DESIGN OF ENERGY EFFICIENT TOWNHOUSES IN SONGKHLA, THAILAND

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ABSTRACT
This project, supported by Energy Policy and Planning Office (EPPO), is a study on the design of energy efficient townhouses for Songkhla, Thailand. Songkhla’s warm humid climate raised problem in the shading, cooling and ventilating of its buildings. The rapid development of its urban areas and corresponding increase use of air conditioners resulted in significantly higher energy consumption. One way to reduce energy consumption would be to have more energy efficient design to limit heat gain into building and hence reduce demand for air-conditioning. The paper describes three townhouse designs that have been developed in this project. The design aim was to achieve comfortable indoor temperature and sufficient daylight. A combination of passive design strategies, including natural ventilation, insulation, shading devices, earth cooling and daylight, is used to reach the low demands of energy. The prototype houses were built and investigated for their indoor environmental conditions responded to Songkhla’s climate. The monitoring equipments were installed to collect data of environmental conditions of prototype houses compared with those of outdoor conditions during April and May, the hot test period. Each room contained thermocouple sensors to measure the air temperature of indoor environment. In addition, lux-meters were placed in the living rooms for illumination level measurement. The result shows that the prototype houses provide a comfortable indoor environment for their occupants and appropriate daylighting. This leads to the design of energy efficient townhouses that will minimize the future energy consumption required by the occupants for cooling and lighting.

KEYWORDS
Energy efficient design, Townhouse, Thailand
INTRODUCTION

This project, supported by the Energy Policy and Planning Office (EPPO), is a study on the design of energy efficient townhouses for Songkhla, Thailand. Songkhla’s warm humid climate raised problems in the shading, cooling and ventilating of its buildings. The rapid development of its urban areas and corresponding increase in the use of air conditioners resulted in significantly higher energy consumption. One way to reduce energy consumption would be to have more energy efficient design to limit heat gain into building and hence reduce demand for air-conditioning.

The paper describes three townhouse designs that have been developed in this project. The design aims to achieve comfortable indoor temperature and sufficient daylight. A combination of passive design strategies, including natural ventilation, insulation, shading devices, earth cooling and daylight, is used to reach low demands of energy. The prototype houses, built and investigated for their indoor environmental conditions, responded to Songkhla’s climate. Monitoring equipments were installed to collect data of environmental conditions of prototype houses compared with those of outdoor conditions during April and May. Each room contained thermocouple sensors to measure the indoor environment. In addition, light-meters were placed in the living rooms for illumination level measurement. The result shows that the prototype houses provide a comfortable indoor environment for their occupants and sufficient daylight. This leads to the design of energy efficient townhouses that will minimize the future energy consumption required by the occupants for cooling and lighting.

The residential sector accounts for about 25% of Thailand’s overall electricity use. The report of the Energy Policy and Planning Office (NIDA, 2006), also indicates that electricity consumed by the residential sector is a significant portion of utility peak demands. Higher demand for residential energy use, particularly for air-conditioning, is likely to be a continuing trend. Improvements in the energy efficiency of the residential sector would contribute very significantly to electricity savings and would minimize the need for new electrical generation facilities.

The urban landscape of Songkhla is now characterized by concrete buildings with excessive glass, concrete roads and rapidly diminishing foliage. This has given rise to the formation of an urban heat island. The rapid development of its urban areas and corresponding increase in the use of air conditioners resulted in significantly higher energy consumption. Buildings in Songkhla now require more energy to be cooled since they are generally not designed or constructed to provide an adequate level of thermal comfort.
The built environment offers significant opportunities for energy efficiency. Energy savings will be significantly extended from electrical appliances to the entire dwelling by the incorporation of energy conscious principles into the design and construction of houses.

Architects and engineers have been engaged in a conversation since the mid-80s about ways of improving the performance of buildings, and yet consumption of energy and the production of greenhouse gases in Thailand continue to rise at an alarming rate. Thermal comfort in housing could be achieved by air-conditioning, but the running costs of the equipment present a problem. One way to reduce energy consumption would be to have more energy efficient design to limit heat gain into building and hence reduce demand for air-conditioning.

OBJECTIVES OF THE STUDY

This project, supported by Energy Policy and Planning Office (EPPO), is a study on the design of energy efficient townhouses for Songkhla, Thailand. Groups of architects and engineers developed three designs of energy efficient townhouse in his project. The design aim was to achieve comfortable indoor temperature and sufficient daylight. The prototype townhouses were built for the experiment and demonstration.

CLIMATIC CONDITIONS AND THERMAL COMFORT

Songkhla is located in the humid tropics of Thailand at 7°12′ N latitude and 100°36′ E longitude. Songkhla has a wet climate due to the double influence of the northeast monsoon blowing from China in winter and the southwest monsoon from the Indian Ocean which brings in moisture all year round. Its climatic characteristic is dominated by high relative humidity and high ambient temperature with slight variations of both diurnal and annual temperature. The monthly ambient temperature of Songkhla is shown in Table 1.
Table 1. Monthly Temperature of Songkhla

<table>
<thead>
<tr>
<th>STATION</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>SONGKHLA</td>
<td>mean</td>
<td>27.1</td>
<td>27.6</td>
<td>28.3</td>
<td>29.0</td>
<td>28.9</td>
<td>28.5</td>
<td>28.3</td>
<td>28.3</td>
<td>27.9</td>
<td>27.4</td>
<td>26.9</td>
<td>26.7</td>
</tr>
<tr>
<td></td>
<td>mean max.</td>
<td>31.0</td>
<td>31.6</td>
<td>32.7</td>
<td>33.1</td>
<td>33.7</td>
<td>33.5</td>
<td>33.4</td>
<td>32.6</td>
<td>32.5</td>
<td>31.7</td>
<td>29.8</td>
<td>29.0</td>
</tr>
<tr>
<td></td>
<td>mean min.</td>
<td>26.2</td>
<td>25.8</td>
<td>25.9</td>
<td>26.3</td>
<td>26.9</td>
<td>25.9</td>
<td>25.5</td>
<td>25.2</td>
<td>25.1</td>
<td>24.7</td>
<td>24.4</td>
<td>24.0</td>
</tr>
</tbody>
</table>

Warm and humid climates present several challenges for house design. The work of Auliciems (1983) shows that thermal neutrality is a function of the local climate, e.g.

\[ T_n = 17.5 + 0.31 \times T_{o.av}. \]

Where, \( T_n \) is the neutral temperature (°C), \( T_{o.av.} \) is monthly mean outdoor temperature (°C).

Figure 1. presents the comfort zone for Songkhla’s climate. The neutral comfort temperature in Songkhla is 26.56 °C. According to Auliciems’ model, the comfort zone for Songkhla in summer is between 24.56 °CET and 28.56 °CET. An analysis of the climatic data of Songkhla with Auliciems’ model shows that the monthly mean temperature was above the neutral temperature but almost within the comfort limit which is ±2°C from the neutral temperature, except in April and May.

![Figure 1. Comfort Zone for Songkhla’s Climate](image)

Source: Original Research
Songkhla’s warm humid climate raised problem in the shading, cooling and ventilating of its buildings. The intense solar radiation in such climate imposes a large thermal load on houses that can increase cooling costs, affect comfort, and damage home furnishings. Moisture in the form of high humidity and high rainfall is another significant problem. The ambient air has significant levels of moisture most of the year. Because air-conditioning is installed in most new homes, cold surfaces are present where condensation can occur. Controlling the infiltration of moisture-laden air into the building envelope and keeping moisture away from cold surfaces are major goals of design and construction in this climate zone. Relying on natural airflow will provide an important energy saving, and at the same time will bring an improvement of living conditions for the occupants.

PROTOTYPE TOWNHOUSES DESIGN

Designing a house that is appropriate to the climate will help reduce the ongoing electricity costs and resulting greenhouse gas emissions of the house. The design principles for tropical housing have been described by many authors (Givoni, 2000; Tantasavasdi C. 2001; Chenvidyakarn, 2007). Theoretically, thermal comfort and energy efficiency in buildings in hot regions can be achieved by minimizing solar heat gain and maximizing passive cooling.

In principle, all three prototypes consist of living room, dining room, kitchen, 2 bedrooms and service facilities, with a total area of 90-100 sq.m. The structure is typically a concrete frame with masonry walls. The townhouses were designed with careful attention to climate and environment constraints. The design aim was to achieve comfortable indoor temperature and sufficient daylight. A combination of passive design strategies, including natural ventilation, insulation, shading devices, earth cooling and daylight, is used to reach the low demands of energy. Incorporating the following ideas into the design will make the house more energy efficient and reduce the need for air-conditioning.

Site Design

Site planning and building orientation have a large impact on how energy-efficient a house will be. In a warm humid climate, appropriate orientation of the building structure in relation to the sun and prevailing wind is of ten the first design criterion. The sun is the main source of heat in all homes. By looking at how houses receive sunlight, site planning can help optimize how much solar energy is available to heat a house and how much heat must be removed with air conditioning.
**Building Envelope**

Roofs play a key role in protecting building occupants and interiors from outside weather conditions, primarily heat and moisture. In warm humid climates such as Songkhla, the intense solar radiation falling on the roof can often increase ceiling temperature, causing human discomfort from the high mean radiant temperature of the indoor environment.

The flow of air through the house is a primary design consideration for a comfortable house in the tropics. Good design can achieve two objectives: a) a physiological cooling effect; and b) the removal of heat from the house.

Lightweight construction is often preferred in the warm humid climates to minimize any possible heat storage which may otherwise cause discomfort at night.

**Window and Shading Device**

Windows orientation influences the amount of solar radiation incident on building’s glazed surfaces. Solar gain through windows is obviously the largest cooling load component, and window shading can have a significant impact on solar loads. Shading windows in the summer to prevent excessive solar gain can greatly reduce overheating of the house. Daylight can enter the house through roof vents or other upper openings (convective ventilation). A small movement of air across the body is sufficient to create a physiological cooling effect. The effectiveness of natural ventilation is highly associated with the design of the house—including floor-plans, home orientation, narrow buildings or the location and size of windows, louvered or clerestories. Good house design requires consideration of how air flows through the house so as to best utilize this physiological cooling effect.

**Daylighting**

It is acknowledged that by maximizing the use of natural lighting (daylight) a significant reduction in artificial lighting can be achieved. Primary
energy consumption can be achieved. Useful daylight illumination levels should be ensured around the year in order to create visual interest and demonstrate the energy savings potential for electric light. The best way to incorporate daylighting in the houses depends on climate and house's design. The sizes and locations of windows should be based on the cardinal directions rather than their effect on the street-side appearance of the house. North-facing windows are most advantageous for daylighting. They admit relatively even, natural light, producing little glare and almost no unwanted heat gain. Although east and west-facing windows provide good daylight penetration in the morning and evening, respectively, they should be limited. They may cause glare, admit a lot of heat during the summer.

The result of these strategies was the design of three different townhouses as follows.

**Townhouse Type A**

![Figure 2. Plan and Design of Town House Type A](image)

Source: Original Research
Townhouse Type B

Figure 3. Plan and Design of Town House B

Source: Original Research

Townhouse Type C

Figure 4. Plan and Design of Town House C

Source: Original Research
Results and Discussion

The prototype houses were built and investigated for their thermal performance and indoor environmental conditions to respond to Songkhla’s climate. The monitoring equipments were installed to collect data of environmental conditions of prototype houses compared with those of outdoor conditions during April and May, the hottest period. Each room contained thermocouple sensors to measure the air temperature of indoor environment. In addition, lux-meters were placed in the living rooms for illumination level measurement.

Figure 5 shows the recorded indoor and outdoor air temperatures. The recorded outdoor temperatures during this period varied from 25.5 to 36.8°C, while the indoor temperatures from 26.3 to 36.1°C. The indoor air temperatures were always lower than the outdoor air temperatures during the daytime. The average indoor temperature of townhouse type A was lowered below the average outdoor temperature by 3.14°C. The average indoor temperature of townhouse type B was lowered below the average outdoor temperature by 0.22°C. Also the average indoor temperature of townhouse type C was lowered below the average outdoor temperature by 3.71°C.

The indoor air temperatures were lower than the outdoor temperatures from about 12 a.m. till 5 p.m. due to absorbed heat by walls. The indoor temperatures were slightly higher than the outdoor temperatures during nighttime due to the daily heat storage dissipated from walls built with brick or concrete block, which increased attic temperatures above the outdoor temperatures. The system of ventilation is judiciously chosen for these townhouses, which reduces the thermal heat transmitted through roofing material during daytime.
Figure 5. Shows Indoor Air Temperature of 3 Prototype Townhouses and Outdoor Temperature Recorded for 3 Days.

Source: Original Research

The average indoor air temperatures in the townhouse type A and C as can be seen in Figure 5 were lower than the outdoor temperatures during daytime with slight variation at night. The indoor temperature in the townhouse type A could reach up to 34.5°C and seems to be slightly higher than the indoor temperatures expected with townhouse type C. Most probably, this is due to the lightweight wall partitions used in townhouse type A with negligible heat storage, which may explain the raised indoor temperature during daytime, whereas, the thermal capacity of building envelope realized with bricks has the effect of delaying the impact of external conditions on the interior of the building.

The outdoor daylight illumination recorded during this period varied from 6800 lux to 8,000 lux, while the indoor daylight illumination from 300 lux to 1,500 lux. From Figure 6, it can be seen that the daylight illumination of town house type A and C were lower than that of townhouse type B. This was affected by the larger windows area of townhouse type B and less shading.
Figure 6. Chart Shows the Comparison of Indoor Daylight Illumination of 3 Prototype Townhouses and Outdoor Condition.

Source: Original Research

The maxima indoor temperature of townhouse type A was below the maxima outdoor temperature by about 6.3°C. The maxima indoor temperature of townhouse type C was below the maxima outdoor temperature by about 7.6°C. Unfortunately, the maxima indoor temperature of townhouse type B was slightly below the maxima outdoor temperature. The absorption and the release of heat in townhouse type B were rapid unlike the two above houses of the masonry and concrete type where absorption and release of heat were gradual. Consequently, the maximum difference in indoor temperature of townhouse type B was higher than that of the townhouse type A and C by about 3.1 and 4.4°C, respectively. The natural ventilation could well improve the thermal comfort in the townhouse type A and C to an acceptable level, whereas it may not be a sufficient strategy in the townhouse type B.

The result shows that the prototype houses provide a comfortable indoor environment for their occupants and appropriate daylighting. The townhouses type A and C represent the most comfortable houses, due to the average indoor air temperature was significantly lower than the average outdoor temperature. The townhouse type B provides the least energy efficiency among three types. Additional cooling effect can
be achieved by the provision of natural ventilation or electric fan.

CONCLUSION

This study brought attention to design solutions involved in the construction of the townhouse under Songkhla climate. The use of air-conditioning in Songkhla may be inevitable if the occupants require higher standard of comfort. However, attempts can and are being made to reduce the energy consumed by the system. Energy conservation is expected to remain the main focus even into the period of climate change. Professionals in the built environment need to work together in a holistic manner to ensure that all aspects of buildings, including the building envelope, fabric, services and operational use of the building systems function together to ensure good thermal performance with low-energy and low carbon emissions. This leads to the design of energy efficient townhouses that will minimize the future energy consumption required by the occupants for cooling and lighting. Conservation of energy in a house is as much the responsibility of the occupants as it is of the designer. A well designed project may actually consume more energy than a similar conventional project, if the occupants are not prepared to use the building as it is supposed to be used.

BIBLIOGRAPHY


