhiên tại các công trình này là chưa cao. Bài báo đi vào nghiên cứu thực trạng và đề xuất những định hướng thiết kế nhằm nâng cao hiệu quả thông gió tự nhiên cho chung cư thấp tầng hiện nay tại Đà Nẵng, một loại hình nhà ở phổ biến tại các dự án nhà ở xã hội của thành phố Đà Nẵng.

Từ khóa - thông gió tự nhiên, chung cư thấp tầng, thông gió nhờ áp lực khí động, thông gió nhờ chênh lệch nhiệt độ, thiết kế thụ động

1. Introduction

Since Danang became the city directly under the Central government (1997), it has made many achievements in urban planning and urban development. Many of the urban infrastructures, residential sections, civic buildings... have been constructed.

A low-rise apartment building (LRAB) is a type of building constructed in many residential sections. The apartment buildings (ABs) have satisfied the basic needs of urban occupiers. However, they still have many problems that need solving, including apartment microclimate comfort (indoor air quality), operational management, public areas, etc.

In the context of sustainable development in general and sustainable development in construction in particular, designers have to resolve many pressing problems, such as exploiting and finding solutions to enhancing the effect of natural ventilation towards micro-climate comfort and indoor air quality for apartments and energy saving.

2. Realities of Effective Natural Ventilation in Low-Rise Apartment Buildings in Danang City

2.1. Natural Ventilation in Buildings

2.1.1. Concept

Natural ventilation (NV) is a movement phenomenon of air through buildings under the influence of natural forces [2].

NV plays an important role in improving the building microclimate comfort such as reducing the temperature of building surfaces and indoor air; body cooling (enhancing the body heat rejection process by convection and evaporation of sweat); improving indoor air quality. In a hot and humid climate like that of our country, NV plays a very important role creating microclimate comfort for building.

NV is considered to be one of the passive design solutions aimed to adapt to local climatic conditions, to use the natural energy sources (wind) for operation and to create comfortable buildings which are environmentally friendly and energy-saving.

2.1.2. The Norms for Evaluating the Effectiveness of NV

The evaluation of the NV effectiveness in buildings is always dependent on the following norms:

-The flow of ventilation (G) is measured with the volume of ventilation in a span of time (m3/h or m3/s).

- Multiple ventilation (n) is defined as the ratio of the flow of ventilation (G) over the volume of room (V) (dimensionless).

- Wind velocity (v) in the room (m/s) and ventilated area (S) in the room. [4]

2.2. Overview of Investment and Construction in Low-Rise Apartment Buildings

2.2.1. The Concept of Low-Rise Apartment Buildings

Low-rise apartment buildings (LRAB) are types of 5-storey apartments or lower, with lobbies, stairs and infrastructures system used as a common property of many households and individuals.

In urban areas in general and in Danang City in particular, the type of LRABs is commonly applied to the resettlement sections and the social residential sections

2.2.2. The Investment and Construction Situation of the Apartment Buildings and LRABs in Danang City

Along with the urban development, many projects on apartment buildings (AB) have been carried out in Danang City including

- High-rise AB projects:

. Commercial high-rise ABs: Indochina Riverside Tower (25 storeys and 13 storeys), Vinhtrung Plaza (20 storeys), Danang Plaza (19 storeys), HAGL View Lake (32 storeys), Azura (35 storeys), etc.

. High-rise AB projects - social housing: Nai Hien Dong (12 storeys), Phongbac (11 storeys), Southern Tran Thi Ly Bridge (9 storeys - 12 storeys), etc.

- Seven-storey AB projects: Nai Hien Dong, Hoahiep No2, Southern Tuyenson Bridge, Phongbac, etc.

- LRAB projects:

. Five-storey ABs: Vungthung, Ending of EasternBach Dang St, Nai Hien Dong No2, An Cu No5, Beginning of Sontra - Dienngoc St, Binhan, Nguyen Tri Phuong No4, Hoacuong, Western Hoathuan, Western Thanhkhe, Thanh Loc Dan C, Tran Cao Van, Hoaminh, Thanh Loc Dan – Wide open Hoaminh, Southern Tran Thi Ly Bridge, Khue Trung, etc.

. Four-storey ABs: Nai Hien Dong, Manthai, Ancu, Binhhien, Thanh Loc Dan C, Le Dinh Ly, Bac My An, Khuetrung, etc.

. Three-storey ABs: Special Forest Products Hoacuong, Thuanphuoc, Hoaminh, etc.

In recent years, Danang City has planned many policies that supported and solved the housing problems for city-dwellers, especially for low-income people, such as resettled people, poor people, social policy people, government officials, soldiers...Most ABs in Danang are for resettlement, for low-income people and social housing projects.

Danang is the city that has taken the lead in the realization of "Social housing" programs. According to statistics, up to now, more than 7,385 apartments [6] have been constructed and put into operation in Danang City. Among them, LRABs have 4,186 apartments (making up 57% of the apartments controlled by Danang Apartment Buildings Management Company). The number of apartments and construction sites (for each district) of LRABs are shown in Figure 1.

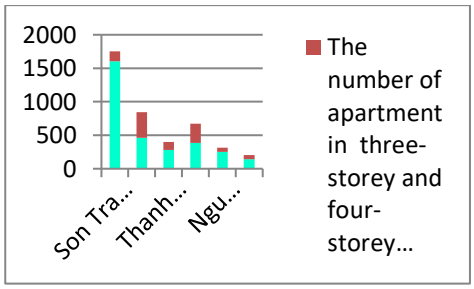


Figure 1. *Statistics of the number of apartments in LRABs in Da Nang (Source: Danang AB Management Company)*

2.3. Reality of Effective Natural Ventilation in Low-Rise Apartment Buildings in Danang City

2.3.1. General Characteristics of the LRAB Areas in Danang

According to statistics, the number of apartments in five-storey ABs makes up 74.7% of total apartments in Danang's LRABs. Therefore, we selected five-storey ABs as a research objective.

The five-storey ABs has some main characteristics as follows.

- The blocks were built in terms of 2 models (or correction from this model), that have been approved by the city government.

- The master plan consist many blocks and building density of 30% - 40%.

- Functional areas under the storeys: parking areas, community areas, kiosks and apartments on the 1st floor; apartments on the typical floor (2,3,4 and 5).

- The plan figures are of rectangular and middle corridor types. Each typical floor has 8 apartments (2 apartment types: A and B). Average space: 50m^2/apartment. (See Figure 2)

- Standard comfort, equipment and finishing material are at the minimum level to offer the lowest prices.

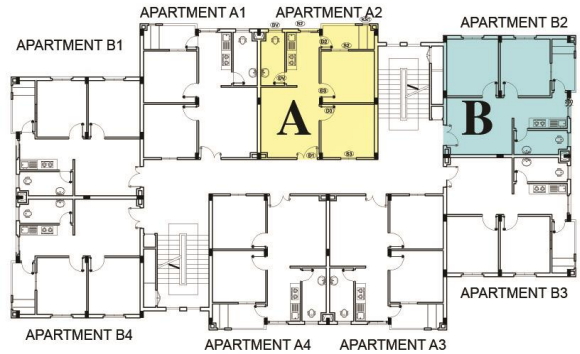


Figure 2. *Typical floor plan – B model [1]*

2.3.2. Reality of effective natural ventilation in low-rise apartment buildings in Danang City

Through fieldwork and ventilation research on apartments, we can bring up some assessment in terms of effective NV in LRABs in Da Nang City as follows:

- Wind field on the master plan: due to the arrangement in cluster with high density, most of the blocks, except in front of wind blocks, are located in windless areas.

- Landscapes (trees and water) are not designed properly to improve the micro-climate of AB areas. The apartments with only one side exposed to natural conditions (except four apartments in the corner with 2 contact sides) - have only 2 or 3 rooms that are naturally ventilated directly. In this single-side ventilation situation, the effect of NV is very low (the values of G, V, n and S are small).

- Normally, 1 or 2 room(s) in the apartment are not absolutely ventilated naturally. This is the main weakness of current LRABs.

- With a closed corridor and limited ventilation openings at the staircase, the effect of NV at the corridor and the door of the apartment towards corridor is very low.

3. Proposing Some Design Orientations to Enhance the Effectiveness of Natural Ventilation in Low-Rise Apartment Buildings in Danang City

3.1. The Foundations for Proposal

3.1.1. Geographical Location and Climatic Characteristics in Danang

Expanding from 15 ° 55 'to 16 ° 14' North latitude and 107 ° 18 'to 108 ° 20' East longitude, Danang City is located in the coastal South Central climatic region (The IIA area) – It is a tropical monsoon climatic region with cool winters (The Viet Nam Building Code 02:2009/MOC). The climate in Da Nang has some main characteristics as follows.

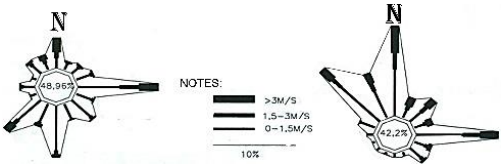
- Located nearby the seaside, Hai Van Pass stops cold wind and solar activities are of equatorial and tropical forms. Danang is still influenced by hot-dry West wind.

- The annual frequency of biological weather comprises comfort limit zone (85.42%); cool weather but humid (8.85%); light cold weather (4.53%); hot weather (1.2%).

- Apparent activity of the Sun: through Zenith twice a year on May 5th and August 9th. Those are the days of maximum solar radiation. Much time of the year, the sun moves at the Southern Hemisphere. The sun's position peaks are from mid-April to mid-August - those are the hottest months of the year.

- Humidity is not more than 70% in daytime and 90% at night.

- In the hot months (June, July, August) prevailing wind direction is East (frequency 10%) and South (about 7%). Southwest hot-dry winds also appear with a frequency of about 5%. In the three cold months (December, January, February), the North wind prevails. East wind and North West winds have the same frequency (about 10%) (See Figure 3). [3]



a. Wind frequency in June, b. Wind frequency in December, July & August January & February

Figure 3. *Wind frequency in Da Nang [3]*

- Every year, Da Nang city suffers the influence of at least one storm or tropical low pressures with level-6 winds and over [7].

3.1.2. Socio-Economic Characteristics

The occupiers of LRABs are resettled households, poor people, social policy people, civil servants, soldiers,... who have low incomes and comfort for them, in AB designs, is required to a minimum.

The proposed solutions should have low costs in construction and operation to ensure the feasibility for the project.

3.1.3. The fundamental Principles of Natural Ventilation

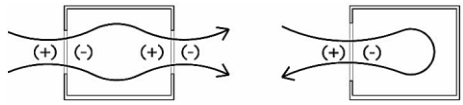
There are two fundamental principles:

- Wind driven ventilation: the movement of air is based on the pressure difference between the windward side (positive pressure) and leeward side (negative pressure). (See Figure 4a)

Wind driven ventilation is divided into two types: Cross ventilation and Single-side ventilation. (See Figure 5)

a. Wind driven ventilation b. Stack effect ventilation

Figure 4. *The fundamental principles of natural ventilation*



a. Cross ventilation b. Single-side ventilation

Figure 5. *Wind driven ventilation*

- Stack effect ventilation: the movement of air is based on the temperature difference between the inside and outside of the building. The air at high temperature (+) moves up high and air in lower temperature (-) invades the place. (See Figure 4b)

3.2. Some Design Orientations to enhance the Effectiveness of NV in LRABs in Danang City

3.2.1. The master Plan

- Danang is of great advantage in the natural landscape and environment. Thus, the orientations of master planning should follow natural elements, taking the advantage of landscapes and minimizing the impacts on nature.

. Limiting the use of concrete surfaces, increasing plant trees and creating lake-fountains to reduce the temperature and clean the air around the building before it blows into the building.

. Planting trees on the master plan: paying attention to the prevailing wind direction (East, South, North and North West) to ensure that the wind is not prevented from blowing into the building and creating wind ditches into blocks.

- The main direction of ABs is selected basing on limitation of direct solar radiation, picking up the prevailing wind direction, increasing door-opening area for light and ventilation into the room. According to the characteristics of climate conditions in Danang, solar activities and wind frequency, we propose to choose the direction of ABs from South East to Southern South West.

- Limiting the set of blocks on windless areas.Windless areas of block depend on height, width, depth, shape, direction of blocks and layout solution of apartment blocks. Typically, windless areas have the size by height 3.75 times, width 2.75 times and the depth 2 times of the blocks [4]. If the master plan satisfies this demand, it will be difficult to ensure the economic efficiency of the low-income projects. During the planning activities, the following should be drawn into attention.

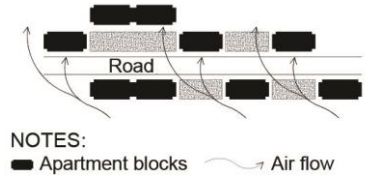


Figure 6. *Illustrations of master design solutions for ABs.*

. Setting the blocks in the staggered form to create the gaps between the blocks and ensure airflow to all blocks. (See Figure 6)

. Increasing the area of gaps on the 1st floor of the blocks, so wind can blow through the block to limit the windless area at the back of the block.

3.2.2. Architectural Design

- Choosing the rectangular-shape plan (ratio of length and width are greater than 2) or jagged rectangular-shape plan. The long sides are oriented towards the main direction.

- The lay-out plan is a central corridor type. Create NV for the corridor by providing an open space for it. Enhance wind to blow through the corridor via the door of the staircase, etc.

- Typical floor (the 2nd floor to the 5th floor): the main space (the apartment) and secondary space (lobby, corridor, stairs, technical rooms, etc.). The secondary space should be set on the West and East (ends of the rectangle).

- In each apartment, priority is given to designing. This is aimed at acquiring natural ventilation and lighting for the rooms, living rooms, bedrooms, drying grounds, kitchens and toilets. With the rooms and corridors that are deep in the floor, we have to create hollow spaces in the plan. At the position of such hollow spaces, the drying ground will be set out to ensure the aesthetic aspect of the building (Figure 7).

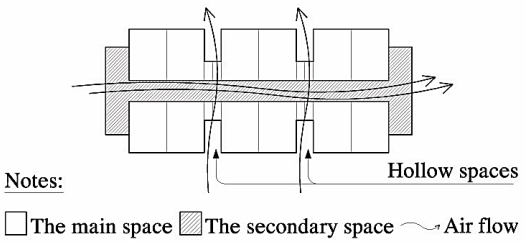


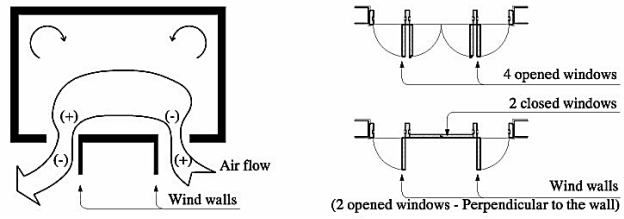
Figure 7. *Illustrations of planning solutions for AB.*

- Creating the maximum window opening towards the sides that are exposed to the nature to catch the wind (for the sides that are exposed to the influence of solar radiation have to acquire appropriate shading solutions). The size and location of doors have to be appropriately calculated to increase the ventilation flow G and ventilated area S in rooms. It is necessary to have ventilation solution for the middle room (not to expose to the nature).

- Enhancing the elements of trees, water in the balcony-drying ground: in order to cool the air before it blows into the house.

- Choosing the rectangular parallelepiped for the block shape, "plate shape ", or as "plate shape with jagged" (in the plan).

- Ventilation in apartment's room is usually single-side. To enhance NV for this room, the solution to be used is creating the wing walls to create pressure (+) and (-) on the same sidewall [2] (see Figure 8a). For ABs, depending on the time, we can close or open the windows to create the wing walls, enhancing the value of G, V, and S (see Figure 8b).



a. The principles of wing wall [2] b. Proposing the structure

Figure 8. *Illustrations of wingwalls solutions.*

- Creating the airflow through the room in the same apartment, especially in the central apartment rooms by opening more windows. Right here, we have to solve the problems of sound proof and privacy for the room.

- The doors between public and private space (corridor and apartment; rooms in the same apartment) should have 2 layers, including 1 shutter layer (open) and 1 panel wood layer (or steel or glass). The doors are flexibly open in view of using them to enhance cross ventilation for rooms.

- The doors (windows, doors,...) located in the outer cover should be drawn into attention in respect of the following solutions:

. Storm protection: increase the thickness of glass by adding metals near the glass, etc.

. Flexibly change the windward area of the door as wind velocity increases by the building height, so the windward area of the doors of the apartments is located on various floors- - the higher they get the smaller the area of the door is.

. With the doors which need shading: use the shutters and prioritize the shutters that can be flexibly controlled to catch the wind.

3.2.3. Setting the Wind Suction Grille

- Applied to the room unexposed to the nature, located inside the room and the central corridor.

- Solutions:

. *Chimney cowls*: create the negative pressure at cowls by rotating cowls to suck air outlet of the room by the conduit systems. The effect of suction depends on the characteristics of local winds, type of cowl and the flow rate.

. *Solar chimney*: based on the temperature differences. Use the solar heat to warm up the air in the conduit, the temperature of this air is increased and the air flies up high under the conduit to escape. The air in the other area of the conduit will overflow into the gap. Absorbable Solar energy glass is placed in the direction of the East and the West. [2].

- Architectural composition:

. Chimney cowls (cowls placed in a positive wind pressure areas, should be higher than the rooftop). They receive solar energy section (the glass type can absorb solar radiation) and the air suction grille (with cowls being protected against rain, dust, insects, etc) are set on the roof.

. Air conduits are located in the technical box;

. The air suction grilles are located close to the ceiling. (See Figure 9a and 9b).

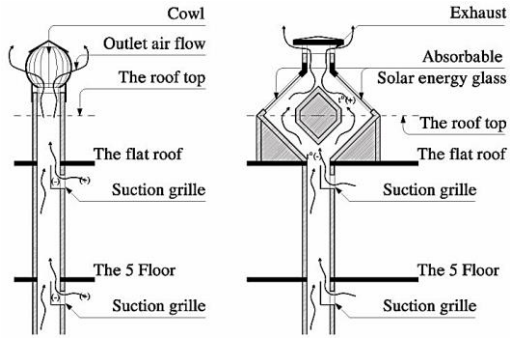


Figure 9a. *Chimney cowls* ***Figure 9b.*** *Solar chimney*

To increase the efficiency of ventilation and reduce the construction cost, the designer can combine 2 solutions into one system. We propose to use this solution (see Figure 10a)

3.2.4. Setting the Wind Diffuser Grille

- Applied for a room which is not exposed to the nature, located inside the room and the central corridor.

- Solution: Wind towers and winds enter via the windward direction having a positive pressure coefficient. Then air, which can be cooled down in the course of moving, is directed through the tower into the room [2].

- Architectural composition:

. Wind receiving section (which can rotate automatically or manually rotate to catch the wind from many directions) is set on the roof. The air diffuser grille is located at the positive wind pressure areas, usually set higher than the top of the roof.

. Air conduits are located in the technical box;

. The air diffuser grille is located close to the floor. (See Figure 10b)

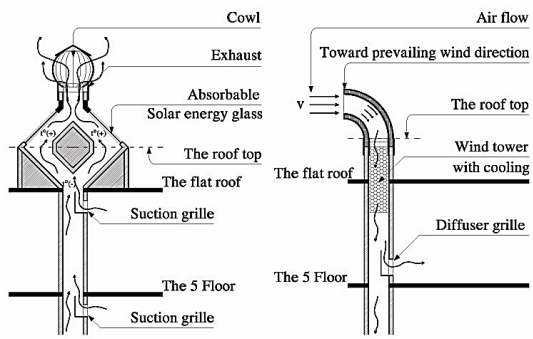


Figure 10a. *Combining Chimney* ***Figure 10b.*** *and Solar chimney Structure of Wind tower*

Figure 11 illustrates the site of the air suction grille (combined solution) and the air diffuser grille for the LRAB - B model.

In addition, to improve the microclimate comfort in the apartment, enhance the effect of NV and adapt to the different characteristics of weather conditions, we can use low energy devices, such as ceiling fans in rooms, fan in the diffuser grille and the suction grille.

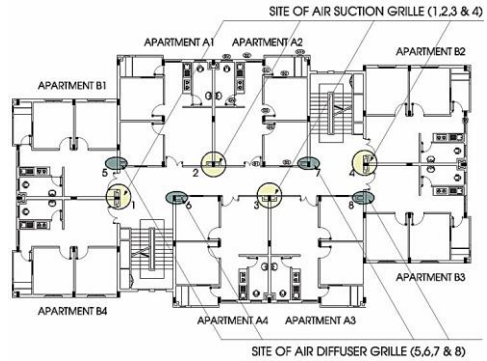


Figure 11. *Proposing the site of the diffuser grille and the suction grille on a typical plan.*

4. Conclusion

In the context of resource exhaustion, energy crisis, environmental pollution and global climate change, NV is a passive design solution which plays an important role in the creation of the building, which is environmentally friendly, energy saving and towards sustainable development in construction.

In this article, we have highlighted some limitations of the effectiveness of NV in current LRABs and proposed some orientations in designing to enhance the effective NV in low-rise apartment buildings in Danang City. Depending on the characteristics and requirements of each project, the designer can apply the orientations (section 3.2) to designing the master plan, designing new LRAB models, altering the models that have been approved by the city government (currently applicable to construction) or repairing LRABs that have been built.

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