Emphasis on Passive Design for Tropical High-rise Housing in Vietnam

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Abstract: Passive design is a key element of sustainable building. It aims to maximize comfort for people living in a home while minimizing energy use and other impacts on the environment. This means making the most of free, natural sources of energy, such as the sun and the wind to provide heating, cooling, ventilation and lighting and to contribute to responsible energy use. During recent years, high-rise apartments quickly developed in Vietnam's urban areas. There is, however, a limitation of architectural design theory for high-rise buildings, especially those lacking passive design principles. This study focuses on the basic principles of passive design for high-rise housing in Vietnam in relation to the local climate. Firstly, the Vietnamese climatic conditions are presented. Then, the lessons learned from traditional housing design in Vietnam are mentioned. Finally, a passive design method of Vietnamese high-rise housing is introduced based on five points i.e. i) configuration and orientation; ii) façade; iii) natural ventilation; iv) daylighting; v) passive heating, cooling and thermal storage. Results of the study with potential recommendations for design principles in Vietnam are outlined.

Key words: High-rise housing, Passive design, Local climate, Vietnamese architect.

1. Introduction

Passive mode is designing for improved comfort conditions without the use of any electromechanical systems. Examples of passive mode design strategies include adopting appropriate building configurations and orientation in relation to the locality's climate and suitable façade design. Passive-mode design does not preclude using mixed-mode or productive mode devices, although, they should be the last option for creating optimal comfort levels inside the building. Passive mode requires an understanding of the climatic conditions of the locality, then designing not just to synchronize the built form's design considering the meteorological conditions, but to optimize the ambient energy of the locality into the design with improved internal comfort conditions. Furthermore, if the design optimizes its passive mode, an improved level of comfort remains during any electrical power failure [16].

Maximum utilization of natural resources such as solar energy, wind and daylight is the most efficient way of saving energy. The so-called passive design is directly generating power through utilization of climatic characteristics but not in virtue of mechanical system. Properly designed and constructed passive buildings offer many benefits: low energy bills year-round; high economic return on the incremental investment on a life cycle cost basis and greater financial independence from future rises in energy costs; greater thermal comfort, less reliance on noisy mechanical systems; reduced building maintenance costs resulting from less reliance on mechanical systems; increased daylighting or higher quality lighting systems which can increase environmental sanitation and health; reduced energy usage and reliance on fossil fuels [13]. The significance of passive design is very important for high-rise housing as it consumes more energy. This means that architects and designers should comprehend and consider the environment, geography and climate during the design procedure. Thus, the design should adapt to climatic characteristics by means of thermal insulation, natural ventilation and sunlight shading.

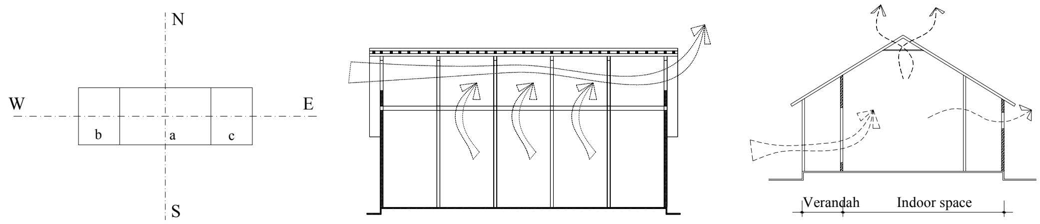
Along with the development of industry, commerce, finance and rapid increase of urban population, land resources became scarce. As a result, the main cities of Vietnam, such as Hanoi City and Ho Chi Minh City (HCMC) are in the process of transforming into the high-density, high-rise living and working environments. In this context, high-rise apartments are being quickly developed because of their gigantic economic value. During recent years, the 'international style' with fully glazed facades has become a popular trend among Vietnamese architects. Meanwhile, international design teams are almost always insensitive to local climate conditions when designing buildings in Vietnam, often resulting in unnecessary discomfort and energy waste. Natural ventilation and illumination are not considered carefully but on an average level. The core is usually closed and located in the centre. In many cases, a solid form with a huge rectangle or a square is designed. There is no suitable method to prevent the evil influence on housing from direct solar radiation [4]. Additionally, there is absolutely no high-rise building using sun energy nowadays. Although high-rise buildings can decrease the waste of land resources and return more land to nature, their negative impacts on the environment have become more and more serious due to consumption of a large amount of natural resources and energy. Passive design should become a national strategy regarding Vietnamese architecture to reduce building maintenance costs, to protect the environment and human health and to develop high-rise buildings in a sustainable way [3]. In this study the basic principles of passive design for the high-rise housing of Vietnam in relation to the local climate is investigated and the results with potential recommendations for design principles in Vietnam are outlined.

2. Local Climate of Vietnam

Vietnam is located in the tropical and temperate zone, in the centre of South East Asia between the latitudes of 23.22^0 and 8.30^0 north, lying in the eastern part of the Indochina peninsula. It is characterized by a strong monsoon influence, a considerable amount of sunny days and with a high rate of rainfall and humidity. There is a difference in climatic parameters between the north and the south of Vietnam. Hanoi experiences the typical climate of northern Vietnam, where summers are hot and humid, and winters are relatively cool and dry. The summer months receive the majority of rainfall in the year (1,682 mm rainfall per year). The winter months are relatively dry, although spring then often brings light rains. Rains become more intense with the monsoons in the winter. The minimum winter temperatures can dip as low as 6– 7^0C not including the wind chill, while summer can get as hot as 38– 40^0C. While HCMC experiences the typical climate of southern Vietnam which has a tropical climate, with an average humidity of 75%. A year is divided into two distinct seasons. The rainy season, with an average rainfall of about 1,800mm annually (150 rainy days per year), begins in May and ends in late November. The dry season lasts from December to April. The average temperature is 28 ^{0}C; the highest temperature sometimes reaches 39 ^{0}C around noon in late April, while the lowest may fall below 16^{0}C in the early mornings of late December [12]. It can be stated that cooling is the dominant demand throughout the year in both Hanoi and HCMC, but a smaller amount of heating is required in Hanoi which amounts to about 20% of the occupied period. The amount of cooling in degree hours (above 25 ^{0}C) in HCMC is almost double that of Hanoi. In both cities dehumidification is a significant demand [2].

3. Lessons from Vernacular Housing in the Traditional Vietnamese House

Generally, a locality's traditional buildings offer the best examples of appropriate passive-mode design or bioclimatic design. Learning from traditional examples, it is important to adopt a design strategy that begins with a design of the built form by optimizing all the passive-mode strategies appropriate to the climate and ecology of that locality. The basic design of the traditional house and its construction methods give it great flexibility so that extensions to the house can be carried out whenever necessary [15].



(a) (b) (c)

Figure. 1 (a) Main part of folk house typical; (b) Cross ventilation through two air-holes in lengthwise section; (c) Ventilation in the cross section

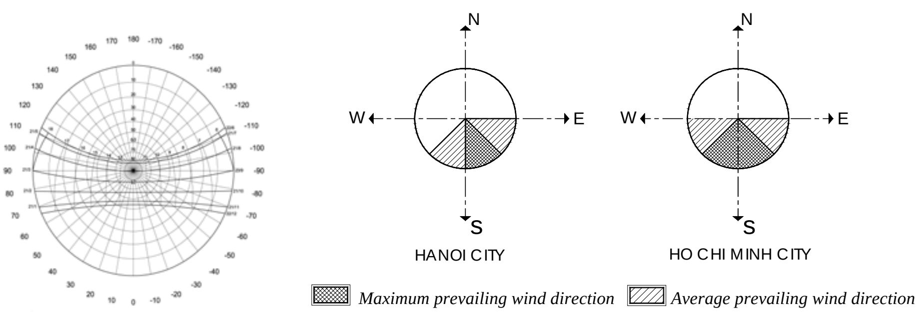
A distinctive feature of the typical Vietnamese house is that the main house's shape always is rectangular along an east-west axis to reduce solar insolation on the wider sides of the building as shown in Figure 1(a). The roof, having a big slope with gables at both ends, is covered with a lightweight and excellent thermal insulator made from thatch, which holds little heat during the day and cools down at night. The gables are covered by eaves which provide protection from driving rain while allowing ventilation as shown in Figure 1(b). The doors and windows are made by bamboo or wood, lining the main facade and providing good ventilation and views for the house. This quality of openness is also reflected by the large open interior spaces with minimal partitions. Another distinctive feature is that large and deep verandas, next to the forecourt, provide sun protection, splashing rain prevention, channels for ventilation, and buffer spaces between the outdoor and indoor environment as shown in Figure 1(c). A pond is often positioned in front of rural houses. Climbing plants covering the surface of the house are used as a living and self-generating cladding system. Fruit-trees of short or medium height are located in front of the main façade while those which are higher and have bigger canopies are planted at the rear. These features help to channel cool breezes, to avoid cold winds, to provide shading from the sun and to increase natural ventilation. The "ground" floor is often sited at a high level with insulation layers made by refined bricks. Houses on stilts are common in the highlands and mountainous areas. These features help the houses not to contact directly with the humid ground. One of the most congenial of the traditional Vietnamese house is its openness. The house is divided into areas, rather than rooms, for various social and household activities. In the typical urban architecture of ancient cities, inner courtyards provide natural light and combine with corridor systems to promote natural ventilation. From a distance, the traditional Vietnamese house seems to merge naturally with the environment.

4. Basic Principles of Passive Design for High-rise Housing in Vietnam

Based on an understanding about typical climatic conditions and learning from traditional housing construction, together with studying about the theory and the practice of passive method in the world, the basic principles of passive design for tropical high-rise housing in Vietnam is outlined in 5 points as follows.

4.1 Built-form Orientation and Configuration

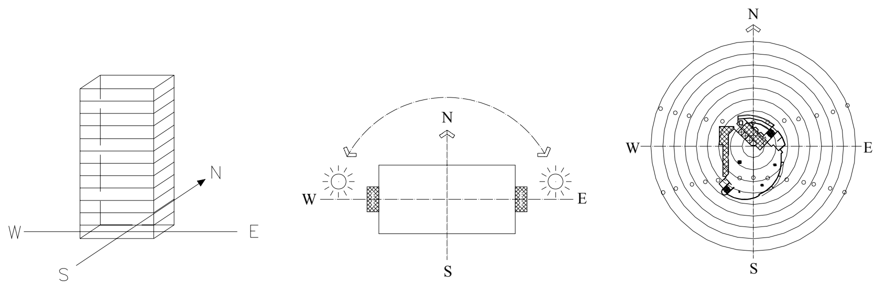
Built-form orientation is a significant design consideration, mainly with regard to solar radiation and wind. High-rise houses are more exposed than lower-rise houses to the full impacts of external temperatures, wind and sunlight and therefore their built form configuration, orientation, floor-plate shape and use of buffer components can have particularly important effects on energy-conservation design and natural lighting of the interior spaces. The sun light route way, in Figure 2(a), decides the main orientation of high-rise housing that ensures the utilization of natural sunlight resources to process daylight, passive solar energy heating and solar electric power generation. The local wind direction as shown in Figure 2(b) and air flow distribution are also prerequisites for composition that avoid intercepting cold and moist air during the cold season and encouraging coolness during the hot season. According to Xu et. al.'s approach, the most suitable orientation and composition that utilizes the potential of the natural climate in the site can be ensured through a careful study on basic micro climatic conditions.



(a) (b)

Figure. 2 (a) Sun path in HCMC [3]; (b) Direction of the prevailing wind in Vietnam

Making the built form in the configuration appropriate to the sun path for that latitude can reduce energy consumption by as much as 30% to 40% at no extra cost. The classic design approach to orienting a building on its site is to locate the long side on a true east-west axis to minimize solar load on east and west surfaces, particularly during the hot season. Windows on the east and west surfaces are typically minimized to eliminate as much as possible the potential of high morning and afternoon solar loads. South-facing walls will experience a variable sun load during the day and windows are easily protected from solar loads through the use of roof overhangs, shading devices, or recessing the windows [1]. It is generally held that the built form should have 1:2 to 1:3 length ratios for climatic zones like in Vietnam. A tropical high-rise house in Vietnam, if arranged longitudinally from north to south as shown in Figure 3(a), has to be ar an air-conditioning load that in un-optimized conditions (i.e. without special façade treatment for the external walls) is 1.5 times that of a building arranged longitudinally from east to west. To arrange according to priority, the orientations ensuring natural ventilation for housing in Vietnam are south, east-south, east, west-south, west, west-north, north, and east-north [3]. Good orientation increases the energy efficiency of a home, making it more comfortable to live in and cheaper to run.



(a) (b) (c)

Figure. 3 (a) Fitting orientation of the urban high-rise housing in Vietnam; (b) Service cores on the hot sides of built form; (c) Sun path and HCMC tower designed by Ken Yeang [17]

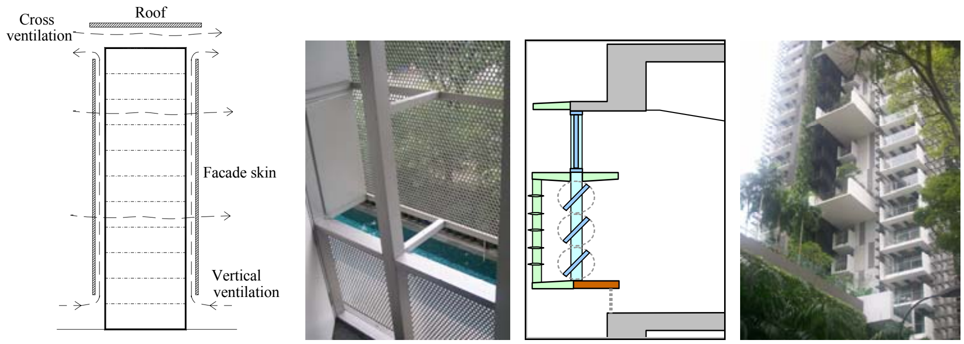
Internal layouts should be adapted to climate and building orientation so that rooms or spaces with specific functions are located adjacent to the most appropriate facades [13]. The rooms, which are located adjacent to direct nature, are according to priority the bedroom, family room, living room, kitchen, toilet and dinning room. Similarly, the orientations for open space in apartments are south, east-south, east, west-south, west, west-north, north and east-north [3]. The service cores can be positioned on the 'hot' east or west sides of the building, or both as shown in Figure 3(b), to serve as solar buffers in the tropical zone. The double-core configuration is clearly the type providing a minimum air-conditioning load, in which the opening is from north to south and the core runs from east to west. Conversely, the core type characterized by maximum air-conditioning load is the central core configuration, in which the main daylighting opening lies in the southeast and northwest directions. A good example is HCMC tower design by Ken Yeang as shown in Figure 3(c). In this high-rise building, the west façade is shaded by long sky-terraces and the core is located in the west-north side.

4.2 Building Envelope

A well-designed building envelope will yield significant energy savings. The building envelope must control solar heat gain, conduction or direct heat transmission, and infiltration or leakage heat transmission [1]. Compared with ordinary buildings, the building envelope of high-rise buildings has its special characteristics. The important guidelines for building envelope design in Vietnam are recommened as follows:

- Wind speed and wind pressure grows quickly with the escalation of height that leads to quick heat exchange between building envelope and outside. This situation is not of benefit to energy conservation. Furthermore, a high-rise house receives more sunshine than a low-rise house (including direct radiation, diffused radiation and radiation reflected from roof of the nearby multistory buildings). Thus, materials with high thermal mass and enough thickness should be chosen for the building envelope of high-rise housing to reduce and delay the impact on internal space cause by external wall temperature fluctuation [13].
- The ideal external wall should act as an environmentally responsive filter as shown in Figures 4(a) and 4(b). The envelope should have adjustable openings that operate as sieve-like filters with variable parts to provide natural ventilation, control cross-ventilation, provide views to the outside, give solar protection, regulate wind-swept rain and discharge heavy rain, provide insulation during cold season, meet demands of hot season, and promote a more direct relationship with the angle for both summer sun penetration and winter sun penetration, as these differ. The permeability of the skin of the building to light, heat and air and its visual transparency must be controllable and capable of modification as

shown in Figure 4(c), so that the building can react to changing local climatic conditions. These variables include solar screening, glare protection, temporary thermal protection and adjustable natural ventilation options [15].



(a) (b) (c) (d)

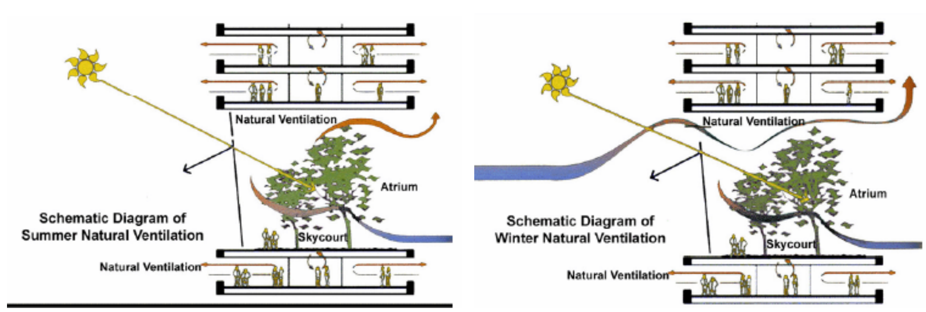
Figure. 4 (a) Vertical and cross ventilation model for the building envelope; (b) Horiziontal ventilation and vertical sun-screening on the South facade of the Moulmein Rise, Singapore; (c) Controllable window [5]; (d) Protruding balconies in the Newton Suites, Singapore.

- A useful device is the use of recessed terraces or 'sky-courts' to serve as interstitial zones between the inside areas and the outside areas. Besides providing shading to that portion of the building, sky-courts can also serve the following multiple functions: as emergency evacuation (example in the event of future increase in permissible plot ratio); or as areas for the future spatial addition of executive washroom, kitchenettes, etc. They also furnish the built form's users with a more humane environment as an optional open-to-the-sky zone for them to step out from the internally enclosed floor areas, to enable them to experience the external environment directly and to enjoy views as shown in Figure 4(d).
- The green approach runs contrary to those façade designs that rely on hermetically sealed skins. The 'green' façade can reduce solar heat gain to the space through external shading devices, provide fresh air ventilation, serve as an acoustic barrier, give maintenance access and make a contribution to the building's aesthetics.
- The designed system's green roof should be considered as the building's fifth façade [15]. The roof of a high-rise built form is less important thermally compared to that of the lower rise building type because of its small surface area compared to the extensive external wall area. The direction of solar-heat absorption of the roof on the topmost floors needs to be considered. In Vietnam, roofs should be constructed of low thermal capacity materials with reflective outside surfaces where there is no shade. The roof should preferably be of double construction and provided with a reflective upper surface. Roof and terrace areas might also be vegetated.
- The external façade should be as light colored as possible to reduce the heat effect and to lighten overall air-conditioning loads. For Vietnamese housing, there is a necessity to prevent direct radiation mainly from the north-west, west and south-west [3].

4.3 Natural Ventilation

Natural ventilation includes a number of ways in which external air and wind can be used to benefit the occupants of buildings. Natural ventilation may be used for increasing comfort (air movement), for health (air change) or for building cooling (wind speed). It addresses two basic needs in buildings: the removal of foul air and moisture and the enhancement of personal thermal comfort. Reasonable organization of natural ventilation leads to energy saving and cost cutting. The energy consumption of the natural ventilation is only half of using air-conditioning. Meanwhile, it decreases dependency of those equipment which use by mechanical ventilation and air-conditioning to ensure a healthy building environment. Furthermore, it reduces the emission of carbon dioxide. High-rise housing has a much longer vertical distance and much bigger volume than that of the ordinary buildings. Thus the organization of natural ventilation in high-rise housing is more difficult [13]. Some guidelines for natural ventilation in Vietnam are presented as follows:

- Conventional types of natural ventilation include wind pressure ventilation and thermal pressure ventilation. But simply using these two types in high-rise housing are not suitable because of the instability of natural wind and heat loss in the upper air. Mixed ventilation combined with an atrium are better ways to establish ventilation strategies in different seasons and use mechanical ventilation under extreme climatic conditions. Figure 5 presents natural ventilation strategies with an atrium in different seasons used in Commerz Bank Headquarters, Frankfurt, Germany that was designed by Norman Foster [13].



(a) (b)

Figure. 5 Natural ventilation strategies in summer (a) and winter (b) in Commerz Bank Headquarters [13]

- For the façade of high- rise housing, wind performance grows exponentially as it moves upwards. Therefore, if natural ventilation is used in the building, then a series of modified venting devices for different height zones is needed. The external façade can consist of a series of systems (e.g. double façade-skin, flue-wall, etc.) depending on the desired thermal effect and venting system. A ‘fly roof’ can be used to shade the entire topmost floors. It protects the core building from radiant heat and allows cooling breezes to flow beneath it. A vertical and cross ventilation model for façade skin and the roof are presented in Figure 4(a).
- A building can be divided into thermal zones with buffer areas such as balconies, verandas, atria, courtyards and arcades, though divisions should avoid providing barriers to cross-flow ventilation if this is required. Enclosed courtyards or atria can save energy by functioning as spaces that bring fresh air into the building and provide natural ‘pre-heat’. Large balconies can have full-height adjustable sliding doors to serve as operable vents in cases where such natural ventilation is needed.
- In hot and humid climate such as Vietnam, natural ventilation is expected in almost every room. Cross ventilation through rooms is increased by large openings on both the windward and leeward sides. The rate, at which airflows through a room, carrying away heat with it, is a function of the area of the inlets

and outlets, the wind speed and the direction of the wind relative to the openings. The amount of heat removed by a given rate of airflow depends on the temperature difference between the inside and outside the building.

- Natural ventilation is generally suitable not only for selective areas such as the lift lobbies, staircase and toilets, which can have openable windows or air gaps to the exterior, but these should also be ventilated by a calculated percentage of air loss that is permitted to seep in from the air-conditioned spaces.
- The local wind direction is shown in Figure 2. For better natural ventilation, depth should be less than 17 metres for Vietnamese high-rise housing without a courtyard [3]. The horizontal ventilation following traditional monsoon window as shown in Figure 4(b) should be encouraged.

4.4 Day lighting

Daylighting provides more desirable and better quality illumination than artificial light sources. This reduces the need for electrical light sources, thus cutting down on electricity use and its associated costs and pollution. Because of the characteristics of height, high-rise housing prefers to use side lighting rather than to use toplighting. So, it is important to avoid direct sunlight and control thermal gain near the window [13]. Some usable principles are list as follows:

- Establish the location, shape, and orientation of the building on the site based on daylighting performance objectives.
- Almost all rooms, including kitchen and toilet, need to receive daylighting due to environmental and health requirements in the hot and humid climate of Vietnam. Window squares should be from 15% to 25% in comparison with the room's floor square [3].
- Avoid excessive thermal gains and excessive brightness resulting from direct sunlight, which can impair vision and cause discomfort. Use indirect lighting through reflecting ceiling and equip with traditional elements such as shades, screens, and light shelves.
- Transitional daylight designs can provide adequate daylight within about 4.6m of conventional height windows [15]. For the large plane, the inner courtyard must designed to improve daylighting.
- Integrate daylighting systems with the artificial lighting system to maintain required task to ambient illumination while maximizing the amount of lighting energy saved.

4.5 Passive Heating, Cooling and Thermal Storage

Integration of passive heating, cooling and thermal storage features into high-rise housing can yield considerable energy benefits and added occupant comfort. Incorporation of these items into high-rise housing design can lead to substantial reduction in the load requirements for building heating and cooling mechanical systems [13]. For Vietnamese climatic conditions, cooling is the prerequisite in the whole country.

- Passive cooling strategies include cooling load avoidance, shading, natural ventilation, radiative cooling, evaporative cooling, dehumidification, and ground coupling. Passive design strategies can minimize the need for cooling through proper selection of glazing, window placement, shading techniques [13]. Some cooling strategies are listed as follows: control external gains in the hot time by screening (such as movable shutters, canopies and blinds) where necessary and using pale-colored wall and roof; use energy efficient appliances to minimize internal gains; ensure there is adequate cross-ventilation to the apartment, and that sunspaces can be vented outside; using balcony screens which are perforated facilitate the flow of ventilation air to the terrace and interior of the apartment; using enclosed courtyard or atrium to support passive stack ventilation; provide adequate cut-off between sunspace and body of the dwelling; use vegetation, and water for positive cooling.

- Passive solar heating is about keeping the summer sun out and letting the winter sun in. It is the least expensive way to heat the house. Passive solar heating requires careful application of the following passive design principles: northerly orientation of daytime living areas; appropriate areas of glass on northern facades; passive shading of glass; thermal mass for storing heat; insulation and draught sealing; floor plan zoning based on heating needs; advanced glazing solutions. This will maximize winter heat gain, minimize winter heat loss and concentrate heating where it is most needed. Passive heating works particularly well in climates where many sunny days occur during the cold season. Attention should be paid to match the time when the sun can provide daylighting and heat to a building when the building needs heat.
- Thermal mass storage can handle excess warmth; so as to reduce the cooling load, while storing heat that can be slowly released back to the building when needed. The thermal mass can also be cooled during the evening hours by venting the building, reducing the need for cooling in the morning.

5. Conclusion

The design, construction and operation management of high-rise buildings have a huge impact on the environment and its resources. Passive architectural design can have a huge impact on land resources saving, material saving and energy saving. As a key element of sustainable building, the passive design of high-rise housing is significant. Nevertheless, high rise housing where passive methods are applied is rare in Vietnam. It is due to: the lack of understanding of what passive design can do in Vietnam; the lack of passive design research and available community resources or service weather conditions; the lack of any strategy of specific and innovative passive design. The design of high-rise housing in Vietnam should be emphasized according to the economic conditions, climatic characteristics and cultural traditions. Five points must be considered during the design process: i) configuration and orientation; ii) building envelope; iii) natural ventilation; iv) day lighting; v) passive heating, cooling and thermal storage. We should ascertain corresponding design objects and design principles and adjust and apply them to the design practice. This will ensure that high-rise housing in Vietnam integrates organically with the civil environment and develops toward ecological and sustainable building design practices. Passive design should become a national strategy regarding Vietnamese architecture in order to reduce building maintenance costs, to protect the environment and human health and to develop high-rise buildings in a sustainable way.

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