Thermal Exchanges Through Attics: The Effect of Insulation and Low Emittance Floor

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KEYWORDS

Attic Ventilation, Ceiling Insulation, Thermal Performance of Roofs.

ABSTRACT

To study the thermal exchanges through ventilated attics, a computer simulation algorithm was developped and validated by comparison with attic temperatures measured in-situ for one year. One of the main variables which influence the thermal behaviour of attic-spaces is the air exchange rate which takes place through the roof. Leakage data for tiled roofs were measured and are reported. Major conclusions are that: 1) the influence of the solar absorption of the roof coating is negligible in the winter but important in the summer; 2) increasing ventilation rates lessens the influence of the mass and of the insulation level of the roof coating; 3) the influence of the insulation of the attic floor is very significant and increases with the attic ventilation rate; 4) the influence of attic floor emittance decreases with the attic ventilation; this influence is more significant for the summer heat gains. A correlation for the total heat-transfer coefficient of roofs is presented.

La Transmission de la Chaleur à Travers des Toitures sur Comble: l'Effect de l'Isolation et de l'Emissivité du Plafond

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MOTS CLÉS

Isolation des Toitures, Performance Thermique des Toitures, Ventilation des Combles.

SOMMAIRE

Pour étudier la transmission de la chaleur à travers des toitures sur comble, un programme de simulation a été dévelloppé et validé pour comparaison avec les températures du comble mésurés in situ tout au long d'un année. Un des principaux paramétres qu'influence le comportement thermique des combles est l'infiltration de l'air à travers de la couverture. Valeurs des taxes d'infiltration pour toitures sur comble ont été mésurés et sont presentés. Avec ces donnés, le comportement thermique des toitures sur comble a été calculé. Les principaux conclusions sont les suivants: 1) l'influence du facteur d'absorption du rayonnement solaire de la couverture est negligeable dans l'hiver, mais par contre important dans l'été; 2) la ventilation de comble réduit l'influence de la mass et de l'isolation thermique de la couverture; 3) l'influence de l'isolation thermique du plafond est très important et augmente avec la ventilation du comble; 4) l'influence de l'émissivité du plafond réduit avec la ventilation du comble; cette influence est plus considérable dans l'été. Une correlation pour le coefficient de transmission thermique des toitures est presentée.

INTRODUCTION

To study the thermal exchanges through ventilated attics, a computer simulation algorithm was developped and validated by comparison with attic temperatures measured in-situ for one year[1,2]. This program is based upon hour-by-hour heat transfer simulation, and it uses the so-called ASHRAE weighting factors to incorporate the heat gain effects into the cooling load. The program calculates the amount of energy necessary to maintain thermal comfort at a desired level or, if the capacity of the heating system is insufficient, it determines the new temperature prevailing in each zone.

One of the main variables which influence the thermal behaviour of attic-spaces is the air exchange rate which takes place through the roof. Leakage data for tiled roofs were measured and are reported in Table I.[3]

With this data, the thermal behaviour of ventilated attics was calculated and is presented in terms of the following parameters: solar absorption of the roof coating; U-value and specific mass of the roof coating; U-value and specific mass of the attic floor; and attic floor emittance.[4]

A SUMMARY OF MAJOR RESULTS

The simulations that were performed for various types of roofs have permitted an evaluation of the influence of the important parameters upon roof performance. The major conclusions are listed below:[4]

- The influence of the solar absorption of the roof coating is negligible in the Winter but important in the Summer; a variation $\Delta\alpha=0.3$ can cause a 30% change in the heat gains.
- Increasing ventilation rates lessens the influence of the mass and of the insulation level of the roof coating. Moreover, as it is important to ventilate attic spaces to control condensation in Winter and reduce Summer heating loads, it appears more effective to act upon ceilings rather than roofs. Two options are available:
  - i) insulating over the ceiling;
  - ii) covering the ceiling with a layer with low-emissivity.

To compare these two strategies, two cases were simulated: 1 cm of insulation ($\lambda \simeq 0.04$ W/m^{2}K) or a layer of aluminum coated paper ($\varepsilon = 0.3$) over the ceiling floor. The effect of ceiling mass was neglected.

It should be noted that the "reference" roof (heretofore designated as "initial" values) is noninsulated and, thus, the application of a 1 cm layer of insulation corresponds to a significant improvement. While noninsulated ceilings have a U-value of 2.8 W/m^2.K the insulated version has U-value of 1.7 W/m^2.K.

Fig. 1 and Fig. 2 show the hourly heat losses respectively for non-ventilated and ventilated roofs.

Fig. 3 and Fig. 4 show the hourly heat gains respectively for non-ventilated and ventilated roofs.

These figures show that:

- The influence of the level of insulation of the attic floor is very significant and increases with the attic ventilation rate.

  The reduction of the maximum hourly heat loss is about 35% for non-ventilated attics, increasing to about 37% for ventilated attics (41 air changes per hour-ACH). The reduction in the total daily heat loss also increases with the ventilation rate, in both absolute and relative magnitudes (10 to 14 W/m^2 and 30 to 34% of the initial value).

  In the Summer, the reduction of the magnitude of the heat gains is about 40% in terms of hourly maxima, with or without attic ventilation. Moreover, insulation introduces a 3 hour lag relative to the noninsulated conditions. In terms of total daily gains, the reduction is also independent of the ventilation rate (about 4 W/m^2, or roughly 33% of the initial value).

- The influence of attic floor emittance decreases with the attic ventilation rate. This influence is more significant for the summer heat gains.

  The reduction in hourly heat losses during the Winter season is practically constant all day long. In non-ventilated attics, the reduction is about 8.5 W/m^2 (20% of the initial value) while it is only 4 W/m^2 (10% of the initial value) for ventilated attics (28 ACH). In terms of mean daily losses, the same conclusions apply - reductions of 7 or 3 W/m^2 for non-ventilated or ventilated attics, respectively.

  In the Summer, the maximum heat gains are reduced by 13 W/m^2 in non-ventilated attics (38% of the initial value) and by 6.5 W/m^2 in ventilated attics (30% of the initial value). Average daily heat gains are also reduced, with a larger reduction in non-ventilated attics (6.5 W/m^2) than in ventilated attics (3.5 W/m^2).

CONCLUSIONS

The figures show that the insulation is much more efficient in Winter conditions, but in Summer the aluminum coated paper and the insulation have similar performances.

A correlation for the total heat-transfer coefficient for ventilated roofs (Uv) is presented in function of the total heat-transfer coefficient for non-ventilated roofs (U) and the ventilation rate (in air changes per hour-N) of the attic space (N = 13 and N = 9 for asbestos cement shingles and N = 41 and N = 28 for ceramic tyles, respectively in Winter and in Summer).

$$Uv = U + \alpha_{w(s)} N^{0.70} \qquad (1)$$

where $\alpha_{w(s)}$ is the ventilation factor, whose values are given in Table II.

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TABLE I. Experimental values of flow coefficients of roof coatings

Roof type	Flow coefficients C (l/s.m^2.Pa)	n	Statistics[a] N	r^2
Ceramic tiles				
- Type I	4.59	0.537	11	0.999
- Type II	3.97	0.595	12	0.997
Cement tiles	4.64	0.385	12	0.976
Asbestos cement shingles				
- Type I	1.08	0.936	12	0.933
- Type I[b]	0.67	0.688	14	0.972
- Type II	0.64	0.688	14	0.997

[a] Number of experimental points and correlation coefficient

[b] Wheather stripped

TABLE II. Values of the ventilation factor $\alpha_{w(s)}$

Roof type	α_{winter} (W/m^2.K)	α_{summer} (W/m^2.K)
Usual	0.024	-0.031
Attic floor insulated	0.010	-0.020
Attic floor low emittance	0.042	-0.010

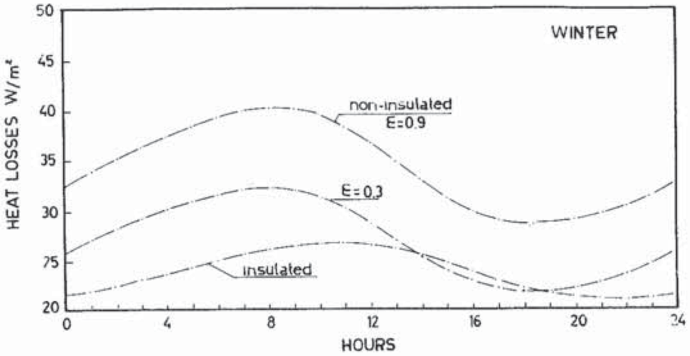

Fig. 1 Comparison of hourly heat losses between different non-ventilated attic roofs.

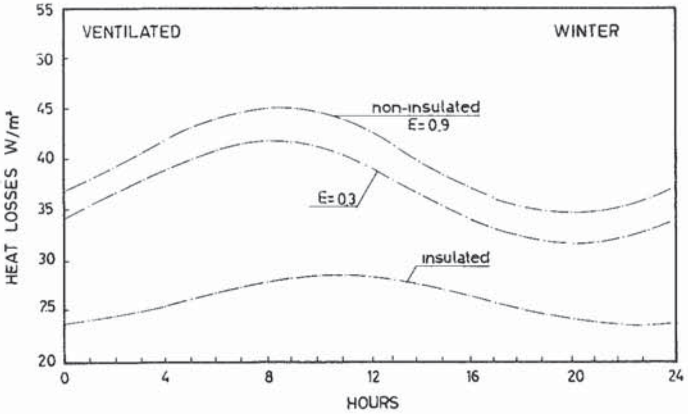

Fig. 2 Comparison of hourly heat losses between different ventilated attic roofs.

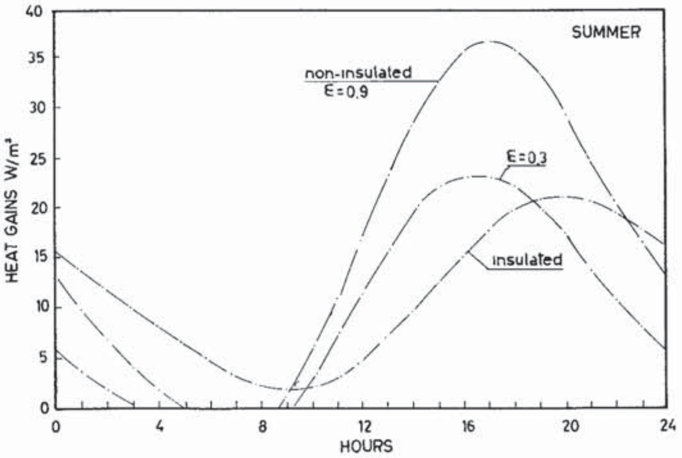

Fig. 3 Comparison of hourly heat gains between different non-ventilated attic roofs.

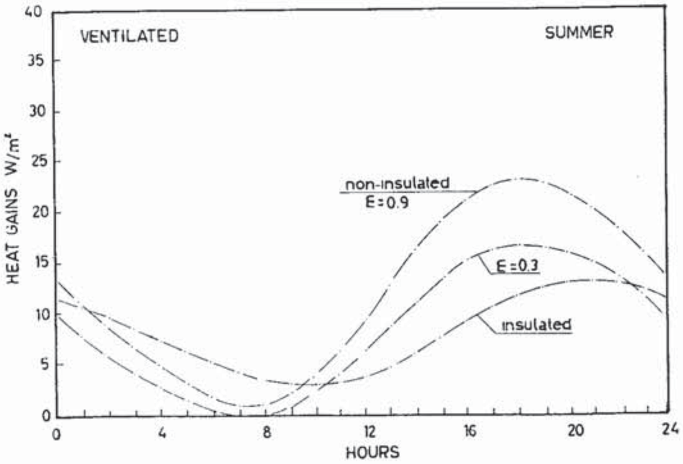

Fig. 4 Comparison of hourly heat gains between different ventilated attic roofs.

An Appraisal of Convection Coefficient Algorithms in Dynamic Thermal Models.

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KEYWORDS

Algorithms Review, Convection Heat Transfer Coefficients, Dynamic Thermal Models, Sensitivity Studies, Validation.

Heat transfer coefficients are used to represent the complex interactions of conduction, convection and radiation at the surfaces of the building envelope. Many of the dynamic thermal computer simulation models developed to date use one dimensional representations of the heat conduction equations. This fact forces the form of the heat transfer coefficients to also be one dimensional, although in reality this manifestly is not the case. In order to utilse such one dimensional heat transfer coefficients approximations must be made. One facet of the thermal model validation exercise has been to look in detail at the various sub-processes and algorithms of some discrete dynamic thermal models. An extensive review of heat transfer coefficient algorithms has been performed. Sensitivity studies have been performed on for example surface roughness, wind speed, direction, profile and turbulence, the building dimensions, the thermophysical properties of the air, etc. This has enabled the various algorithms to be assessed in the context of dynamic thermal modelling of buildings and should allow the significance of heat transfer coefficients in whole building simulations to be defined.