THE EFFECTS OF SOFFIT VENT AND THERMAL INSULATION ON REDUCED HEAT GAIN IN HOUSES IN THAILAND

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Abstract

Many residential buildings in hot humid climate are designed to have soffit vent, so that it can reduce heat gain through roof. The objective of this research is to confirm whether the design of residential buildings using soffit vent is necessary and comparing its effect in reducing heat gain with thermal insulation alone without attic ventilation. The experiments were conducted in a real building, using two rooms on the top floor of three-storey building. The results shows that the soffit vent does not help in reducing room air temperature during daytime as most designers expect. When comparing its efficiency with using thermal insulation, fiberglass, it is found that using insulation can reducing room air temperature and ceiling surface temperature during daytime much better than using soffit vent. However, during nighttime the room air temperature of the building with soffit vent will be lower. The experiments also show that under air conditioning control the room with thermal insulation will use less electricity consumption, with economic internal rate of return higher than the acceptable rate, 9%, indicating feasible investment.

Keywords: Soffit Vent, Attic Ventilation, Thermal Insulation, Roof, Reducing Heat Gain, Fiberglass

1. Introduction

Traditionally, houses in Thailand are commonly designed to ventilate hot air from attic. This is with the believe that attic ventilation can reduce heat flux from the ceiling. However, research that confirms the efficiency of this practice in hot-humid climate of Thailand is scant. Design of attic venting in Thailand needs to take into account the problem of rain intrusion during storm events. Thus, the soffit vent is more widely use for residential building than gable and ridge vents. In addition, it needs to prevent the opportunity for insect and rodent infestation in the attics by installing insect screen at the vented area. This often causes blockage at the vents due to dirt and dust. Thus, the efficiency in reducing heat gain by attic ventilation is questionable. Nowadays, many types of insulation are available in the market at inexpensive price. In practice it was found that attic venting causes deterioration of air impermeable insulation, such as fiberglass because of high moisture level in the attics.

Parker (2005) from Florida Solar Energy Center conducted comprehensive literature review of the impact and need for the attic ventilation in Florida homes. This was to find the impacts of attic venting on cooling energy use and the rationale of most U.S building codes which require the ratio of the net free vent area to the attic area at least 1:300. It was concluded that the rationale of the vent area is to control moisture in the attic for cold climate to prevent ice dams. The justification for attic ventilation for moisture control in hot humid climates is not scientifically defensible. Ventilated attics allows moisture laden air into the attics. The author also concluded that attic ventilation can reduce space cooling energy in typical homes with conventional insulation by 5%. However, the air conditioning system used in Florida homes are mostly attic duct systems, in which energy use depends on duct system leakage. In Thailand, most houses use air-conditioning system without duct, such as wall type. Thus the result may not be directly applicable to house conditions in Thailand

The study by Hendron et al. (2003) conducted field test of vented and sealed attics in Las Vegas Nevada and Tucson Arizona was shown to produce negligible savings when the duct system was tight. Cooling energy savings were clearly seen when the duct was leaky. Under typical circumstances with 10% duct leakage, sealed attic reduced cooling energy by about 8%.

In the literature review by Rose and TenWolde (1999) concluded that attic ventilation is recommended only as a design option in hot humid climates. The attic ventilation does slightly reduce summer shingle temperatures, but the impacts of shingle color and geographic location are much larger. They also cited the research done by Burch and Treado , 1978 [5] that the performance of soffit vent without ridge vents was much like performance without ventilation and enhance ventilation (i.e., ridge vents, turbines or a power fan) in addition to soffit vents produced less than 3% reduction in daily cooling loads of test houses.

In contrast, some research support the effect of attic ventilation in reducing heat gain. Such as the study by Beal and Chandra, 1995 [7], cited by TenWolde and Rose (1999), found that the soffit vents were important in providing cooling to atticd. They found that a 1:230 attic vent ratio gave a 25% reduction in heat flow through the ceiling, but they did not indicate how much this would reduced the total cooling load of the building.

Thus, from the research review it seems unclear about the effect of attic ventilation in hot humid climates. Some research concluded that attic ventilation is only design option without any significant effect in reduce heat gain through roof, but some showed supportive. Therefore, it would be benefit to conduct the research in Thailand to find out the effect of attic ventilation, different from previous research in terms of climates and different research methods. This would contribute to the better understandings in architectural design about the necessity of soffit vent and to find out its efficiency in comparison with using fiberglass in sealed attic.

2. Research Objectives

(i) The research is aimed at investigating the reduction of room air temperatures when (a) using attic ventilation through roof and (b) using fiberglass insulation in sealed attic.

(ii) The cooling energy consumption between using attic ventilation and using fiberglass in sealed attic are compared.

(iii) The economic internal rate of return (EIRR) for fiberglass insulation in order to consider the suitability of investment for new houses and retrofitted houses.

3. Methods

3.1 Experimental Procedures

The research methods employed in this research are different from previous research, as they had used computer simulation or test cells. This research aims to investigate the effect of attic ventilation in real situation. Thus, two three-storey row houses in Bangkok were selected. The test rooms, 4x5 m each, were on the top floor. One house having wooden soffit vent. The net free area of the soffit vent to the attic is 1:25. The other room with sealed attic. The houses were located in medium density area in Bangkok. The test room faces west direction. No wind obstruction through the attic space due to the height of the buildings nearby. The houses adjacent to the test rooms were unoccupied, thus no effect from the air-conditioning usage from the adjacent houses. The attics of the two test rooms were separated by concrete block wall high up to the roof tiles. The air space above the soffit of each room was installed with 10 cm. expanded polystylene foam to prevent air flow above the soffit space of each house.

The study consisted of fifth experiments, conducted during May through June 2006. The outdoor air temperature, attic air temperatures, ceiling temperatures and indoor air temperature were recorded by thermocouples. The electricity consumptions of both rooms were recorded by watt-hour meters.

3.1.1 First Experiment: *Vented attic vs. sealed attic without insulation under air-conditioning control.*

This experiment was to compare between the test room with vented attic and the one with sealed attic under 24- hour air-conditioning control at 25^{o}C. It was found that the average attic temperatures of the vented attic was close to that of the sealed attic, 30.6 and 30.8 ^{o}C respectively. Although the vent area was large, 1:25 ratio, in comparison to that specified by the U.S code, 1:300, the attic temperatures of the vented and sealed soffits did not show substantial different. Thus, the soffit vent area was closely investigated. It was found the insect screen being blocked by dust behind vented soffit. This reflected the evidence of soffit vent blockage in real situation of most houses, no cleaning ever for vented soffit.

3.1.2 Second Experiment: *Vented attic vs. sealed attic without insulation no air-conditioning control.*

In this experiment the insect screens were then removed to observe the effect of attic ventilation to achieve the highest possible net free area of the existing soffit vent. It was found that without insect screen the maximum air temperature of the vented attic was noticeably reduced to be lower than that of the sealed attic about 2.7 ^{o}C., 40.6 ^{o}C for vented attic and 42.9 ^{o}C. for the sealed attic. It was noticed that the indoor air temperatures of the rooms with vented was not lower than that of the sealed attics in the afternoon. It should be noted that the vented attic can help lower the room air temperature during nighttime rather than daytime (Fig. 1).

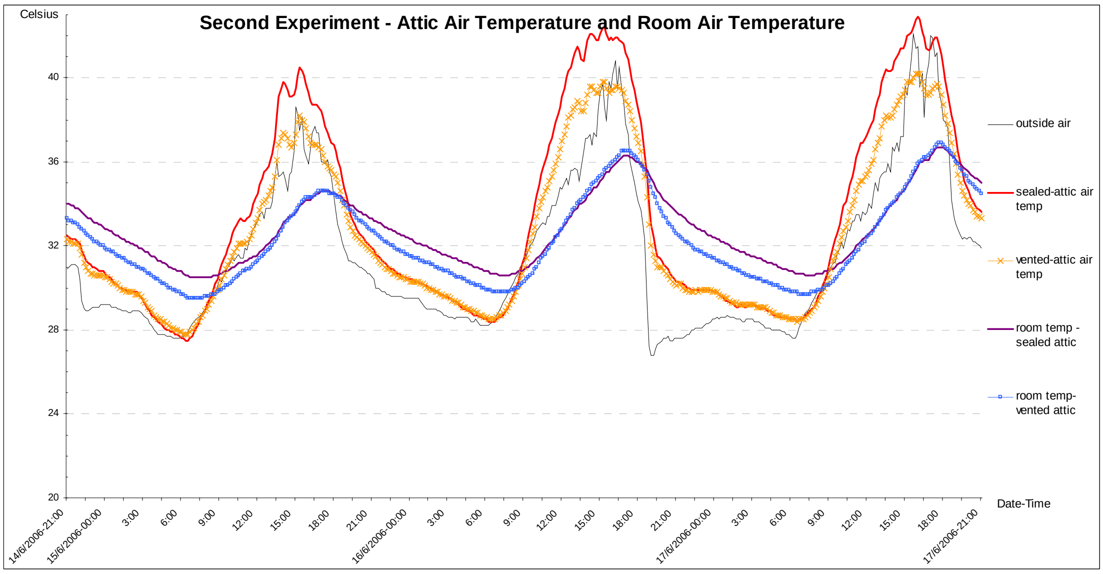

Fig.1 Attic air temperatures and room air temperatures with vented and sealed attics

3.1.3 Third Experiment: *Vented attic vs. sealed attic with fiberglass under air conditioning control at nightime*

In this experiment the three-inch thick fiberglass wrapped with aluminum foil (R=11.54 Hr ft^{2} ^{o}F/Btu), was installed horizontally above the ceiling. Both rooms were controlled at 25 ^{0}C from 9 P.M to 6 A.M. for three nights. The result of the experiment clearly showed that ceiling surface temperature of the room with fiberglass insulation was closer to the room air temperature than that using attic ventilation alone, 0.4 ^{o}C higher compared to 1.5 ^{o}C higher of the room without insulation.

3.1.4 Fourth Experiment: *Vented attic vs sealed attic with fiberglass under air conditioning control during daytime.*

This experiment was similar to the third experiment but conducted from 9 A.M. to 6 P.M. under air conditioning control at 25 ^{o}C. It was shown that fiberglass insulation can substantially reduce the ceiling surface temperature. The ceiling surface temperature of the room with fiberglass was 0.4 C higher, while that without was 4.3^{o} C higher, indicating less heat flux to the conditioned room (Fig. 2).

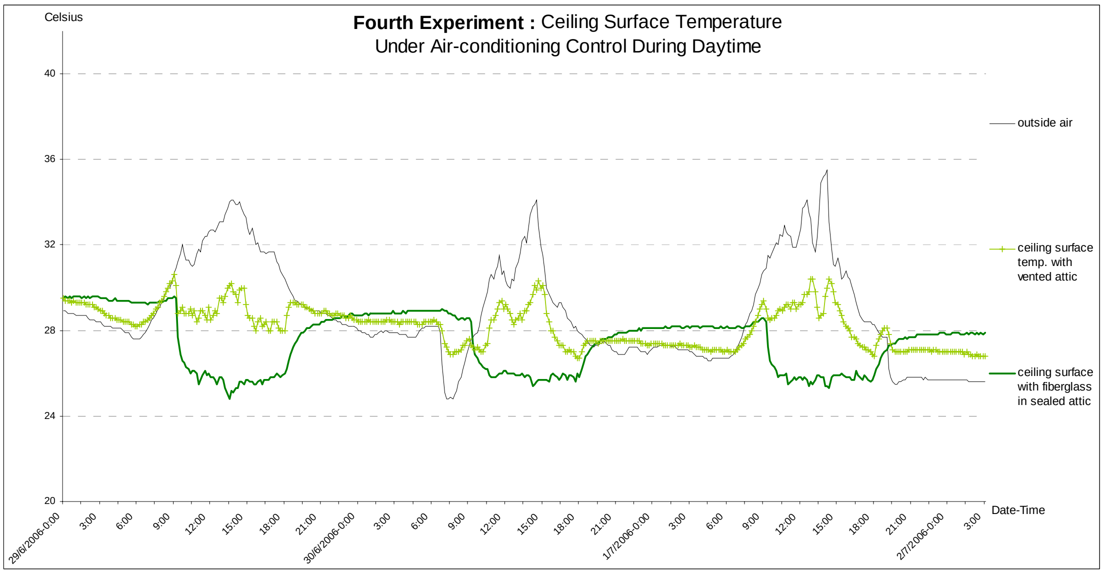

Fig. 2 Ceiling surface temperatures of the rooms with vented attic and sealed attic with fiberglass under air-conditioning control during daytime

3.1.5 Fifth Experiment: *Vented attic vs. vented attic with fiberglass under 24 hour natural ventilation*

It was found that during daytime room air temperature with vented attic was higher than the sealed attic with insulation about 1 ^{o}C, but lower during nighttime. However, it should be noted that the maximum ceiling surface temperature of the room with insulation was much lower, about 6 ^{o}C. As a result the mean radiant temperature of the room with insulation was lower, allowing better thermal comfort condition (Fig. 3).

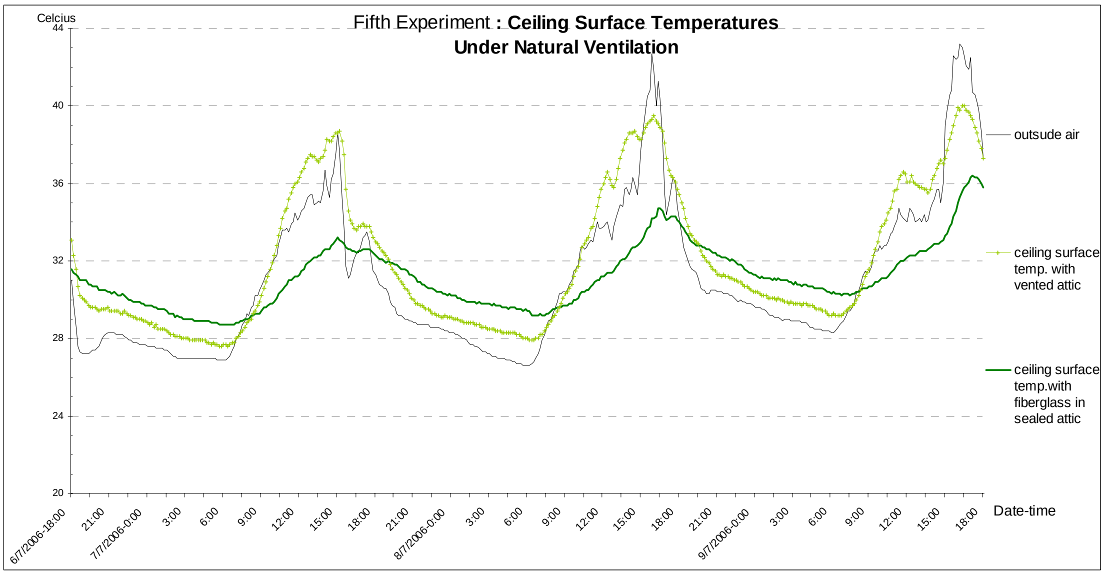

Fig. 3 Ceiling surface temperatures of the rooms with vented attic and sealed attics with fiberglass

4. Cooling Energy

It was obvious that the cooling energy of the room with fiberglass insulation in sealed attic was lower, during both nighttime and daytime operation. The hourly average electricity consumption during nighttime from 9 P.M to 6 A.M. was 0.32 kWh for vented attic and the 0.17 kWh for sealed attic. The hourly average during daytime,9 A.M. to 6 P.M., was 0.75 kWh for vented attic and 0.29 kWh for sealed attic.

5. Economic Internal Rate Of Return (Eirr)

Based on the cooling energy recorded, in the case of retrofit the existing building the EIRR when the using fiberglass was 12.7% with the payback period 6.75 year if conditioning the space during nighttime. The EIRR will increase upto 42% with the payback period 2.5 years for operating during daytime. Such values indicated that it is worthwhile for installing fiberglass to saving cooling energy. In addition, using fiberglass for the new building results in better investment. The EIRR was 16% with the payback period 6.2 years for nighttime. The EIRR will increase upto 49% with the payback period 2.3 years for daytime.

Discussion

The results from this research indicated that in real environment the attic venting has less efficiency in reducing heat gain in comparison to using insulation in sealed attic. The results also agreed with the conclusion of previous research by Parker (2005), indicating that the attic ventilation in hot humid climate had no significant effect in terms of reducing heat gain. Attic venting is only a design option.

The difference in cooling energy between both rooms some part may come from the different in room air temperature that were not exactly equal, even they were set at the same thermostat set point. In the experiments new and identical air conditioning systems were used for both rooms, and the refrigerant pressures were measured to be equal in order to eliminate the effect due unequal efficiency of the air conditioner.

In addition, the cooling energy recorded in this research was conducted under empty room conditions, without internal heat gain from people, lighting, and equipment. Therefore, the percentage of cooling energy reduction as compared between two test rooms may differ from the actual environment.

Conclusion

The research result indicated that the efficiency in reducing heat gain of the attic ventilation is lower than using fiberglass insulation in the sealed attic. Using insulation can substantially reduce room air temperature by about $1^{o}C$ under natural ventilation and reduce ceiling surface temperature by about $6^{o}C$ during peak in the afternoon, which in turn affecting mean radiant temperature and heat flux through ceiling. Using insulation can contribute more to thermal comfort than attic ventilation due to lower mean radiant temperature. In the building that use air-conditioning system, using insulation obviously saved cooling energy better than attic ventilation and worth investment.

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