Article Title: Apartment Prototype with Enhanced Natural Ventilation System for Vietnam

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Abstract

With boundary-less efforts being made to increase the sustainability of human existence, the architecture field has also been making great efforts concerning this global trend. On the other hand, the urban conditions of developing cities require high-density housing solutions to house their rapidly increasing populations. In the case of apartments, the latter takes priority over the former, thus resulting in high-energy consumption for climate control and therefore high utility bills. This conflict is most pronounced in hot and humid tropical climate areas such as Southeast Asia, where passive climate control is virtually impossible to achieve in high-density housing types. In this paper, the authors make an attempt to develop an apartment prototype for Vietnam that 1) reflects the spatial organization of the Vietnamese "Tube House," 2) allows natural ventilation that is absent in the Tube Houses, while 3) maintaining a high level of density. In doing so, the authors applied environmental strategies used in Vietnamese vernacular architecture and tested the performance of the prototype through air current analysis. As a result, the first two goals were achieved, while the third goal was achievable only to a certain extent.

Keywords: apartment prototype; natural ventilation; Vietnam; vernacular architecture

1. Introduction

1.1 Background and Goal

In Asia, apartments have become the symbol of modernization, industrialization, technological advancement, and economic prosperity. While in the Western context high-density apartments are criticized for their lack of local identity, they are received as high-end housing types in Asian countries such as Korea, China, and Hong Kong. The next wave of developing countries such as Vietnam, Indonesia, and Malaysia are no different as more and more apartment projects are being launched.

However, with such countries being located in the tropical climate zone of Asia, adoption of high-density apartments faces challenges set out by the hot and humid climate, which is significantly different from the rather mild climates of the northern part of Asia. Most noticeable is the extremely hot temperatures, which remain constant throughout the day due to the high level of humidity. While thermal comfort can be achieved by means of thermal lag in dry regions, this possibility is eliminated in tropical climates. Moreover, congested airflow, combined with the humidity, can create damp indoor climates that can cause fungal decay and threaten the habitability of houses. In dealing with these conditions, it is easily assumed that the thermal environments of apartment buildings in tropical climates can be controlled by mechanical facilities. Socio-economically, this creates a discrepancy between the housing market and upcoming middle class residents, as they might struggle with the high cost of operating the mechanical facilities, thus high-density apartments are failing to establish themselves as the mainstream housing type.

Therefore, in this study, the authors will explore a prototypical high-density apartment that provides thermal comfort and natural ventilation in tropical climates through minimal maintenance costs, thus contributing to the diffusion of high-rise living throughout the region.

1.2 Methodology

In this paper, apartment prototypes will adopt the climate control mechanisms found in Vietnamese vernacular architecture. First, climate characteristics and examples of Vietnamese vernacular architecture will be discussed. The 'Tube House,' which is currently the most common housing type in Vietnamese cities but which lacks climate control mechanisms, will also be investigated. Secondly, two apartment building
prototypes will be developed; a single-layer type that focuses on enhancing passive climate control, and a double-layer type that applies the enhanced climate control strategy onto an even higher density apartment building. Building plans and unit plans of these prototypes will be presented. Finally, passive climate control performance of the prototypes will be verified through simulated air current analysis.

2. Local Architecture and Apartments

2.1 Limitations of 'Tube House' and Further Design Ideas

At the heart of Southeast Asia between latitude 8.30°N and 23.22°N, Vietnam is located in the tropical and temperate climate zone. Due to the strong monsoon, most days are hot and humid. The average annual temperature of Hanoi, the nation's capital, is 23.2°C with an average summer temperature of 29.2°C and average winter temperature of 17.2°C. For houses in Hanoi, air conditioning and ventilation is indispensable as high humidity can cause corrosion and fungal decay. (Na, 2011) Such extreme climate conditions have long been a major objective in the designs of local architecture. Table 1. categorically lists the major characteristics of Vietnamese vernacular architecture, the examples of which are shown in Fig.1., and their effects. Minimizing heat storage and maximizing natural ventilation were the most critical issues and considered through the orientation, shape, and material of the construction.

South-facing orientation has relevance to natural ventilation and is the most basic planning method in adapting to the climate. By maximizing the temperature difference between the front and rear of the building, south-facing orientation causes natural airflow. As solar radiation warms the front side of the south-facing building, and the rear side of the building is kept relatively cool because of the shade created by the building mass, a cool breeze is generated that comes from the rear side of the house and moves through the openings in the front side. This mechanism is enhanced through the presence of courtyards since they are more prone to solar heat gain, thus increasing the temperature difference between the front and rear sides of the building. Long rectangular shapes and the lightweight materials used in traditional houses contribute to adjusting the climate as they, respectively, reduce the air flow distance and minimize heat storage. These characteristics resulted in the successful adaptation of traditional houses to the local climate.

<table>
<thead>
<tr>
<th>Category</th>
<th>Method</th>
<th>Effects</th>
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<tr>
<td>Orientation</td>
<td>Southern Orientation</td>
<td>Cross Ventilation</td>
</tr>
<tr>
<td>Plan Layout</td>
<td>Long and Rectangular Shape</td>
<td>Cross Ventilation</td>
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<td></td>
<td>Courtyard</td>
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<td>Terrace</td>
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<td>Material</td>
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<td></td>
<td>Bamboo Screens</td>
<td>Solar Protection</td>
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Fig.1. Traditional Houses of Ethnic Groups in Vietnam

'Tube Houses' (called 'Nhà Ông' in Vietnamese), currently the most common housing type and introduced during Vietnam's French colonization (1887-1954) however, lack such characteristics and quality of climate control. Though tube houses follow the long rectangular shape principle (2-4 meters in width, 20-60 meters in length), the openings are located only at the ends of the elongated rectangle. Originally, tube houses had open courtyards within the building to improve ventilation, but with the introduction of air-conditioners, these courtyards were converted into indoor spaces. As a result, tube houses are no longer adaptive to the local climate conditions. It can be said that tube houses have the physical looks of Vietnamese vernacular architecture, but have abandoned their climate control functionalities. In developing the apartment prototype, such functionalities should be restored through south-facing orientation and openings along the sides while retaining the overall elongated rectangular shape.

Fig.2. Typical Floor Plan of a Tube House (Na, 2011)
2.2 Introduction of Apartments in Vietnam

According to the cultural context, the term 'apartment' can refer to different physical beings. In the West, the term generally refers to a building that consists of multiple units and provides amenities to the residents (Wright, 1983). In the East, however, the term also refers to a cluster of buildings with a well-defined, and often gated, project boundary. (Park, 2013). Wright argues that even the single-building apartments, not to mention the building-cluster apartments, conflict with the Western value of individualism and therefore cannot become the mainstream housing type in Western cities (Wright, 1983). There is also the traumatic image of the demolition of the Pruitt-Igoe housing project, a cluster of 33 apartment buildings, which devalues the clustered apartments. However, Korean cities directly contradict such criticism as more than half of the nation's population reside in clustered apartments. While there can be many explanations for this phenomena, Park's analysis that clustered apartments provide open spaces, which are likely to be absent in rapidly-developed cities, seems applicable to this study (Park, 2013, see Fig.3.). Vietnamese cities also lack spatial openness, which can be provided by apartments as building clusters. One of the apartment prototypes in this study, the double-layer prototype, also relies on this definition of apartments.

3. Prototype Development
3.1 Basic Concept

The basic concept of the apartment prototype begins with a unit that applies the overall spatial structure of the tube house and at the same time improves the microclimate. This is achieved by simply rotating the tube house unit so the sides face the open air while the ends border the adjacent units. This design strategy maximizes cross ventilation and the effects of southern orientation.

Another achievement of this concept is spatial efficiency. Because tube houses are entered from the end, an excessive amount of space is used for internal circulation. The prototype, however, locates the entrance on the side of the plan, thus reducing circulation space. This can be understood in light of rationalizing the spatial structure of the tube house.

3.2 Building Plan and Mechanism
(1) Single-Layer Prototype

Based on the basic concept, apartment units can be combined to form building blocks. We begin by simply laying out the units in a linear form, like a row house, and inserting vertical circulation between units. As long as the building blocks are oriented to face south, there will be sufficient daylight throughout the house, contrasting with the dark and damp indoor spaces of the tube houses. This orientation also allows efficient ventilation as temperature difference occurs between the southern and northern sides of the building, similar to the characteristics of the Vietnamese vernacular architecture where the south-facing buildings had a cool breeze in the summer and avoided the monsoon in the winter (Na, 2011). Because of the extremely shallow depth of the building block, natural ventilation can be maximized. However, this prototype has some limitations. First, the concept of 'rationalizing the spatial structure of the tube house' is compromised as vertical circulation can only be connected to the units at their ends. Second, the shallow depth of the building block can cause the building to become structurally unstable as the number of floors is increased. Finally, relatively low density can be quite infeasible. That is, if a building block of a similar length can have twice the number of units (which will be shown in the double-layer prototype), twice the number of single-layer building blocks will be required to match the number of units, and even more land between the building blocks. Therefore, a solution that offers higher density should be considered.
(2) Double-Layer Prototype

The double-layer prototype can be seen as two single-layer prototypes put together, thus providing greater density. The limitations of the single-layer prototype are solved as the public corridor allows the freedom to locate the units' entrance points to best suit the unit plans. The greater depth of the building block offers structural stability thus allowing the building block to increase its height, while compared to the single-layer prototype, a smaller number of building blocks and less amount of land is required for the same number of units.

However, the ability of natural ventilation is highly compromised because no unit has both its southern and northern sides open to the air. Therefore, 'artificial openings' or 'natural air conditioners' are installed on the internal sides (refer to the red marks in Fig.7.) where a continuous breeze of air is provided to ventilate each room. This is made possible by a sectional planning of the building block that combines geothermal cooling and stack effect.

In high-rise apartments in mild climates, the stack effect is used where consumed warm air rises and escapes the building, creating a negative pressure at the lower levels and pulling in fresh air from the outside. In tropical climates, however, the outdoor air near the ground level can actually be warmer than that of indoors, thus the stack effect would lack any kind of cooling effect. Therefore, the warm air must be cooled before it rises through the stack effect. This is done by sufficiently passing the warm air through the ground, emitting heat to the earth and cooling it down. This geothermal cooling method is specifically effective in large apartment projects that consist of multiple buildings with open areas in between, because then the earth below the large open spaces can be used to lengthen the section where cooling occurs. While the stack effect mechanism relies on the geothermal cooling mechanism to provide cool air, the latter also relies on the former to drive the intake of warm air into the geothermal intakes, as under natural conditions, warm air is unlikely to 'sink' to the earth.

4. Prototype Verification

In this section, we will verify the ventilation performances of the two prototypes through simulated air current analysis and calculating the 'age of air.' For the simulated analysis, the authors used STAR-CCM+ by CD-adapco. For geographic climate data such as temperatures, wind direction and velocity, data provided by weatherspark.com were used.

4.1 Single-Layer Prototype Verification

Fig.9. visually illustrates the air current analysis of the single-layer prototype. In this case, wind velocity was assumed to be 1.0 m/s from the south. As expected, most major rooms were adequately ventilated. In fact, some rooms such as the living rooms were 'over-ventilated' because the air current velocity well exceeded the comfort zone of 0.5 m/s. In such cases, the user will have to manually operate the openings to control the breeze. Analysis was reiterated from various wind directions and the results were quite similar. Fig.10. shows the age of air analysis. Again, it can be seen that very rapid ventilation occurs thus requiring the user to operate the openings.

Therefore, it can be said that the single-layer prototype offers adequate passive climate control performance.
4.2 Double-Layer Prototype Verification

Figs.11. and 12. show the air current analysis and age of air analysis of the double-layer prototype. Since the building has a symmetrical form, only one half of the building was simulated because the other half would merely be a mirror image. It can be seen that the four floors at the bottom of the building have a small amount of breeze coming from the outlets (approximately 0.15 m/s). However, the floors beyond the fourth floor do not benefit from the system. The same can be said for the age of air. Though not as good as the single-layer prototype, the lower floors have an age or air performance of roughly 20 minutes while the upper floors can exceed 40 minutes. Therefore, it can be said that the double-layer prototype functions only at the lower floors, thus limiting the overall height of the building block.

5. Conclusion and Discussion

So far, the authors have developed two apartment prototypes that attempt to provide natural ventilation for apartments in tropical climates. In doing so, the authors narrowed the development to consider the vernacular architecture and the more recent tube houses of Vietnam. The single-layer prototype was successful in providing natural ventilation but had its limitations regarding development density. The double-layer prototype adopted a more innovative scheme that, in theory, could allow higher development density, but operates only to a certain extent (fourth floor).

In terms of feasibility, it comes down to choosing between four-story double-layer building blocks or relatively higher (the maximum height of which should be determined through further structural analysis) single-layer building blocks. If the single-layer prototype can exceed 8 floors, no extra building blocks will be required, meaning better feasibility. However, the extra height will affect the spatial quality of the outdoor spaces, which is not to be ignored. At an urban scale, such high-rise apartments can be visually disturbing to the townscape that is dominated by 4 to 5 story tube houses. Such decisions require broad interdisciplinary debate that cannot be fully covered in this paper.

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