THE IMPORTANCE OF ATTIC VENTILATION

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Introduction

Pitched roofs are part of traditional building all around the world in climates as diverse as tropical and temperate, as well as in cooler territories. The part of the envelope of houses most exposed to the climate is the roof. The effect of the sun, wind, rain and snow are generally more pronounced on the roof than on any other part of the building, so that heat transmission through pitched roofs with an attic is crucial for the quality of the indoor climate of the house. Attic ventilation is generally used for heat rejection and to avoid condensation. This paper deals with heat rejection, a very important matter in hot climates.

Heat Transmission through Roofs

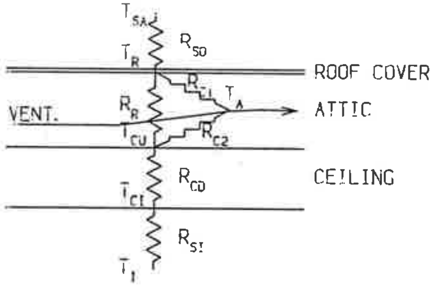
The heat transmitted through a roof will depend on the quality of the roof cover, emissivity of the attic surfaces, thermal resistances and capacities of the components and ventilation of the attic. The quality of the roof cover will determine the short and long wave radiation that are generally the main source of energy in the system. The emissivity of the underside of the roof will determine how much radiation is emitted from it to the ceiling. This is the main source of heat to the ceiling, but there is also heat transfer by convection. Thermal resistances and capacities will govern the conduction in the components. The ventilation will influence the convective transmission from the roof to the ceiling by the attic air. Although radiation is not directly changed by ventilation, it is slightly modified by the change in surface temperatures. The importance of attic ventilation for heat rejection will depend on the combination of the above characteristics and on the temperature of the ventilating air. Natural ventilation is caused by the wind and by stack effect. To use the wind, eaves openings are sufficient, but to use the stack effect eaves and ridge openings are needed. As ridge openings are expensive for low cost housing, this paper will consider only eaves ventilation.

The Mathematical Model

A simple mathematical model based on one node to represent a whole surface and one node for the attic air has been developed for steady state network analysis. An electrical analogy of the model is shown in figure 1.

All thermal resistances are taken from the guide of the Chartered Institution of Building Services (CIBS), but the radiation resistance was calculated based on the surface temperatures. The ventilation was taken into account, considering the attic air temperature as a mean between the input and output air temperatures.

This model has been run with climatic data of a summer day with 2.5% probability of occurrence in Porto Alegre, Brazil (1). The solar radiation was 935 W/m² on the horizontal surface and the screen air temperature was 32.4° C. The inside air temperature was taken to be 30° C, assuming a house without air conditioning and of low thermal capacity.



Temperatures

T_{SA} Sol-air
T_R Roof
T_{CU} Upperside of Ceiling
T_{C1} Underside of Ceiling
T_1 Room Air Thermal

Resistances

R_{SO} Roof Outside Surface
R_{SI} Ceiling to Room
R_R Radiation, Roof to Ceiling
R_{C1} Convection, Underside of Roof
R_{C2} Convection, Top of Ceiling
R_{CD} Conduction through Ceiling
T_A Attic Air Temperature

Fig. 1. Mathematical Model

Discussion

The results obtained from the model are shown in Figures 2 and 3. Figure 2 shows the variation of the ceiling heat flux with ventilation, with different solar absortivities of the roof cover and emissivity of the roof to the attic, for a ceiling thermal resistance of 0.17 m².K/W (25 mm of wood). Figure 3 shows the same for a ceiling thermal resistance of 2.0 m².K/W (25 mm of wood and a 50 mm board of polyurethane). It can be seen from both figures that the higher the solar absortivity, the more pronounced is the benefit from the ventilation. With a thermal resistance of 0.17 m².K/W (Fig. 2), a reduction of emissivity was more effective than a reduction in the solar absortivity, but with a thermal resistance of 2.0 m². K/W it was the opposite in the natural ventilation range. Both graphs show that the main part of the reduction in ceiling heat flux is in the natural ventilation range. This agree with the conclusion of other workers (2, 3, 4, 5) stating that forced attic ventilation is not worthwhile.

Conclusion

The increase in ceiling thermal resistance has been shown to be the best way of reducing heat flow through the ceiling, but it is expensive and, in low cost housing, generally not possible. Ventilation is not so effective and it must be remembered that natural ventilation depends not

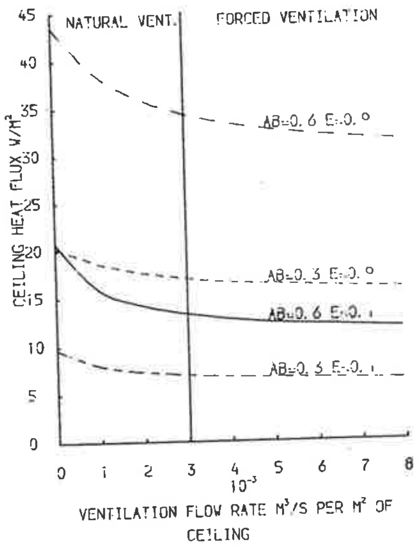


Figure 2 - Variation of Ceiling Heat Flux with ventilation for different absortivities (AB) and emissivities (E) in a roof with ceiling thermal resistance of 0.17 m² K/W

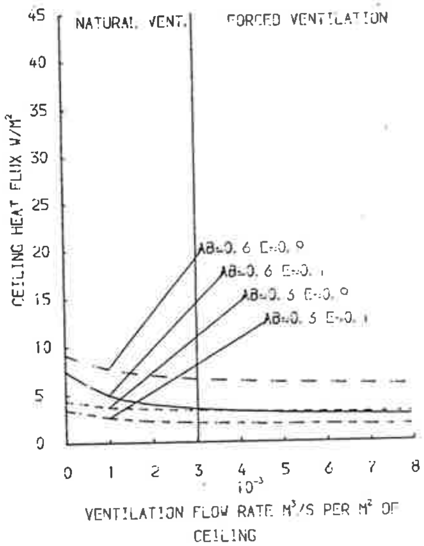


Figure 3 - Variation of Ceiling Heat Flux with ventilation for different absortivities (AB) and Emissivities (E) in a roof with ceiling thermal resistance of 2.0 m² K/W

only on the roof design but also on wind which is variable. However, ventilation can still help towards a better thermal performance of the roof and, what is more important, a greater ceiling heat flux reduction occurs in the range of natural ventilation, at no extra cost. Thus, natural ventilation must be maximised during the summer, particularly in roofs having covers of poor thermal quality.

Other simple solutions with a good cost-benefit relationship can also be used together with natural ventilation. White washing is a good improvement that will need some maintenance, but it can be done quite easily by the owner of the house. Lower emissivity in the attic has shown good results. One way to achieve this is to place an aluminium foil on the under surface of the roof cover. This positioning of the foil avoids dust (that reduces the effectiveness of the foil (6)) and forms a cavity between itself and the roof cover, so slightly increasing the thermal resistance of this part of the roof. Research is needed to study the deterioration of low emissivity materials used in this way.

Research is being continued by the authors on ventilation for attic heat rejection. Experimental measurements are being done with an indoor roof test rig of 2m by 4m in which all variables can be controlled. Parallel work will be done on the mathematical model of this phenomenon and more complex models will be compared with simple ones to analyse the errors of simplifications.

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References

(1) Sattler, M. Personal Communication.

(2) Brewster, D. & Arkfeld, T. Analysis of attic ventilation test. In: Workshop on summer attic and whole-house ventilation. National Bureau of Standards SP 548, 1979, p 105-17.

(3) Burch, D.M. and Treado, S.J. Ventilating residences and their attics for energy conservation; An experimental study. In: Workshop on summer attic and whole-house ventilation. National Bureau of Standards SP 548, 1979, p 73-104.

(4) Butt, G.S. and Harrje, D.T. Forced ventilation for cooling attics in summer. In: Workshop on summer attic and whole-house ventilation. National Bureau of Standards SP 548, 1979, p 25-38.

(5) Grot, R.A. and Siu, C.I. Effect of powered attic ventilation on ceiling heat transfer and cooling load in two town-houses. In: Workshop on summer attic and whole-house ventilation. National Bureau of Standards SP 548, 1979, p 39-56.

(6) Lotz, F.J. The effect of dust on the efficacy of reflective metal foil used as roof/ceiling insulation. C.S.I.R. Research Report 212, C.S.I.R., Pretoria, 1964.

SUMMARY

R. Lamberts, D. Fitzgerald, W. Houghton-Evans, The Importance of Attic Ventilation. Attic ventilation is compared with other means of ceiling heat flux reduction in low cost housing. A simple steady state mathematical model has been run with climatic data for a summer day of Porto Alegre, Brazil. The increase in ceiling thermal resistance has proved to be the best improvement, but it is expensive. The greatest proportion in ceiling heat flux reduction is in the natural ventilation range and forced ventilation adds little to it. As natural ventilation does not imply extra cost, it is very important in low cost housing and should be optimised. Further research is being carried on in an indoor test rig to analyse the phenomenon in detail.

RESUME

R. Lamberts, D. Fitzgerald, W. Houghton-Evans, L'importance de la ventilation de grenier. La ventilation des greniers est comparee avec d'autres moyens de réduction du flux theknique au plafond dans les habitations à coût modéré. Un modèle mathematique simple a été opere sur des données climatiques d'une journée d'été a Porto Allegre, Brésil. L'augmentation de la résistance thermique prouve être la meilleure amélioration, mais coûteuse. La plus grande proportion dans la réduction de flux thermique au plafond se trouve dans le champ de la ventilation naturelle, et la ventilation artificielle y-contribue peu. Comme la ventilation naturelle n'implique par de coût en plus, elle joue un rôle important dans l'habitation a coût modéré et devrait être optimisée.

L'on poursuit les recherches sur une toiture en laboratoire afin d'analyser le phenomène en détail.

KURZFASSUNG

R. Lamberts, D. Fitzgerald, W. Houghton-Evans, Die Wichtigkeit der Dachstuhllüftung. Die Lüftung des Dachstuhls wird verglichen mit anderen Wegen den Wärmefluss durch die Decke in das Zimmer in billigen Häusern zu verkleinern. Ein einfaches mathematisches Model mit zeitunveränderlichen Parametern wird mit den klimatografischen Tatsachen für einen Tag im Sommer in Porto Alegre (Brasilien) benützt. Die Vergrösserung des Wärmewiderstandes der Decke ist eine gute Verbesserung, aber sie ist teuer. Der grösste Teil der Wärmeflusserniedrigung liegt im Bereich der natürlichen Lüftung. Erzwungene Lüftung hilft wenig. Da natürliche Lüftung keine weiteren Kosten verursacht ist sie für billige Häuser sehr wichtig und muss optimisiert werden. In weiterer Forschung im Laboratorium wird diese Erscheinung im Einzelnen studiert.