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The Criteria of Passive and Low Energy in Building Design for Tropical Climate in Thailand

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Abstract: Due to high level of energy consumption and increasing environmental concerns, energy efficiency has become a critical issue today. Buildings alone account for around 30 percent of the world's total energy consumption. The way buildings are designed and constructed today will not only have an impact on their operating costs, but it will also affect the world's energy consumption patterns and environmental conditions for many years to come. For much of the building industry in Thailand, the designed-in approach to energy-efficient design does not reflect current market practice. In reality, without passive design, numerous opportunities for designing better performance buildings can be wasted. The integration of passive design is thus a key to energy conscious buildings. The integration of passive design approach optimizes the interactions between the natural environment, building envelope and systems as an integrated system. This research examines which components work best altogether to save energy and reduce environmental impacts on buildings in the tropical region. The outcomes of this research aim to set up the criteria of passive and low energy in building design for the tropical climate in Thailand. These fundamental differences will lead to a very different architectural and constructional design. It is imperative that the decision be made at an early stage in the design and there are tremendous opportunities to use smart, energy efficient designs to reduce the energy footprint of the built environment for decades to come.

Keywords: Criteria, Passive Design, Energy Efficiency, Building in Thailand, Tropical Climate

1. Introduction

Due to high level of energy consumption and increasing environmental concerns, energy efficiency has become a critical issue today. Buildings alone account for around 30 percent of the world's total energy consumption. The way buildings are designed and constructed today will not only have an impact on their operating costs, but it will also affect the world's energy consumption patterns and environmental conditions for many years to come. Many technological and other solutions exist to improve building energy efficiency, as seen in numerous green building projects being developed around the world. Much of the new construction in Asia is large commercial office buildings and mixed-use developments that embrace such modern design features as glass facades and centralized air conditioning. The building sector currently accounts for about one-quarter of Asia's social and economic energy consumptions [1].

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Then the new building design is a cost-effective opportunity. Wen Hong et al. [1] explains that it is far more cost-effective to build energy efficiency into the design of a new building than to retrofit an existing building because the new building offers flexibility in all its construction parameters. In Asia, where the majority of the world's new construction will take place over the next decade, there are tremendous opportunities to use smart, energy efficient designs to reduce the energy footprint of the built environment.

The integration of passive design is a key to energy conscious buildings. Developers who take the energy performance of new construction seriously are using integrated and passive design techniques to maximize energy efficiency. The integration of passive design approach optimizes the interactions between the natural environment, building envelope and systems as an integrated system and examines how these components work best altogether to save energy and reduce environmental impacts.

According to William Browning, a senior fellow at the Rocky Mountain Institute in Colorado [1], integrating green principles can generate 40 percent more savings and 40 percent better performance than simply adding green technologies to a traditionally planned and designed facility. Then this research investigates a group of theories on passive design for energy saving in hot and humid climates. The outcomes of this research aim to set up the criteria of passive and low energy in building design for the tropical climate in Thailand.

2. Methodology

This research approach is based on the knowledge acquired through the literature related to the standard and criteria of passive design in buildings in tropical climates. The following content will explain the workflow of the research methodology.

a) Problems of high energy consumption in Thailand will be identified.
b) Standards and criteria of passive design theories in building based on the tropical climate have to be taken into considerations.
c) Theories of passive strategies for hot and humid climates will be investigated.
d) The outcomes of research will be the criteria of passive and low energy in building design for the tropical climate in Thailand.

3. Literature Review of Passive Design Theories and Applications

The southwest and northeast monsoons influence the climate in Thailand to have different seasonal characters [10]. The southwest monsoon causes abundant rain in most of Thailand, which starts from May until October. The southwest monsoon is characterized by the movement of warm weather and moist air from the Indian Ocean to Thailand to cause rain. The northeast monsoon carries cold and dry air from China to over most of Thailand, which starts from October until February. However, when in southern Thailand, the monsoon brings mild weather and abundant rain on the eastern coast. Based on the Köppen climate categories, most parts in Thailand are classified in a "tropical wet and dry or savanna climate" type [2]. A tropical monsoon climate can be seen in the Fig. 1.

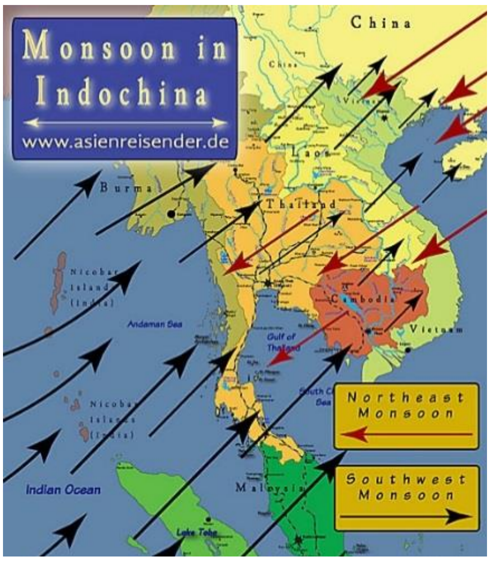


Fig. 1 – Monsoon in Indochina

Thailand has three seasons [2]. The rainy season or southwest monsoon starts from mid-May to mid-October. The wettest period of the year by abundant rain occurs during August and September and this can occasionally lead to floods. Then the significant rainfall is caused by the southwest monsoon. The winter season or northeast monsoon starts from mid-October to mid-February. The mild temperature and dry weather influence most parts of Thailand in contrast to the southern region, which receives abundant rainfall between October and November. The summer season runs from mid-February to mid-May and is characterized by the warm weather [2].

3.1 Reduction of Solar Gains

Solar Gains through Fabric: gains through fabric occur due to the heating effect of absorbed solar radiation conducted to the interior [3] in Fig. 2. This can be minimized by:

a) Using of shading to reduce the amount of radiation falling on the building (e.g. by vegetation or by other buildings);
b) Reducing the absorbed radiation by use of highly reflective finishes;
c) Increasing the insulation value of the roof and walls.

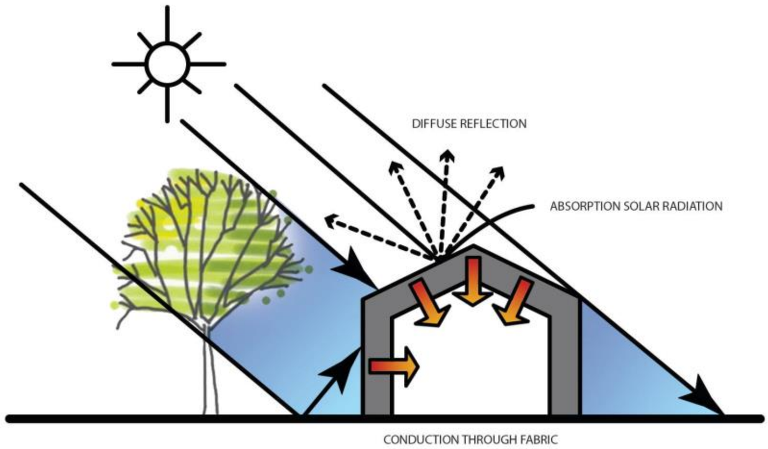
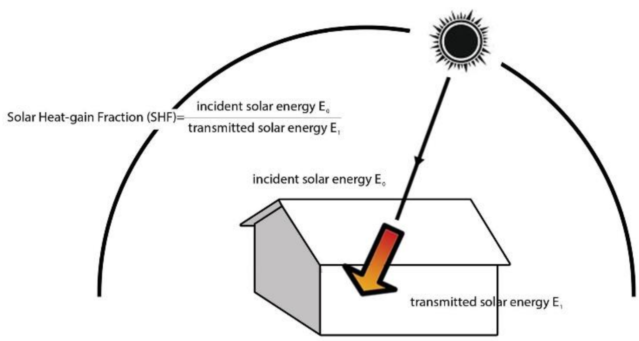


Fig. 2 – Solar heat gains through fabric

Solar Heat Gain Factors (SHF): When considering the degree to which solar gain is transmitted by fabric of the building, it is helpful to use the concept of Solar Heat Gain Factors (SHF) [3]. This is defined by Koenigsberger et al [4] as the heat flow rate through the construction due to solar radiation expressed as a fraction of the incident solar radiation. In constructions involving massive elements such as brick and concrete, the passage of heat is delayed, i.e. a time lag is introduced. In these constructions, the Solar Heat Gain Factors (SHF) is applied to an integrated 24-hour total, rather than an instantaneous value [3]. The factors affecting the value of SHF are:

a) The absorptivity of the external surface;
b) The insulation value of the envelope;
c) The mass of the envelope.



$$\text{Solar Heat Gain Fraction (SHF)} = \frac{\text{incident solar energy } E_0}{\text{transmitted solar energy } E_t}$$

Fig. 3 - Definition of Solar Heat Gain Factors

It is found that the relative position of insulating and mass layers in the construction have a significant effect on the SHF. The 24-hour integrated value of SHF may also be influenced by the infrared emissivity of the external surface since this will affect the loss of heat (from daytime solar gains) to the cool night sky. SHF is normally expressed as a percentage. It may also be applied to thermally massive buildings which have been cooled down at night [3].

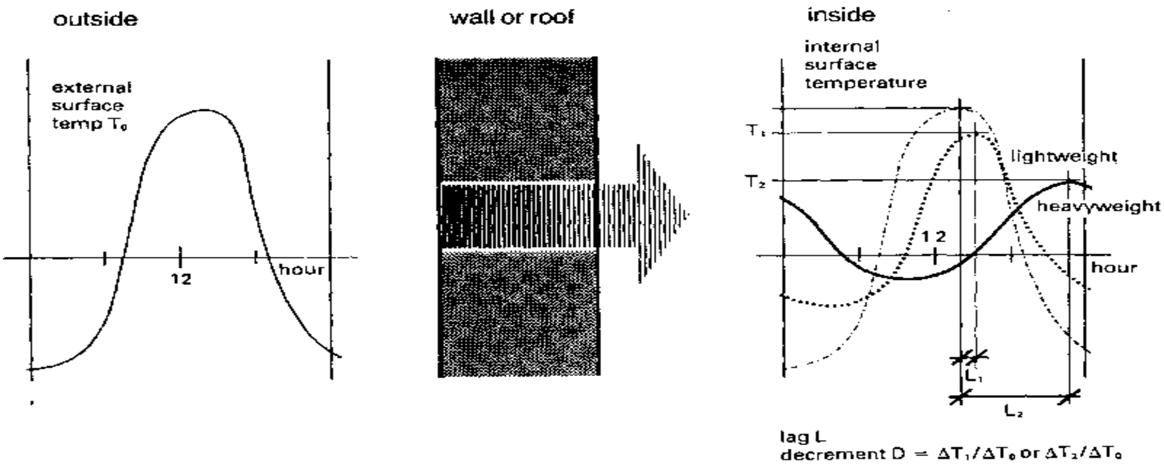


Fig. 4 - Time lag and decrement for heavy and light constructions

Solar Gains through Openings – Shading. Where ambient temperatures are generally within or above the comfort zone such as the tropical climate, any ingress of solar radiation will contribute to discomfort. To carry out the shading function, one or more of a number of shading devices can be employed [3]. The devices can be classified into three types in Fig. 5.

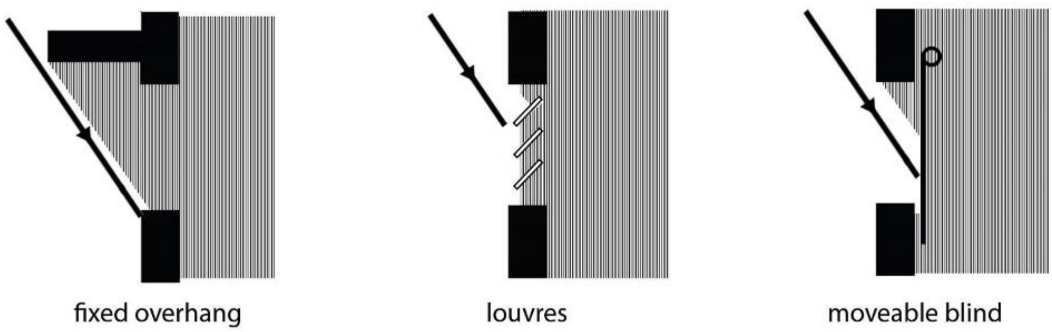


Fig. 5 - Classification of shading types

Movable blinds or curtains: these have limited application in non-air-conditioned buildings since they seriously impede air flow. In the air-conditioned buildings, where the outside air temperature is above room temperature, windows will be glazed and the question of air flow does not arise. In this case, an opaque (or translucent) blind could be considered as a means to reduce cooling load. The more reflective the fabric, i.e. lighter in color, the more the radiant energy will be reflected back out of the building.

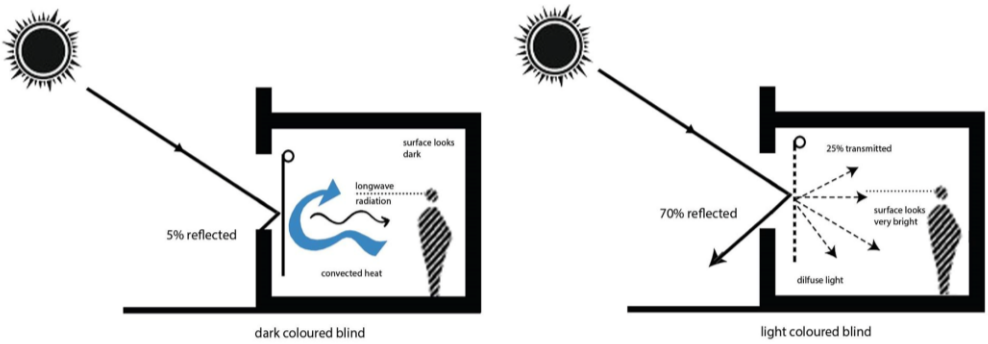


Fig. 6 - Performance of various blind materials

Geometric shading — overhangs and louvers: the traditional method of shading in the tropics is by the use of fixed overhangs together with careful consideration of building orientation [5]. Geometric shading follows the preferred orientation of the building and the long axes east (E) and west (W). The roof provides sufficient overhangs to protect the entire north (N) and south (S) walls and also provides a verandah for access to the rooms protected (to some extent) from rain. For the same number of overhangs, the E and W gable ends would not be so protected since the sun will strike these at a much lower angle. As a result, openings on these E and W walls should be kept to a minimum and insulation standard (Solar Heat Gain Factors) which would have to be better than those on the N and S walls.

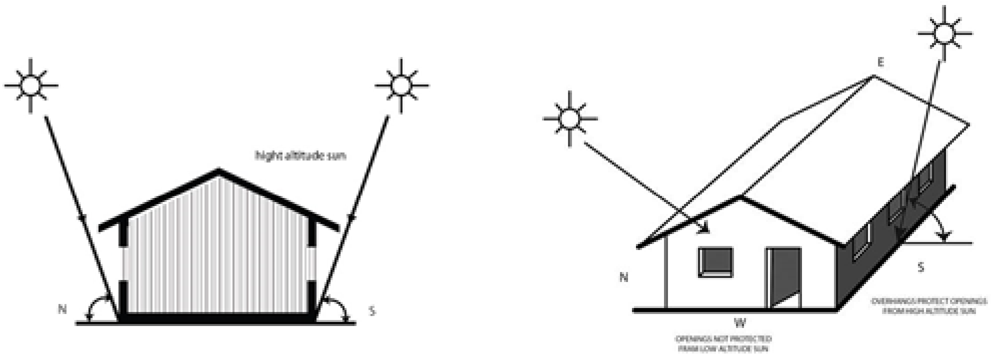
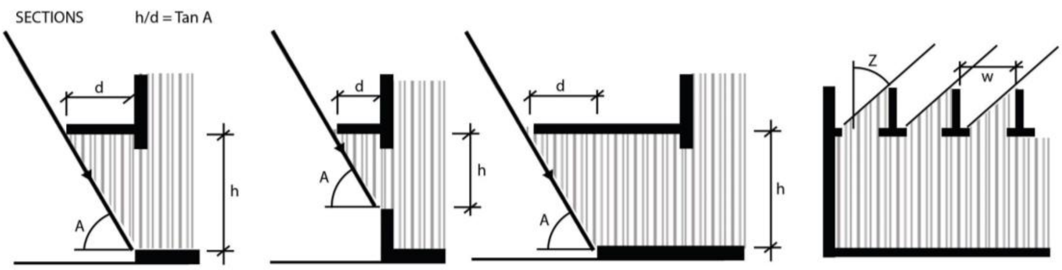


Fig. 7 - Orientation of the east and west of building to provide shading to openings in long walls



Sections h/d = Tan A
Plan w/d = Tan Z

Fig. 8 - The Geometry of shading by overhangs

Sometimes a combination of horizontal and vertical projections is used. A number of geometric shading devices are shown by Evans, M. [6] in Figure 9. In order to be able to specify the correct dimensions of an overhang or fin for shading, we need to know the area of the sky through which the sun will pass at the particular time of the season, or day, for which it wants to be shaded.

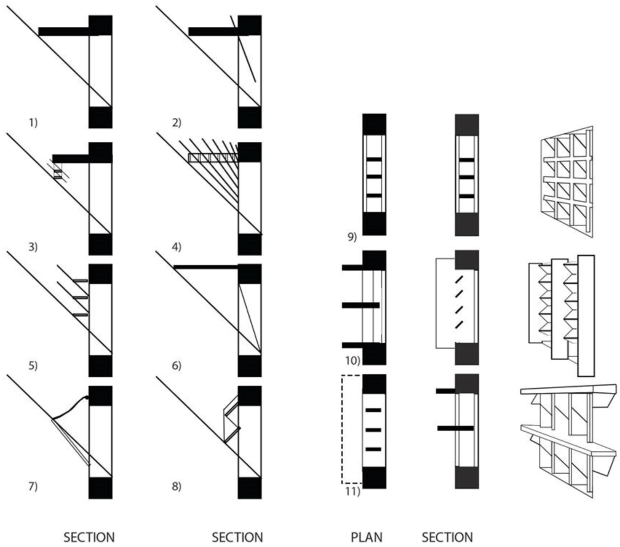


Fig. 9 - Various geometric shading devices

3.2 The use of Daylight

The most efficient way, in principle, of lighting a building, is to admit daylight. This is for two reasons. First, the "luminous efficacy", i.e. the useful visible light in relation to the total energy of the radiation, is high, it is better than any enough light for vision and for indoor activities cause less heating effects to habitants. The heating effect of daylight is about 1 Watt per 100 lumens. This is between 1/2 and 1/10 of typical artificial lighting alternatives. Second, daylight is free. Artificial lighting consumes electricity, usually "on peak" electricity. The light entering a building may be considered as comprising of three separate components [3].

a) Direct sunlight, which must almost always be excluded, is carried out by fixed shading devices and movable shading devices.
b) Light from the diffuse sky varies widely between the clear sky and clouded conditions.
c) Diffusely reflected light from the ground and other buildings may present glare problems due to its low angle.

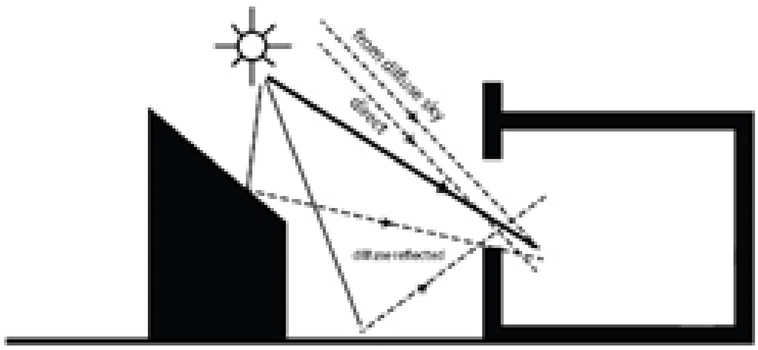


Fig. 10 – Components of light entering a room

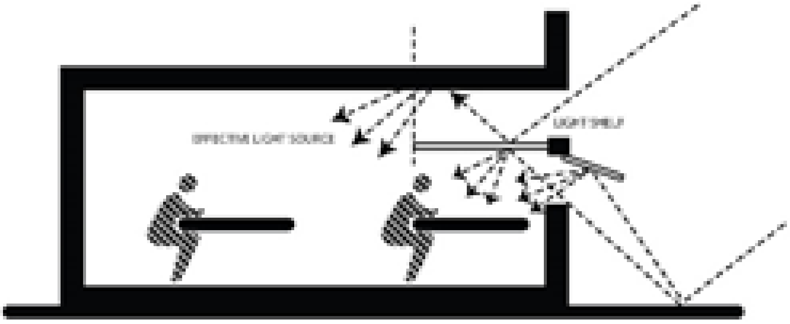


Fig. 11 – Use of a light shelf

In multi-storey buildings, carefully-designed side openings can improve the situation. The provision of daylight to the perimeter zone and the provision for the deeper zones can be split between two sets of openings. These openings may be separated by a "light shelf", which projects back into the room, as shown in Fig. 11.

3.3 Ventilation and Air Movement

Traditional architecture of the hot humid regions is dominated by the provision of air movement [12]. Fortunately, the tropical climate enjoys steady breezes, which make the provision of thermal comfort somewhat easier [5]. 1) Stack-effect ventilation: stack-effect ventilation relies upon the buoyancy of the warmer air in the building causing the air to rise and leave the building from a high outlet and be replaced by heavier cooler air via a lower inlet Fig. 12 Fig. 13.

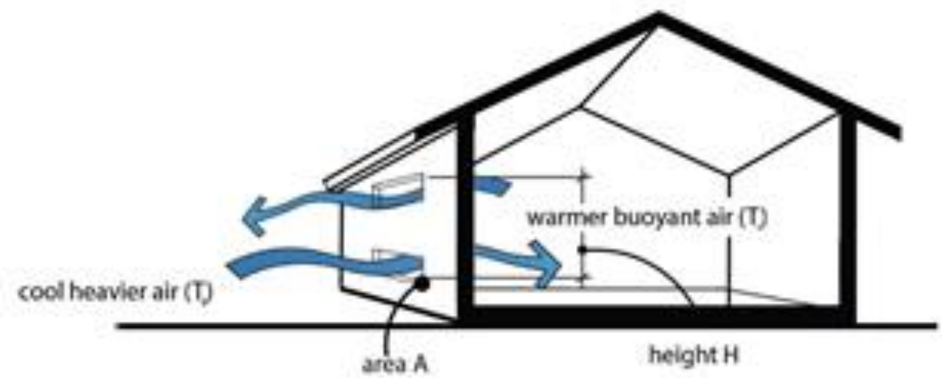


Fig. 12 – Stack Effect ventilation

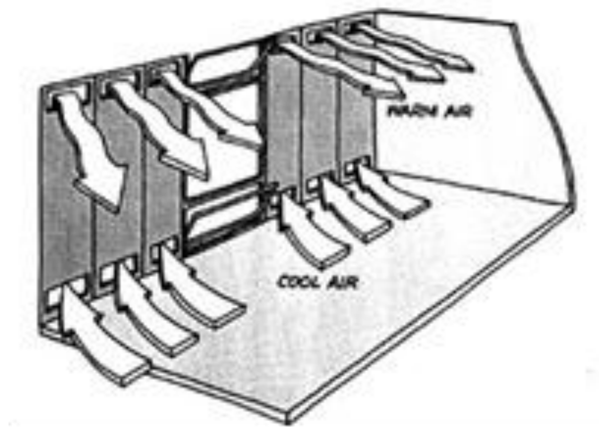


Fig. 13 – Single-side ventilation

The ventilation rate for openings of roughly equal area is given by

$$V = 0.121 \times A \times H \times (Ti - T0)$$

Where
V is volume flow in m^3/sec,
A is area of each opening,
H is the distance between inlet and outlet, and
Ti and To are inside and outside temperatures.

3.4 Micro-climate and Passive Design in Traditional Architecture in Asia and Thailand

An example of the Indonesian long house in Fig. 14 is located in the hot humid tropics [7]. Temperatures remain close to or above comfort levels at daytime and nighttime. The only way to provide comfort is to maximize the effect of breezes and to protect the house from the direct sun. Thus, traditional architecture gives the characteristic lightweight porous structure with lofty roof space and deeply overhanging eaves. Houses of Hyderabad in Fig. 15 have wind catchers, which direct the breeze down a shaft to be introduced into the lower rooms of the houses via an opening containing a porous pot of water. This system does not only provide ventilation air in a crowded urban locality, but it also provides evaporative cooling. Similar devices have been identified in Egyptian tomb paintings dating back to 1300 BC. [3].

Fig. 14 - The Indonesian Long House

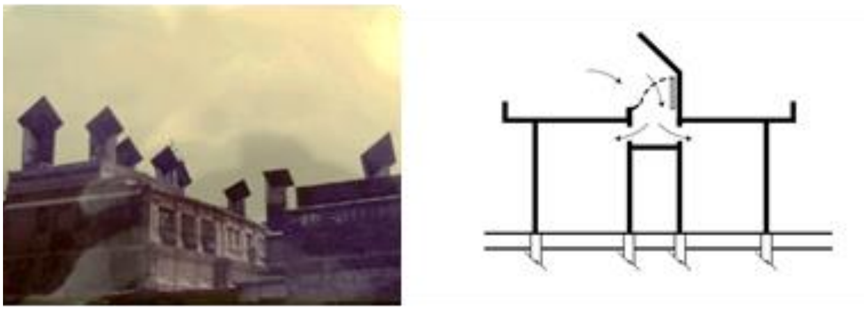


Fig. 15 - Wind catchers of Hyderabad, Pakistan

In Thailand, the traditional Thai house is ideally adapted to its environment [10] and [11] . That is, an open high-pitched roof facilitates air circulation [7]. Open windows and walls in combination with a large central terrace provide ideal ventilation and offer relief from the hot and humid climate (Figure 16). Wide overhanging eaves protect the house from the sun and rain. Rainwater runs off the steep roof quickly and falls through the permeable terrace and the house floors. The use of wood and bamboo reflects the once abundant forests that provided these materials ubiquitously and cheaply. In addition, Antarikananda [7] gives terms of development and application of traditional Thai houses as follows:

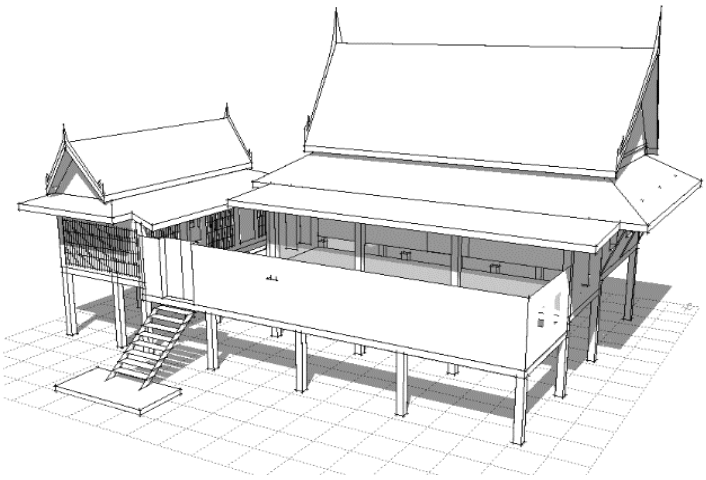


Fig. 16 - Traditional house in the central region of Thailand

In the northeast of Thailand [13] and [14], where there is a more pronounced period when occupants might feel too cold, there may be benefits from incorporating adjustable openings in the building envelope to increase occupant control of ventilation. In the southern region [13] and [14], longer roof overhangs are required to increase shading for a new house. Houses in the central region would also benefit from improved shading, particularly on the southwest and west facades.

4. Results and Discussion

4.1 Reduction of Solar Gains

With significant air temperature differences between inside and outside, the insulation of the envelope will become critical. Walls and roof, or even floors, will have to be insulated. Openings will not only be glazed, but double glazing may be worthwhile.

4.2 The Use of Daylight

The key strategy for efficient building envelopes is the integration of design strategies to bring daylight into a building's interior without heat and glare. The designs that make extensive use of day lighting reduce the need for artificial light. The use of high-efficiency lighting can reduce both electricity demand and heat gain, which in turn means that designers can select smaller cooling systems. The Daylight Factor of a building is fixed by the geometry of the building itself. Unless the building employs movable devices which can vary the Daylight Factor in response to the varying sky luminance, internal daylight illuminance will also vary widely. In tropical climates, there is need to control direct sunlight because it is between 5 and 10 times more intense than the diffuse sunlight. Thus, it is common that tropical buildings with heavy shading devices successfully exclude direct sunlight and reduce daylight levels more effectively than artificial lighting, which is required all day. Furthermore, if movable shades are employed, they can be used to vary the Daylight Factor as well to suit conditions. Other considerations will include the exclusion of insects by screens. Last, security may be a major concern. In non-domestic buildings unoccupied at night, ventilation may still be required to cool the structure. Thus, openings will have to be provided.

4.3 Ventilation and Air Movement

Passive measures of ventilation and air-conditioning today are both significant in all respects. Because of the rising expectations of occupants, together with their levels of affluence, buildings may subsequently be air-conditioned, whereas the passive measures of ventilation obviously are applied to the lower cost housing and buildings [8] and [12].

4.4 Micro-climate and Passive Design in Traditional Architecture

Changing lifestyles, technologies and user expectations are leading to increased heat gains within a home and possibly a reduction in the degree of adaptation to high domestic temperatures. It is concluded that the traditional housing of Thailand does provide useful indicators of appropriate architectural design responses to the tropical climate, particularly in the context of purely passive environmental control. The results indicate that improved performance might be achieved by combining selected lessons from the traditional design e.g. improved shading, regional variations in window size related to orientation, and adoption of adjustable ventilation and window openings.

The cumulative energy savings from an integrated design end up being greater than if energy-saving features are implemented individually. The whole process requires an interactive cycle of modeling to yield the most cost- effective energy performance. Such fundamental differences will lead to a very different architectural and constructional design, and it is imperative that the decision whether to use passive design for the tropical climate in Thailand has to be made at an early stage in the design.

5. Conclusion

In this study, the conclusion of the criteria in terms of passive design strategies is presented as follows.

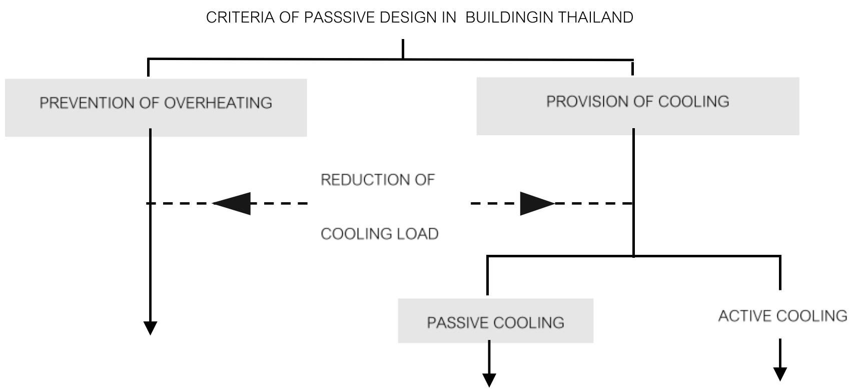


Fig. 17 – Criteria of passive design in buildings in Thailand

Elements of passive design are concluded as follows:

i. Climate and Site Analysis: the key to passive design is to make the most use of the natural environment.

ii. Orientation: orientation is the key to improve comfort and reduce energy consumption. Effective passive cooling and passive heating are the results from such appropriate orientation.

iii. Passive Solar Heating: passive solar heating keeps heat from the summer sun out and lets heat from the winter sun in.

iv. Passive Cooling: passive cooling uses design and modification of buildings to achieve summer comfort and minimizes or eliminates energy use for cooling.

v. Insulation Installation: insulation improves building envelope performance by minimizing heat loss and heat gain through walls, roof and floors.

vi. Thermal Mass: in passive design, concrete, bricks and masonry are used to release, absorb and store thermal energy based on a variety of seasons, i.e. summer, winter and rainy. The external insulation and dense materials are the key consideration for thermal mass.

vii. Windows and Glazing: it is very important to design glazing and windows with a well isolated because heat loss and heat gain occur mostly through the windows. For the design of windows, cooling breezes and air movement are encouraged in summer and cold winter winds are excluded.

viii. Shading: design in shading devices depends on climate analysis and building orientation. In the tropical climate where no heating is a primary requirement, shading of outdoor spaces and whole buildings will save energy bills and improve human comfort.

ix. Skylights: Thailand has a high quality of skylight that can bring the natural light into a building and dark spaces. The design to utilize skylight in building will improve energy performance in the long term.

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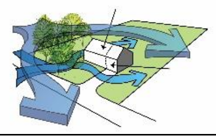
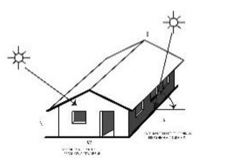
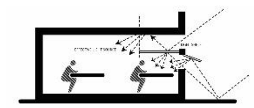
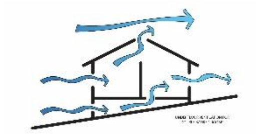
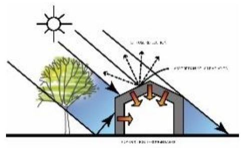
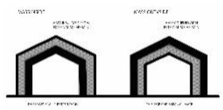
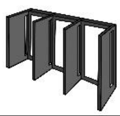
1. Climate & Site Analysis	

2.Orientation	
3.Passive Solar	
4.Passive Cooling	
5.Insulation	
6.Thermal Mass	
7.Windows and Glazing	
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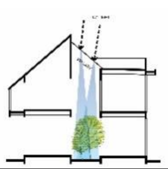
9.Skylights	

Fig. 18 - The Criteria of Passive and Low Energy in Building Design for the Tropical Climate in Thailand.

Acknowledgement

For much of the building industry in Thailand, this designed-in approach to energy-efficient design does not reflect current market practice. In reality, without passive design, numerous opportunities for designing better performance buildings can be wasted. In Asia's urban centers likewise, most new constructions are climate-rejecting. Joseph Deringer, the scientist at White Box, the sustainable energy design consultancy in Berkeley [1], comments that "Designers just seal up the building and add air conditioning." It is far more cost-effective to build energy efficiency into the design of a new building than to retrofit an existing building because the new building offers flexibility in all its construction parameters. In Asia, where the majority of the world's new constructions will take place over the next decade, there are tremendous opportunities to use smart, energy efficient designs to reduce the energy footprint of the built environment for decades to come.

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