Roof Forms for Energy Saving in Thailand

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ABSTRACT

A roof is one of the most important characteristics of Thai architecture especially in a house, traditionally. Also, the roof is a part of the house that mainly effects energy saving due to heat allowance pass through and release from indoor space. The study, based on model experiments, targets to find out the effects of roof forms on indoor air temperature. The purpose is to give information for roof form types selection in Thai Houses. Models, 1x1x1 meter boxes, are used for the experiments by changing their roof forms for comparison. Four types of roof forms, typically used in Thai houses, are selected for the experiments. Those types are gable roof, hip roof, lean-to roof, and flat roof. Temperatures in the middle of the boxes are recorded for the analyses. The results showed that the temperature in the flat roof box is the highest in the middle of the day. However, it dropped fastest in night-time. During the daytime, temperatures in the box of the other roof forms are not much different, while the temperatures in the gable roof model dropped likely faster than the rest. This study gives information for the users in selecting roof forms for their houses.

1. INTRODUCTION

The roof is a part of the building that performs multi-functions. In tropical climate the roof protects the building from rain and sun. So, the roof in this climate becomes an important element of the building especially for a house. The roof is expected to provide a comfortable environment for the house. Indoor air temperature is one of the key elements that related to the human comfort zone, which is emphasized in this study.

For low-rise building, a roof is the element that primarily intercepts solar radiation. So, in hot tropical climate, the roof is designed to control the solar heat loads. It is necessary to reduce the heat transmitted through the roof as it is the most exposed element to solar radiation impact, as it receives sunlight for practically the whole day, and in the tropics the angle of incidence is close to normal in the hotter part of the day. (Kabre 1999) First the radiation raises the temperature of the roof and the air above the roof surface. The heat is then transferred into the building, and the transferring rate is dependent upon the conductivity of the roof material.

Different roof forms accept solar radiation differently. In hot countries, it is popularly believed that the roof is the main heating element of a house. (Givoni 1976) By this, the indoor temperature beneath each building is different depending on the roof forms.

However, in Thailand, mostly, the roof form has been selected with the purpose to show a building's characteristic. So, to

maintain suitable indoor temperature, insulation is largely added to help control heat gain from the roof. However, energy-efficient roof form can reduce indoor temperatures significantly during the summer, and thus reduced the large amount of insulation and the energy requirements for air conditioning. The study of roof forms in terms of thermal performing will be guiding to improvement of the indoor air temperature in Thai Houses.

2. ROOF FORMS IN THAILAND

A configuration of roof selected for a house in Thailand is relatively dependent upon the roofing materials. However, nowadays, roof materials allow designers and owners to have more choices for their roof forms.

A traditional Thai house had a gable roof with slope of 50^{o}-60^{o}. (Fig. 1) This high slope solves problem of water leakage in rainy season as the roof was made of natural material such as grass and wood tiles.

Figure 1: A traditional Thai house had a gable roof with a slope of 50^{o}- 60^{o}.

In 1970s, a new material for roofing, e.g. asbestos cement roof tiles, allowed the roof to be sloped as low as 15^{o} -20^{o}. With this roofing material, the low sloped gable roof had become popular at that time.

Recently, concrete tiles are a common choice for designers and owners because it is more durable and it has many ranges of colours and forms. The concrete roof tiles need a slope between 30^{o} to 40^{o} to avoid leaking problem. (Fig. 2) With these materials, hip and gable roof are popularly selected for a house.

Figure 2: The concrete roof tiles need a slope between 30^{o} - 40^{o}.

With the advance technology of the present, most roofing materials can solves rain leaking problem. The owners and designers can freely select their roof forms. The roof form is designed to show the architectural characteristic instead of its real functions. This mistakenly draws to solve a problem of indoor over-heated by high power air-condition and thick insulation.

Thus, this study aims to show advantages and disadvantages of each roof form by using indoor air temperature as key factor for the analysis.

3. METHODOLOGY

It can be concluded that several roof forms commonly found in Thailand are gable, hip, lean to and flat slab roof. Because each roof form allows heat from solar radiation and others get into or out of the interior space differently, the indoor temperature of each roof form will be different. The indoor temperatures under these four roof forms are used for comparison as the indoor temperature is one of the most important parts of comfortable environment of living space.

Models for the experiment were set on the top of the Technology Research Building in the faculty of Architecture, Khon Kaen University, Khon Kaen, Thailand. It is located on latitude: 16-26 N and longitude: 102-50 E.

The boxes, 1.00 x 1.00 x 1.00 m., sealed with foam as insulation and gypsum board on 5 sides are used for the experiments. Four types of roof forms; gable roof, hip roof, lean-to roof and flat roof, represented the widely used roof forms of Thai Houses. These four roof forms were placed on the top of each box and sealed the connection. (Figs 3-8) Data loggers are placed in the middle of the boxes for temperature measurement. The temperatures inside the boxes are recorded hourly for the comparison and analysis.

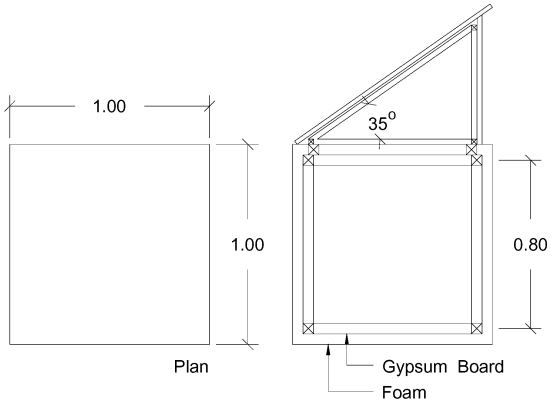

Figure 3: Detail of the lean-to roof model.

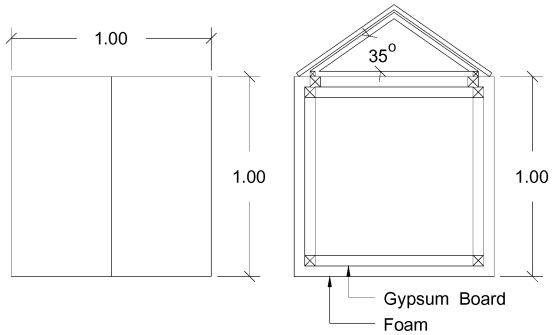

Figure 4: Detail of the gable roof model.

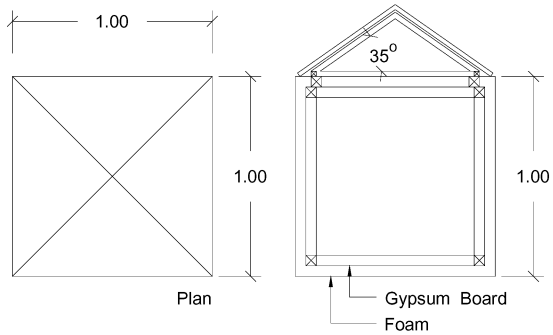

Figure 5: Detail of the hip roof model.

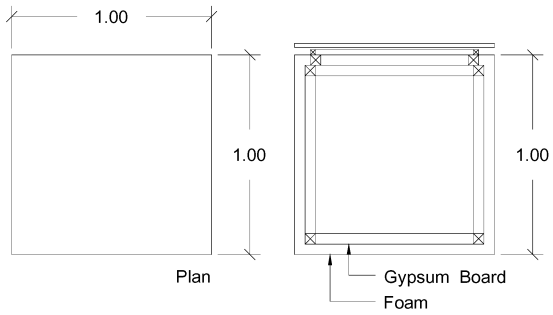

Figure 6: Detail of the flat roof model.

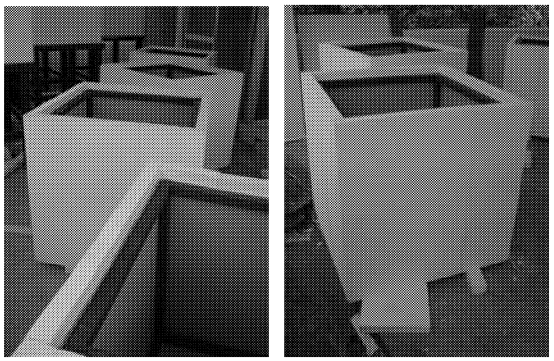

Figure 7: The boxes before places them on the roof

Figure 8: The models were set on the roof top of the research building in Khon Kaen, Thailand

4. RESULTS AND ANALYSIS

4.1 The Comparison of Roof Slopes

This part of the experiment aims to find out the effect of roof slope to the indoor air temperature. Lean-to Roofs with the slope of 15 and 35 degree faced south are used for the study. (Fig. 9)

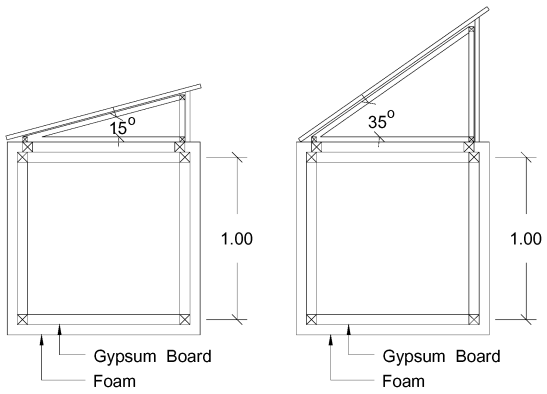

Figure 9: The 15 and 35 degree lean-to roof.

The results of this study (Figs 10-11) showed that the indoor temperatures of the lean-to roof with the roof slope of 15 degree during mid of the day, 11.00 am – 8.00 pm., are higher than the lean-to roof with the slope of 35 degree. During the peak time, the indoor temperatures in both boxes were the highest, the gap of the indoor temperatures between these two roof slopes are widest.

During the night-time and early morning, the indoor temperatures of these two roof slopes are not much different although the indoor temperatures of the 15 degree roof slope are lower.

From the results above, the 15 degree roof slope gain direct heat from solar radiation during the daytime more than the 35 degree roof slope. During the night-time, the 15 degree roof slope can radiate heat to night sky better than the 35 degree roof slope as well.

However, in the hot climate like Thailand, the heat gain from solar radiation is the main factor for indoor temperature. Thus, the 35 degree roof slope has more advantage. The ceiling in real houses, the 35 degree roof slope provides more air space between the outdoor and indoor. This space can be considered as an insulation layer for the house as well.

Importantly, the surface area of each roof form, including wall area, is influenced the heat transmission between indoor and outdoor as well. The 35 degree lean-to roof has larger surface area than the 15 degree lean-to roof, this helps heat dissipation during the daytime resulting in lower indoor temperature and helps heat inflow during the night resulting in higher indoor temperature than the 15 degree lean-to roof.

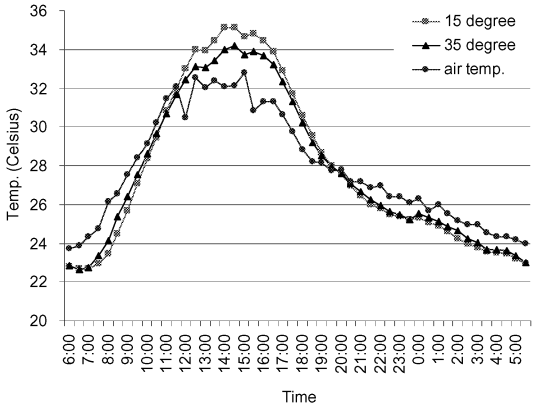

Figure 10: Result of the roof slope experiment in Oct. 15

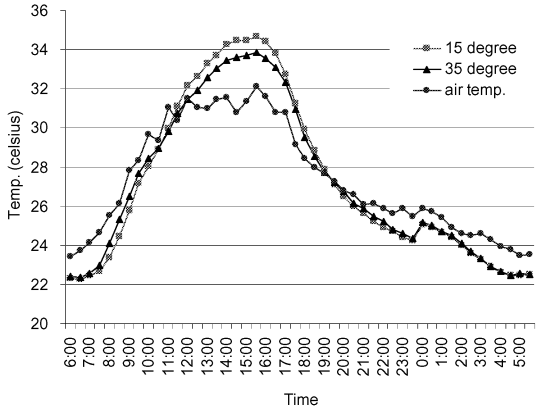

Figure 11: Result of the roof slope experiment in Oct. 16

4.2 The Comparison of Roof Forms

This part, the roof slope of 35 degree is used for the experiment. The four types of roof forms, gable roof, hip roof, lean-to roof and flat roof, are applied to the models for measuring the indoor air temperature.

For the gable roof, the roof faces to north and south, while the lean-to roof faces south. Hence, the amount of irradiance on a house is not influenced by the roof orientation. (Yingsawad and Chumnan 2006)

From the results (Figs 12-13), it is obvious that the indoor temperature of the flat roof is the highest during the daytime and lowest during the night-time. The indoor temperatures of the other three roof forms are not much in different.

During the early morning and the late afternoon, the indoor temperatures of the four

roof forms are close to each others. The indoor temperature of the flat roof becomes much higher than the other three roof forms during the afternoon.

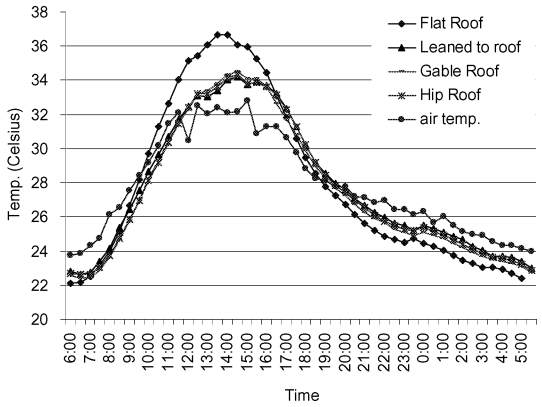

Figure 12: Result of the roof form experiment on 15 Oct.

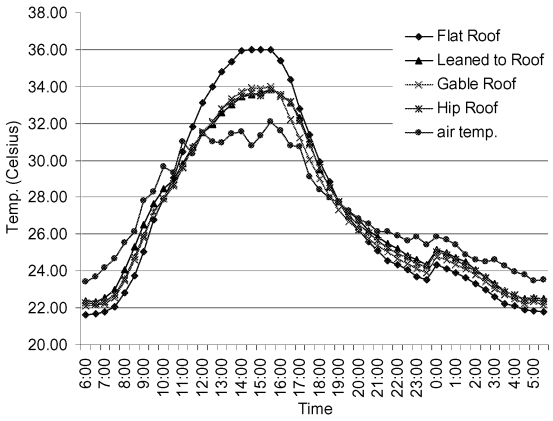

Figure 13: Result of the roof form experiment on 16 Oct.

In detail, the results of the indoor temperatures during the daytime (Figs 14-15) showed that, during the early morning, the indoor temperature of the flat roof are the lowest and the lean-to roof are the highest.

At around 10.30 am, the indoor temperatures of the four roof forms are almost the same value. After this point, the indoor temperatures of the flat roof rapidly increased until it reaches the highest point at around 2.30 pm. The indoor temperature of the four boxes dropped rapidly during the late afternoon.

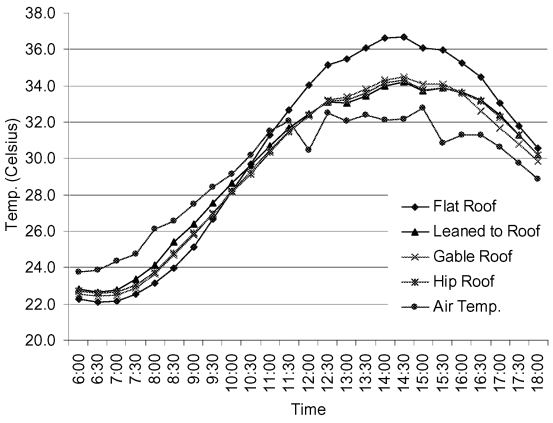

Figure 14: Result of the roof form experiment in Oct. 15, daytime

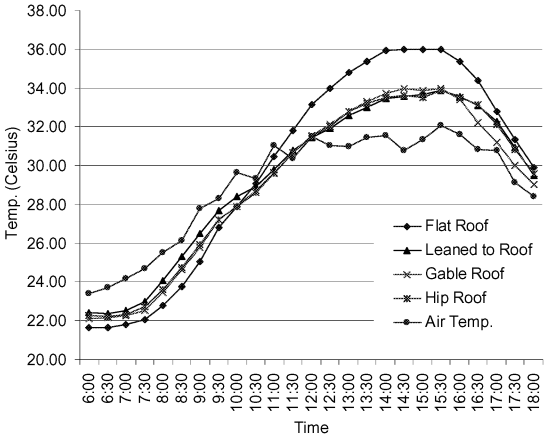

Figure 15: Result of the roof form experiment in Oct. 16, daytime

During the night-time, the results (Figs 16-17) showed that, at 6.00 pm., the indoor temperature of the flat roof is the highest. Then, the indoor temperature of the flat roof dropped faster than the others and became the lowest after 7.30 pm.

The indoor temperatures of the lean-to roof are highest during the night-time.

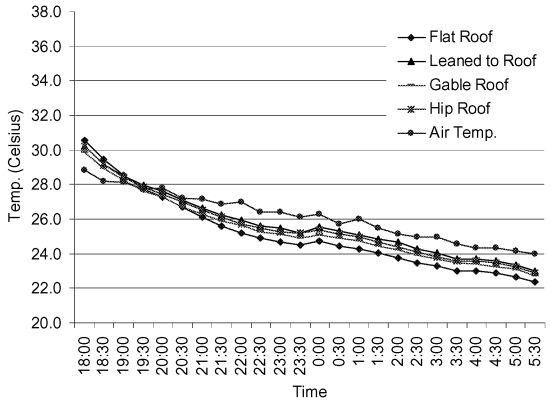

Figure 16: Result of the roof form experiment on15 Oct., night-time

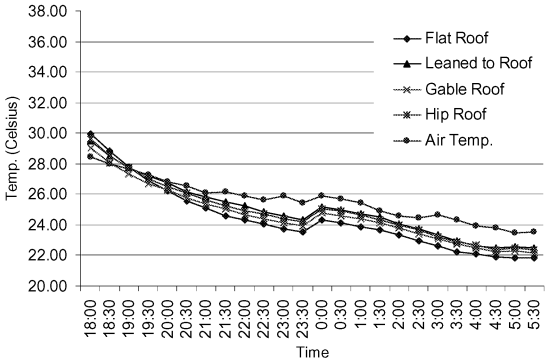

Figure 17: Result of the roof form experiment on16 Oct., night-time

From the results, firstly, the flat roof gains heat from solar radiation more than others as the angle of the flat roof can intercept direct heat from the high sun angle in Thailand better than the others.

Moreover, the surface area of the each roof form model, including the characteristic of each wall, influenced by heat flux differently during the night-time and day-time.

This experiment is different from real house condition because the models for this experiment have not include the ceiling, roof ventilation, and the size of the models is much smaller than the real house. The ceiling of the real house can be used as an insulation layer for the indoor space. Also, the heat from the roof that collects in the ceiling space can release from the roof by natural ventilation or mechanical way. The small size of the boxes for this experiment makes the result, indoor temperatures, not much different especially for the gable, hip and lean-to roofs. However, the patterns of the results in both days are in the same direction.

5. CONCLUSION

For selecting roof form, it is necessary to consider the benefit both during the day time and night time. However, the results of this study showed that the daytime heat gain in the hot climate like Thailand has much more significant effect than the night-time.

The comparison of four roof forms; gable roof, hip roof, lean-to roof, and flat roof, can be a guide line for first step roof forms selection for Thai Buildings. The results showed that the flat roof gains more heat during the daytime than others but the indoor temperatures drops faster than others. For the other three roof forms; gable roof, hip roof, and lean-to roof, the indoor temperature is not much different. It can be concluded that for the roof slope of 35 degree the roof form does not effect the indoor temperature.

Finally, the experiment is simulated based on the small model which is different from the real building. Careful consideration of the result is needed before applying to real buildings.

ACKNOWLEDGEMENT

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