Applying Environmentally Responsive Characteristics of Vernacular Architecture to Sustainable Housing in Vietnam

Phuong Ly[1], Janis Birkeland[1], Nur Demirbilek[1]
[1]*Queensland University of Technology, Brisbane, Australia*

Abstract

Over many centuries of settlement, Vietnamese inhabitants have developed a vernacular architecture that is well adapted to the region's climatic and topographical conditions. Vernacular Vietnamese housing uses natural systems to create a built environment that integrates well with nature. The vernacular combines site-sensitive, passive solar design, natural materials and appropriate structure to achieve harmony among nature, humans and the built environment. Unfortunately, these unique features have not been applied in contemporary Vietnamese architecture, which displays energy-intensive materials and built forms. This research is analysing how environmentally-responsive elements of vernacular architecture could be applied to modern sustainable housing in Vietnam. Elements of many types of vernacular architecture throughout the country are reviewed as precedents for future building planning and design. The paper also looks at culturally and ecologically appropriate legislative and voluntary options for encouraging more sustainable housing.

Keywords: *vernacular architecture, environmentally responsive design, sustainable housing.*

1 Introduction

Vietnamese originally inhabited the basin of the Hong River Delta – Northern Vietnam, then moved south, taking cultural aspects of their housing construction to the new southern settlements. Archaeological evidence shows that primitive vernacular houses were constructed in the area with climatically appropriate built forms, materials, and spatial functions (Tran, 1999). Unlike the nomads in northern savannahs, the Vietnamese settled down and cultivated the land. Housing typologies evolved in the South to adapt to harsher tropical conditions like typhoons, humidity and flooding through trial and error.

Vietnamese vernacular architecture evinces both socio-cultural and environmentally responsive design. From a cultural perspective, Vietnamese homes are where family members foster spiritual values, teach moral lessons and care for each other. Home owners, usually local peasants, took climatic patterns and regional conditions into account when constructing their buildings. The site planning, house layouts, and external gardens and landscapes work together to create a sense of place and community. Passive solar design significantly reduces indoor air temperature, induces natural ventilation, and protects the house from direct sunshine and rain. Locally available materials create robust structures that can stand up to natural disasters such as windstorms, typhoons and floods.

Applying Vietnamese vernacular housing principles to contemporary design could enable local inhabitants to preserve the regional traditions and socio-cultural values as well as to reduce negative impacts. Vernacular housing does not require resource-intensive methods and technologies in construction, operation, or maintenance. Indeed, the vernacular has, for thousands of years, been shaped by the natural context as well as regional ordinances and cultural norms. Therefore it can provide an effective model system for modern Vietnamese architecture.

2 Climate and Topography

Vietnam is a long S-shaped country stretching from 8°30' to 23°22' North with two primary climatic regions: Northern climatic region and Sorthern climatic region with the border on the latitude of 16 degrees north, which is located on the Hai Van Pass, Thua Thien Hue Province (Vietnam Ministry of Construction, 1985) (Fig.1). The regional temperature varies with the change of latitudes along the stretch of the country. Northern Vietnam has a humid and subtropical climate, while the South enjoys a tropical climate all year round with the two seasons, dry and wet. The whole country is influenced by seasonal monsoons which bring heavy rainfall to all regions. From November to April, the Northern region is affected by north-eastern monsoons which are cold and dry, while from May to October, highly humid monsoons come from south-west direction influence the South of Vietnam.

The temperatures of the country range from 12 to 34 degrees Celsius and the mean temperature is always higher than 21 degrees Celsius. The North has a cold winter where the temperature sometimes drops down to 6 degrees Celsius, while the temperature in the South remains stable between 21 to 34 degrees Celsius. The period of sunshine in the country annually is between 1400 and 2800 hours. Relative humidity is rather high in all regions, and usually over 77 percent. Rainfall is torrential with annual precipitation exceeding 1000 mm almost everywhere. Therefore, regional flora and rainforests are diverse, and have provided many types of timber for building construction. Heavy rainfall usually combines with windstorms, causing floods in many areas of Vietnam.

Mountainous areas occupy three fourth of the country while the remaining are low-lying coastal plains and deltas. Some higher points of the north-west mountainous regions and the central highland have lower temperatures than other parts due to their higher altitude. The slope of the topography gradually decreases from west or north-west to east or south-east. Dwelling areas and vast rice farms are located on the eastern and south-eastern coastal plains and deltas. The Hong River Delta in the North and the Mekong River Delta in the South are the two main 'granaries' supplying rice and agricultural products for domestic and export purposes.

Vietnamese inhabitants constructed adaptable houses that took these climatic and topographic conditions into account. The typical characteristics of Vietnamese housing, especially climatic features, can be identified in terms of site layout, passive design, material and structure.

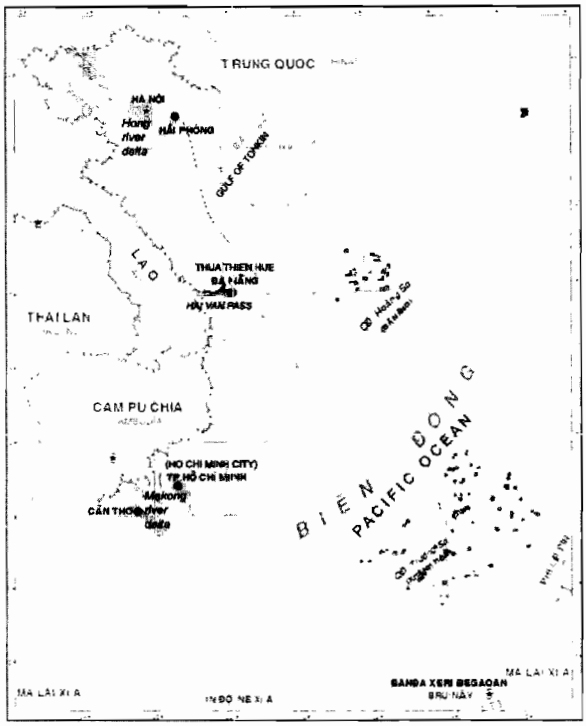


Figure 1. Map of Vietnam. Image edited from Vietnamese Government Website (http://www.chinhphu.vn).

3 Vietnamese Vernacular Housing And Its Typical Characteristics

Vietnamese vernacular architecture has evolved over thousands of years in South-east Asia and has adapted to its regional climate. Images of primitive vernacular houses were reflected on decorative motifs on the tympanums of ancient Dong Son bronze drums (including Ngoc Lu I bronze drum) (Fig.2), which are considered the physical evidence of Dong Son Culture, flourishing in the heartland of the Hong River Delta of Northern Vietnam from 2000 to 3000 years ago. The motifs show that the vernacular houses are an on-stilt structure, which has a saddle roof with two deep gables on two opposite elevation sides (Fig.2). This kind of housing is climatically-appropriate because of its heat-resistant tall roof, elevated floor, shaded overhang and lightweight materials for preventing solar access, increasing natural ventilation, and reducing humidity.

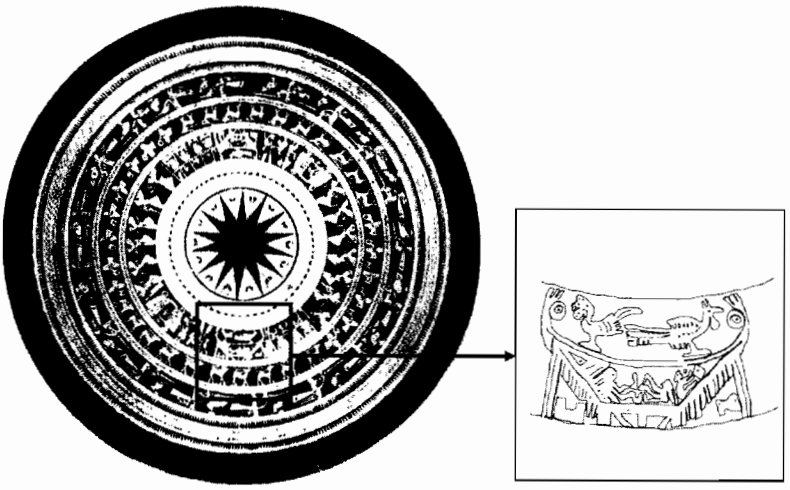


Figure 2. A climatically-appropriate house redrawn from the decorative patterns on the tympanum of Ngoc Lu I, one of the most known Dong Son bronze drums discovered in the Hong River Delta, Northern Vietnam. Photo of the Ngoc Lu I tympanum from Nguyen and Hoang (1975).

Vietnamese vernacular housing has evolved through trial and error to changing conditions of settlement, climate, ecology and culture over time. For example, houses with straight simpler roofs have been preferred over the previous saddle ones to enable quicker construction with limited local materials and skills. Likewise, the on-pile form of houses in the mountains was transformed into ground-lying structures on the plains (Nguyen et al., 2007). As a result, the vernacular was an improved structure to optimise regional climates and to provide comfort for occupants. In Northern Vietnam, the traditional home became a self-contained economic unit within its village that reflects cultural values. In fact, using natural means in construction to provide health and well-being for house owners is the most important function that the Vietnamese vernacular achieved.

Vietnamese traditional housing has adopted principles for designing building in the hot and humid tropics which, according to Lauber et al. (2005), induce maximum natural ventilation and prevent intensive solar heat loads in building living areas. In this paper, typical vernacular houses throughout the country are selected to exemplify their environmentally responsive characteristics. The characteristics are identified in houses located in both rural and urban Vietnamese regions. The houses all use numerous natural means of climatic control. However, common features are the strategies of organising the site, integrating passive solar design, using locally available materials and using appropriate structure.

3.1 Site planning

Depending on available land, rural houses optimize all parts of the site while urban houses, which are usually built on small and constrained plots, integrate with nature through site layout. Vernacular housing in Northern Vietnam is typical of Vietnamese rural houses, which were transferred to other southern areas of the country over the centuries. The rural houses are usually sited on a sufficient large plot that the appropriate orientation - the south in Vietnam - can be selected. Integral exterior design elements such as courtyard, ponds, and vegetation are integrated with the house. In urban houses located on a limited area plot, internal solar courtyards are oriented to induce breezes and to provide natural lighting. Both the rural and urban vernacular designs are adapted to each specific context to facilitate amenity and well-being for occupants.

The rural houses in Northern Vietnam incorporate many common elements such as main housing blocks with auxiliary blocks, sheds for poultry and animals, ponds, a courtyard, an open-air worship place, and vegetation (Fig.3). The compound is well organised so that energy from the sun and wind are optimised to control the house's climate. For instance, the main blocks of housing are usually designed with their long main façade facing south and linked with auxiliary blocks to form a courtyard in the middle. As the heart of the compound, the courtyard induces air flow to living spaces and captures sunlight for drying rice, cereals and clothes. The water ponds are located adjacent to the main blocks to provide cool air for the whole site during hot summers, and treat wastewater with aquatic plants. Fish, poultry, animals and vegetables provide on-site food. Indoor and outdoor places for worshiping the God of land, Buddha, or owner's ancestors reinforce the spiritual values of the occupants.

Water for household use is derived from different sources and treated by traditional methods. Water from ground-wells, rivers or lakes can be stored in containers for depositing and then filtered by tanks that contain layers of charcoal, sand, and grave. Most vernacular Vietnamese houses use rainwater harvesting system to provide water for cooking and drinking. Rainwater is also treated in the same method. After being filtered, water is boiled or baked under sunlight to eliminate bacteria.

In ancient urban areas such as Hoi An - the World Heritage Site in Central Vietnam - most vernaculars have a form of townhouses which have a unique to response to the environment. Located on a small rectangular plot, which is quite narrow on one side and very long on the other, the townhouses serve a dual function of both a shop and a shelter comprised of two or three main timber blocks, single- or two- storey, and solar courtyards between the blocks. Due to facing a street for trading, the selection of the optimal orientation for Hoi An houses is less important, but inside courtyards enable ventilation, lighting and air flows from the interiors to courtyards and vice versa via timber balusters and opening vents. With this type of architectural layout, the urban townhouses are cool and comfortable for residents.

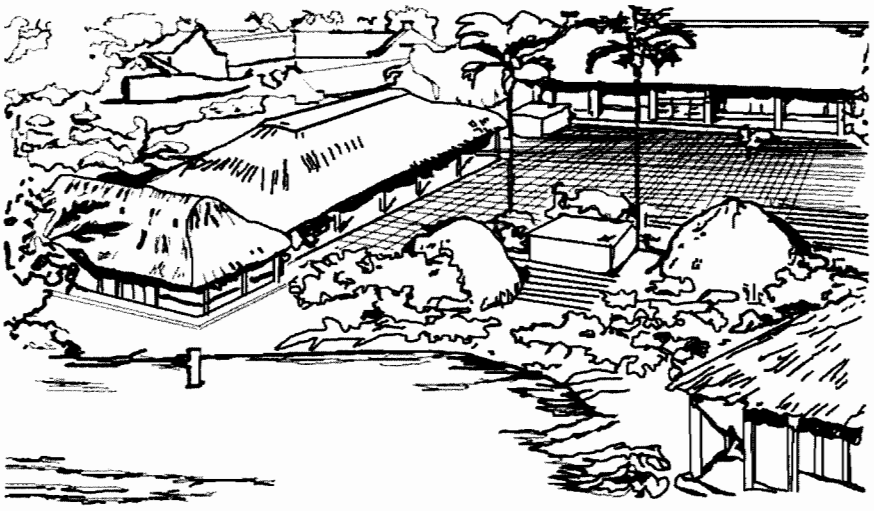


Figure 3. An example of a vernacular compound in Northern Vietnam. Image redrawn from Nguyen and Nguyen (1995).

3.2 Passive design solutions

While appropriate orientation and integrated layout are the two most distinctive organisational features when planning a traditional housing site, passive designs show skill in creating climate responsive housing. The house designs reduce the impacts of solar radiation, wind and rain on their living spaces. Typical solutions in the Vietnamese vernacular include solar courtyard, mediating space, envelope shading device, air vent, and surrounding greenery. Some archetypical passive means can be found in the housing model of Northern Vietnam (Fig.4).

The solar courtyard plays an important role in capturing sufficient natural lighting and cool breezes into rooms. The courtyard is necessary in a rural house. In fact, it is more indispensable in the urban house, which is usually located on a confined plot with surrounded boundary (Fig.5 & 6). As a leeward element, an internal courtyard orients natural air movement into the interiors from all wind directions, and thus cools the house. In rural regions, occupants are able to use the solar access from the courtyard to dry their cultivated rice and cereals. The courtyard provides a place of working and entertaining, and a sense of family identity. It is also a place where ritual activities are conducted.

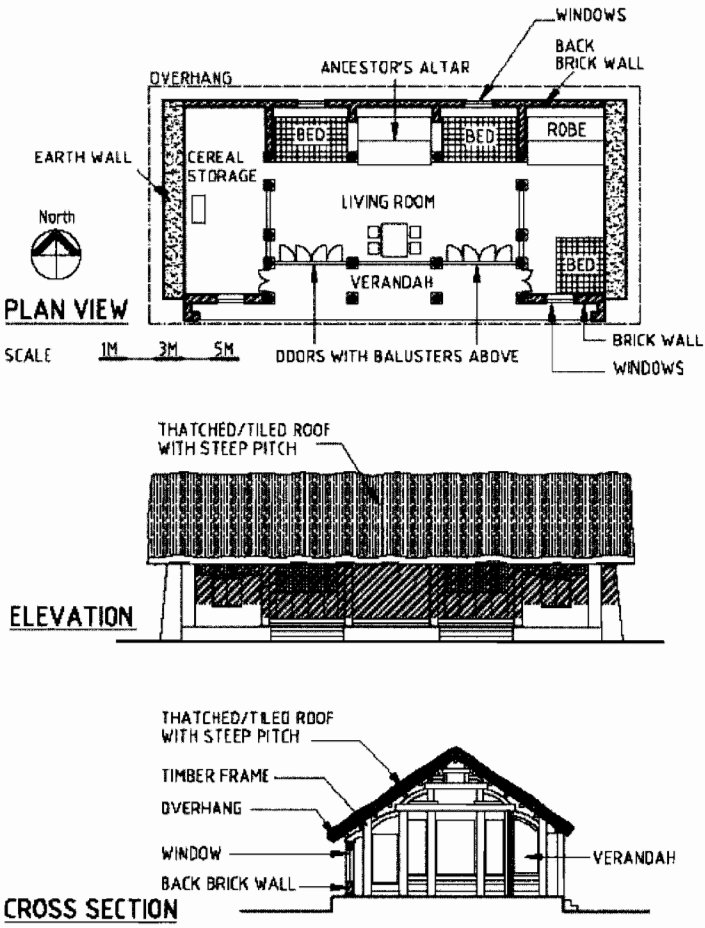


Figure 4. Climate responsive means of a typical vernacular house in Northern Vietnam: verandah, shading overhang, openings and air vents, and appropriate material use of the envelope. Image redrawn from Nguyen and Nguyen (1995).

Most, if not all, Vietnamese traditional houses have mediating spaces such as verandah, porch, balcony, or loggia. These play an important role as a buffer against direct sunshine and rain and connect the house with the surrounding nature. The air under these spaces circulates naturally, providing thermal comfort for occupants. Occupants spend a lot of time in these spaces during the day because they can enjoy cool breezes and daylight, and feel a sense of community. When staying in a verandah or a porch, the view to streetscape is more open than when sitting inside the house. Therefore, the mediating spaces are built with enough space as well as shade for family activities.

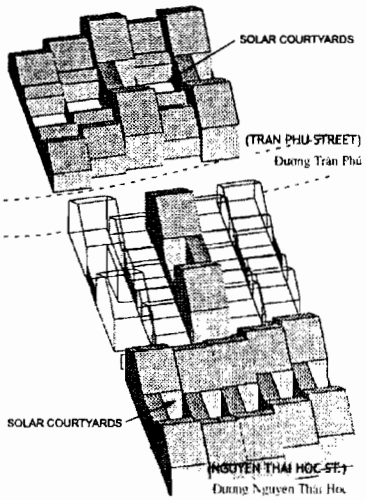


Figure 5. Layout of Hoi An urban townhouses with the use of courtyards to provide a moderate microclimate. Image edited from Institute of International Culture - Showa Women's University (2003, p.40).

Figure 6. A solar courtyard of a townhouse in Hoi An ancient town, Central Vietnam.

Archetypical shading elements of the Vietnamese house include deep eaves, solar canopies and vertical screens. In the tropical climate, they avoid direct sunlight and rain on walls and external openings of the house. Selecting appropriate shading devices for the house is based on the orientation of housing facades. In Vietnam, the sun is in the south, thus north facades are shady all year round. Therefore, only canopies or verandahs on south elevation are needed to provide shade and air circulation. However, surrounding overhangs are used to protect the house from both sunlight and rain. The south elevation is thus important and become the front of most houses. Thick brick or earth walls with limited openings are used on the eastern and western elevations to avoid heat gain. As a result, even without the assistance of mechanical systems, indoor air temperature is remarkably comfortable.

Openings and air vents are used to make rooms airy. In the climate of Vietnam, the wider the openings are, the more natural ventilation is provided for the house. Natural ventilation replaces polluted and hot indoor air with a fresh and cool breeze. In some areas, ceiling fans in the house are combined with the natural ventilation strategy to provide more comfort. To increase the ventilation effect, openings and air vents are built on the external walls, on internal partitions, and on the front doors of the house with a form of top balusters (Fig.7 & 8).

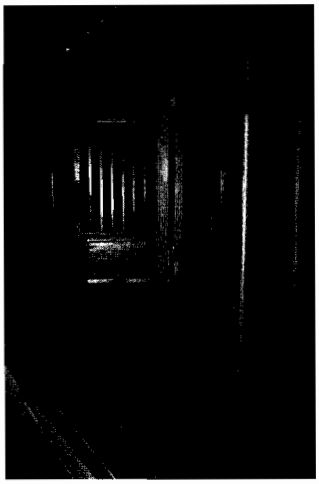


Figure 7. Balusters on doors as air vents for providing ventilation.

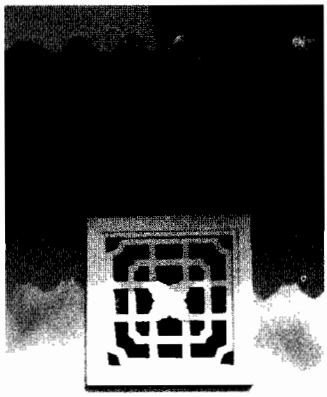


Figure 8. Popular air vents used in vernacular Vietnamese housing.

Last but not least, green spaces are integrated with the Vietnamese house in fruity, herbal, and decorative gardens. They provide landscape, shade, air filtering, food and a reduction of the ambient temperature. On the front of the house, tall slender-trunk palms and herbal shrubs are planted to allow prevailing cool breezes into the house while lush vegetation used at the rear. In Northern Vietnam, rear gardens protect the house against northern cold strong winds in the winter. Gardens also incorporate with solar ponds to regulate the microclimate. Pergolas, trellises, and hanging flower pots contribute to the pleasant living environment.

3.3 Materials

With skills and experiences handed down over many generations, local craftsmen and masons have obtained practical knowledge of material use. They use timber logged from local woods for housing frames. Non-wood plants such as bamboo and rattan are used in construction in various areas as they are cost efficient and locally available. Combined with bamboo frames, rural housing uses inexpensiveness and environmental friendly thatch from rice stems or nipa palms for roofing and walling. Additionally, materials from clay and earth such as fired-clay bricks and tiles are used to build floors, walls, and roofs. Local availability of these materials and simple hand-manufacturing techniques have meant these products have been refined over the centuries.

Timber is popular in most types of Vietnamese vernacular architecture. It is selected for their durability in moist conditions and termite resistance. Timbers from *gỗ mít* (jackfruit-wood), *kiền kiền* (peck-wood), and *gỗ lim* (iron-wood) are chosen in construction according to the value of the house. Timber is used to

make trusses, frames, columns, girders, and beams in both rural and urban traditional houses which have a life span of several centuries.

Low-cost vernacular houses use bamboo and rattan for roofing and framing because of their rapid growth and their ready availability (Fig.9). They are treated using traditional means before use to reinforce their resistance to termites and decay. A thatched roof and wall are combined with a bamboo frame to provide a cool interior atmosphere because these materials have a low-heat transmission and high insulation properties. Bamboo fibres can be woven to make walls, shading overhangs, and solar screens of the house.

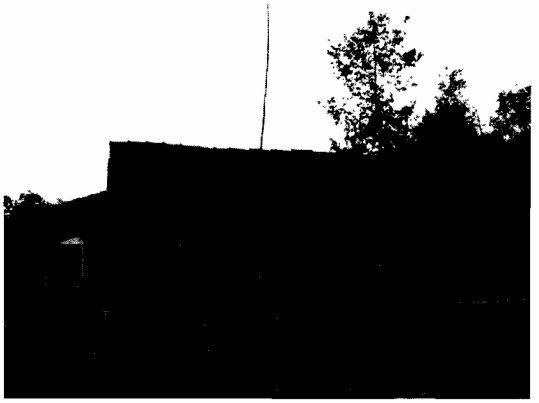


Figure 9. A vernacular house with a thatched roof and wall on a bamboo frame in Tra Vinh Town, Southern Vietnam.

Earth and clay products in forms of compressed earth brick, fired brick, fired tile for roofing and flooring are traditionally used in Vietnam. Earth or brick-work can be walled, based on the orientation of the house to reduce cold wind impacts and provide more privacy. Before the import of cement technology, brick mortar was a mixture of local materials like lime, sand and cane molasses. This traditional mortar has been researched and applied in the conservation and restoration of ancient royal buildings in Hue heritage city, Central Vietnam (Vietnam News Agency on website of the Ministry of Construction, 2009). Roof and floor tiles are commonly selected for housing because of their durability and aesthetic value. Double roof and yin-yang roof of the vernacular are insulated enough to cool the interior without a ceiling system (Fig.10). In fact, most vernacular houses do not have a ceiling because it can prevent air circulation in the roof space. Moreover, the owners can use this space for storing food during floods. Earth and clay products can be mixed with rice husks or straw to make the mixture support more loads.

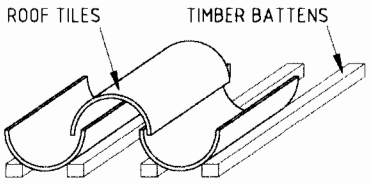


Figure 10. Construction detail of a yin-yang roof. Deep furrows of the roof provide shade and channel rainwater runoff.

The double roof and yin-yang roof are commonly used in Central Vietnam because they can efficiently avoid heat. To provide a cool microclimate, the double roof is comprised of a top thatched roof and a tile layer over a bamboo woven base or timber battens. Air can move into the gap between these layers to ventilate the roof space (Nguyen and Nguyen, 1995). The yin-yang roof is another type of climatic roof, which can shade itself from eastern and western sunshine thanks to its wavy configuration.

3.4 Housing structure

The structure of the vernacular house is made of a timber skeleton and components such as girders and beams, melded together by ties, mortises and joints without modern technical nails and bolts. Traditionally, a main or an auxiliary timber housing block has an odd number of tiered divisions (such as three, five, or seven) with or without two additional wings. Houses with the odd tiered divisions can dedicate the middle compartment to worshiping Buddha and the owners' ancestors. In a cross section, timber trusses, formed by an arrangement of girders and columns, support a pitched tiled or thatched roof. Diverse types of timber trusses have been used in Vietnamese vernacular housing over time according to regional conditions (Fig.11).

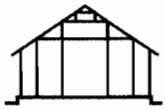
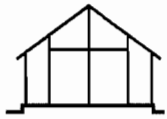
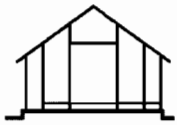
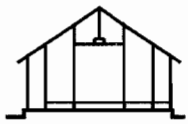
Name of the truss	Diagram	Applied regions
Kèo suốt giá chiêng (Truss with continued multi-layer beams)		Northern Vietnam
Kèo chữ thập (Cross-shaped truss)		Typhoon-prone areas of Central Vietnam due to its wind resistance
Kèo trính (Bridging beam truss)		Flood-prone zones of Central Vietnam due to providing provisional attic for storage
Kèo trính có trụ đội (Bridging beam truss with a prop)		Typhoon and flood prone regions of Central Vietnam

Figure 11. Some examples of timber truss archetypes used in various regions of Vietnam (Thai, 2005).

4 Applying Traditional Characteristics of Vietnamese Vernacular Housing into Contemporary Buildings

Contemporary housing in Vietnam shows environmentally problematic issues which reduce residents' and ecosystems' health and consume more energy and resources. Urban and rural planning regulations have resulted in very dense development patterns to accommodate an increasing population. These regulations do not encourage housing configurations that can take advantage of prevailing winds. Most modern Vietnam housing does not have enough voids for natural air flows, and road direction and vegetation limit the ventilation or shading of buildings.

Vietnamese vernacular architecture is a source of precedents for modern architectural design in terms of its environmental harmony and resource efficiency. Learning from the vernacular does not mean simply copying traditional forms, massing, details or materials. However, by analysing vernacular designs, general lessons or principles can be drawn and applied to future designs (Rapoport, 2006). Legislative and voluntary options can encourage an integration of available resources on site, apply passive design solutions, use local and environmental-friendly materials, and select appropriate structure for the house. Climate responsive strategies applied to contemporary architecture can enhance living conditions and a sense of place and community while protecting ecosystem and the broader life support system.

This research develops guidelines for climatic housing in Vietnam that allows for design creativity and variety. These guidelines consider site analysis and organisation, passive design, material use, and housing structure that can create the sustainable environment for Vietnam.

4.1 Site analysis and organisation

A thorough analysis of the site can better utilise on-site resources and avoid compromising ecosystems and cultural values. Contemporary houses, if having a well-integrated site based on vernacular design, can provide comfort and well-being to occupants with limited energy and resources. The following strategies should be considered:

- **Understand the site contexts and conditions** - including the ecosystems and surrounding habitats, climatic patterns, topography and cultural influences.

- **Protect and improve surrounding natural water systems** which regulate the microclimate and to facilitate rain water runoff.

- **Prioritise south facing buildings** which can capture cool breezes in summer and solar heat in winter (for housing in Northern Vietnam with a cold winter).

- **Select local vegetation** to protect the house from solar access and to channel the air into the building. Shrubs and slender-trunk palms are traditionally planted at the front, and lush and fruit trees are selected at rear for wind control.

- **Integrate the house with courtyard** for air circulation, especially in urban houses which are confined to a closed plot (Fig.12).

- **Combine passive cooling strategies with housing structure and shape** to provide human comfort in Vietnam climate while saving resources.

- **Harvest and purify rainwater** to provide sufficient water for household use; Apply different efficient methods to collect potable water such as solar still and transpiration techniques.

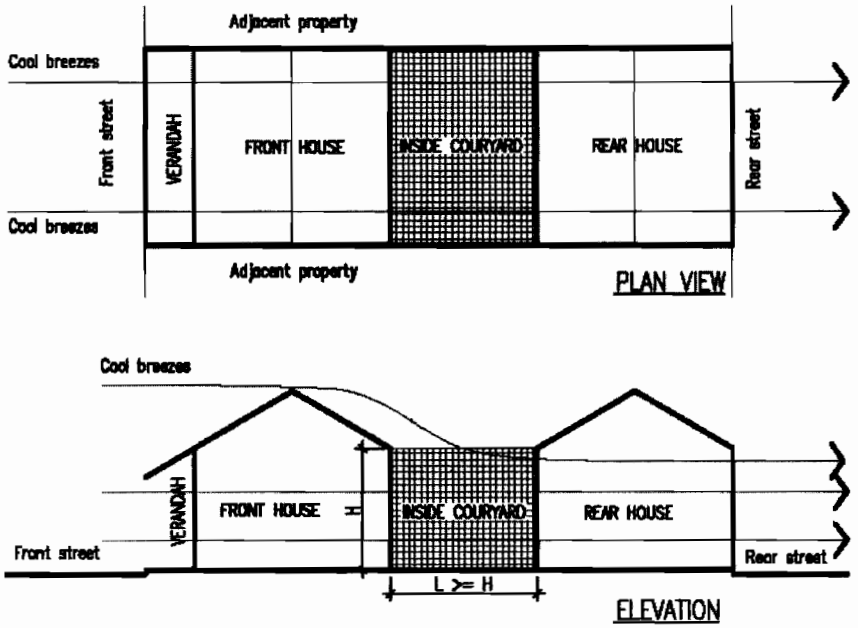


Figure 12. Cool breeze optimisation through internal courtyard and plan layout in an urban ancient house.

4.2 Passive cooling design strategies

Passive cooling strategies can provide natural ventilation and protect the house from heat and rain: the greatest impacts on tropical housing. New technologies for contemporary housing can reduce the impacts of sun and rain but use energy needlessly. Following strategies can be taken into account when designing houses:

- **Construct houses on high ground level or on stilts** for capturing natural breezes for ventilation.

- **Maximise openable windows and air vents** to provide natural air movements through the house. Use top balusters or top hung widows on doors to encourage cool breezes while providing privacy.

- **Use double windows with outside louvers and inside glazing** to provide flexible control in all weather conditions.

- **Ventilate roof spaces naturally** by installing air vents on gables and eave ceilings; Consider double roofs with air space in between for thermo-siphoning.

- **Arrange narrow single rooms** on the layout for natural cross ventilation and heat avoidance. In Northern Vietnam, for example, building with a ratio between its length and depth of 3.7 can maximally reduce sun radiation on all its facades (Fig.13).

- **Guide cool breezes through the building** by using window fins, buffer spaces and courtyards.

- **Use shading devices** such as overhangs and eaves for reducing unwanted heat gain, especially on south facades to shade windows. Moreover, the overhangs also control rain access.

- **Apply thermal insulation to roof**, using natural insulation materials or an air gap.

- **Use lightweight structures** rather than thermal mass construction to avoid heat storage affecting the house.

- **Apply trellises, green walls, and green roofs** to reduce heat gain from the exterior envelope, especially in urban buildings with limited land for gardens.

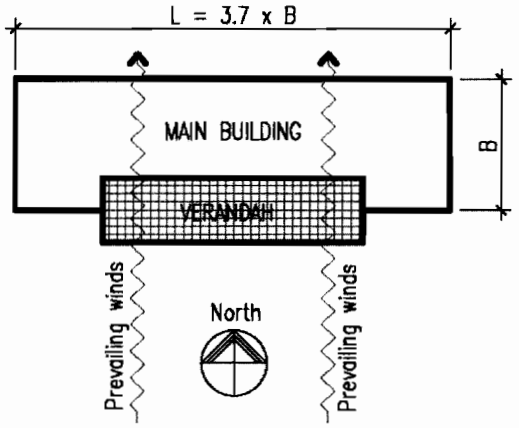


Figure 13. Optimal configuration of a building plan to direct solar radiation in Northern Vietnam.

4.3 Material use

Although hi-tech materials are now imported and used in contemporary Vietnamese housing, local materials are more aesthetically and climatically appropriate. The house will help to create a sense of place if it is built with materials from its own region. Therefore, the use of materials for housing needs to consider the principles below:

- **Use locally appropriate materials** to benefit from cost and energy savings, from the employment of the local labour force, and from the resistance to extreme weather events.

- **Apply rapidly growing renewable materials** such as bamboo, rattan and thatch with a non-polluting treatment process where possible and utilise traditional skills in the use of these materials.

- **Develop technologies for producing durable building materials** from abundant agricultural by-products such as coconut and rice husks (Fig.14).

- **Reuse and recycle materials** where possible to reduce negative impacts on the environment. Timber beams, bricks, doors, windows, steel sheets, cladding panels, etc are reusable elements.

- **Design buildings for disassembly** to facilitate the reconstruction and adaptation process and reuse the materials of building components, including structural skeleton, doors and windows, and roof system.

- **Design buildings for durability and flexibility** to limit the extraction of new construction materials.

Building durability relates to the use of appropriate materials and technologies to avoid condensation and water ingress that can rapidly damage the building.

The flexibility of design aims at providing the capacity for space transformation according to functional changes of the building. This strategy suits the traditional construction of Vietnam as vernacular housing has used assembled timber structure skeletons and a flexible interior space layout.

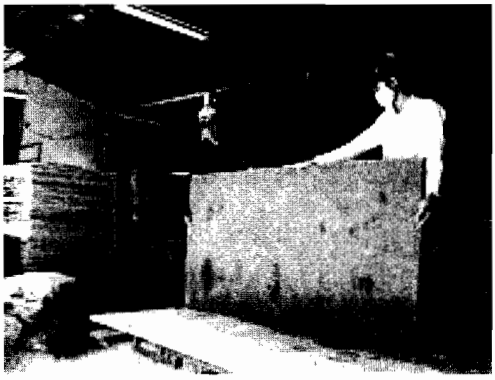


Figure 14. Manufacturing flooring panels from coconut husks in Ben Tre Province, Southern Vietnam. Image from Nguyen (2007).

4.4 Structure

From the lesson of vernacular Vietnamese housing, selecting an appropriate structure for the house is based on specific conditions of the region. The structure should be strong and durable to resist to typhoons and floods which annually affect Vietnam.

- **Reinforce the house in typhoon prone regions**, especially in Central Vietnam, by using storm-resistant types of structure or cable reinforcement.

- **Combine the structure with spatial functions** such as high level storage and shelter to provide optimal adaptability to weather events.

- **Prioritise locally appropriate housing shape, roof pitch, and plan configuration** because they have been evolved over time by trial and error.

5 Conclusion

Contemporary Vietnamese housing should learn from vernacular archetypes to provide greater comfort and reduce negative impacts on the environment. The Vietnamese vernacular housing has become climatically adaptable over time due to the use of on-site integration, passive cooling strategies, natural materials, and appropriate structure. Climate responsive design also creates a sense of identity. Based on the fundamentals from the vernacular houses, guidelines for contemporary housing aim to provide comfort and well-being while lessening burdens of the environment. The guidelines consider sustainable issues, including building orientation, site layout, passive design, suitable material, and appropriate structure in the Vietnam hot humid climate without limiting design creativity. The points in brief are summarised in the following table (Table 1).

Table 1. Climate responsive strategies of the vernacular design applicable to contemporary houses.

Catalogues	**Climate responsive indicators**	**Strategies**
Site organisation	*Orientation*	Priority to north - south orientation to attract prevailing winds and less solar access.
	Integration with nature	Consideration of solar path, wind pattern, vegetation and solar pond in housing design.
	Ventilation optimisation	House on high ground or elevated floor. Use of courtyard and mediating space for air circulation.
	Vegetation	Strategic placement of vegetation on site to channel air movement and provide food and shade.
	Water	Harvesting and purifying of groundwater, surface water, and rainwater. Application of water collection methods of such as solar still or transpiration techniques to provide potable water.

Passive design	*Roof*	Thick roof or double roof to reduce solar heat gain.
	Ceiling	No ceiling for maximum air circulation under the roof space.
	Wall	Use of different exterior types of wall according to the orientation.
	Window and opening	Large windows and openings on south and north for natural ventilation. Openings limited on east and west.
	Door	Full width doors with balusters/hung windows on top for air movement.
	Protection device	Overhangs over windows and wall openings for sun and rain protection, especially on south façade of the house.
Material use	*Local availability*	Use of local timber, thatch, bamboo, and earth products with a consideration of durability and moisture resistance.
	Lightweight	Use of materials with low heat retention and transmission.
Structure	*Type selection*	Use of appropriate structural types based on regional conditions. Priority to local housing shape, roof pitch and plan configuration.
	Functional combination	Structure design integrated with occupant's needs to provide adaptable space to harsher weather events.

References

Institute of International Culture - Showa Women's University. (2003). *Kien truc pho co Hoi-An (Architecture of Hoi-An Ancient Town)*. Hanoi, Vietnam: World Publisher.

Lauber, W. P., Cheret, P., Ferstl, K., & Ribbeck, E. (2005). *Tropical architecture: sustainable and humane building in Africa, Latin America and South-East Asia*. Munich; New York: Prestel.

Nguyen, B. D., Nguyen, V. P., & Ta, H. V. (2007). Rural folk dwelling houses in Viet Nam. *Vietnamese Studies, Vol 43*(2), pp.5-34.

Nguyen, B. D., & Nguyen, V. T. (1995). *Nha o nong thon, truyen thong va cai tien (Rural housing, tradition and innovation)*. Hanoi, Vietnam: Construction Publisher.

Nguyen, K. (2007). Mun dua - Vat lieu xay dung nha cho nguoi thu nhap thap (Coconut husks - Housing Materials for Low Income Inhabitants) (in Vietnamese). Retrieved 15 January 2010, from http://www.bentre.gov.vn/index.php?option=com_content&task=view&id=1675&Itemid=41

Nguyen, V. H., & Hoang, V. (1975). *Nhung trong dong Dong Son da phat hien o Viet Nam (Dong Son Bronze Drums discovered in Vietnam) (in Vietnamese)*. Hanoi, Vietnam: Vien Bao Tang Lich Su Viet Nam (The National Museum of Vietnam History).

Rapoport, A. (2006). Vernacular Design as a Model System. In Lyndsay Asquith & M. Vellinga (Eds.), *Vernacular Architecture in the Tewnty-First Century - Theory, Education and Practice*. USA and Canada: Taylor & Francis.

Thai, Q. T. (2005). *Nhung dac diem va gia tri ve kien truc - quy hoach nha o dan gian cua cac lang truyen thong tinh Quang Nam (Architectural and planning characteristics and values of vernacular housing in traditional villages in Quang Nam province) (Master Thesis in Vietnamese)*. Hanoi University of Civil Engineering, Hanoi, Vietnam.

Tran, N. T. (1999). *Co so van hoa Vietnam (Foundations of Vietnamese Culture) (in Vietnamese)*. Hanoi, Vietnam: Education Publishing House.

Vietnam Government Website. Retrieved 03 May 2010, from http://www.chinhphu.vn

Vietnam Ministry of Construction. (1985). *Climatic data for building design*. Retrieved 22 December 2009. from http://tcxdvn.xaydung.gov.vn/TCXDVN/TCXDVN.NSF/START?openframeset.

Vietnam News Agency on website of the Ministry of Construction. (2009). Trung tu di tich Hue bang cong nghe vua voi truyen thong (Restoring Hue Monuments with traditional mortar technology) (in Vietnamese). 13/01/2010, from http://www.moc.gov.vn/site/moc/cms?

cmd=4&portionId=57&categoryId=86&articleId=31025&portalSiteId=6&language=vi_VN