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Thermal comfort of a TIM-Insulated dwelling

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Abstract

Even under circumstances prevailing in a moderate climat, like in the Netherlands, extensive utilisation of passive solar energy very soon leads to overheating problems in a well insulated building design during summertime. Various options can be distinguished to reduce overheating while solar gain is preserved as much as possible during the heating season. On basis of a so called Shoebox-building model with TIM-insulated walls, modelled at a high level of accuracy at the north and south facades, an extensive number of simulations were carried out with the Suncode-pc computerprogram. The calculated impact on yearly heating and cooling loads and the number of hours exceeding 25 °C will be presented for the various cases.

1. Introduction

Within the scope of the participation of the Netherlands in IEA Task 13 "Advanced Solar Low Energy Buildings" of the Solar Heating and Cooling Program, Transparent Insulation Materials (TIMs) are being investigated for their capability of substantially reducing energy consumption in houses while maintaining thermally comfortable interior conditions.
In the initial studies the concept of TIMs as outside insulation of walls has been a topic of specific interest for its promising energetic advantages.

Practical options to reduce overheating by solar gain from TIM-walls are:

- overhangs above the TIM construction;
- intensity sensitive glazing as outer layer;
- intensity controlled shutters in front of the TIM-walls;
- seasonal controlled shutters in front of the TIM-walls;
- mechanical venting of the cavity between TIM and mass wall outer surface.
- increased venting rates for the indoor air of the building;

Best results will be obtained when one or more particular provisions will be combined within one house design. In order to simulate solar intensity controlled shading devices modifications were added to the source of Suncode and moreover an enhanced treatment of shading by overhangs was implemented. The performance of building models including the above listed options were compared at the one hand to a reference TIM case (no overheating reduction at all) and at the other hand to a reference OPAQUE case (total obstruction of solar gain from TIM-walls). Sensivity studies were carried out to determine adequate input values for the treated options.
As the objective was to assess the effect of a specifically new development on the total energy consumption of a house, no in-depth material-technical calculations were made. As a starting point the choice fell on the global modelling of a particular material within a realistic housing design. The calculations were carried out on the basis of hourly climate data for the De Bilt location in the centre of the Netherlands in accordance with the CEC-TRY climate. From the difference in solar incidence between winter and summertime it already be concluded that maximization of the solar gain for the winter months must be attended with some form of sun shading in the summer season for TIM-constructions. The TIM-modelling was based on the properties of evacuated Aerogel, assuming 20 % of the window area to be non-transparent.

2. Overhangs above the TIM construction

Advantages of overhangs:
- direct solar radiation is mainly blocked when the sun is high (in summer and in the afternoons), i.e. at moments when the solar radiation level is high;
- excess solar heat is collected outside the insulation layer;
- well combinable with other building design functions (e.g., balcony, architecturally);
- little maintenance and practically failure-free;
- no extra energy cost for operation.

Disadvantages of (permanent) overhangs:
- solar gain cannot be controlled, so that part of the radiation is kept out at moments when there is no overheating;
- fairly costly;
- limitation on architectural freedom of the designer.

3. Intensity sensitive glazing as outer layer

Advantages intensity sensitive glazing as outer layer:
- reduction of solar gain only when necessary (at high intensities);
- absence of constructional parts which reduce solar gain;
- excess solar heat is collected outside the insulation layer;
- no mechanical parts or control system;
- no additional energy cost for operation.

Specific advantages to TALD window:
- possibly lower priced in future;
- glass plate with TALD in the transparent state displays a higher solar gain than the original glass plate.

Disadvantages to intensity sensitive coatings are:
- most grades are very expensive;
- it is (generally) impossible for their action to be temporarily stopped;
- they react to conditions outside and not to the climate inside.

Disadvantages to TALD window:
- not yet ripe for being marketed;
- uncertainty about reliable effectiveness in the long run (drying out of the gel coat);
- relatively high solar gain in the diffuse state.

4. Intensity controlled shutters in front of the TIM-walls

For model calculation of energy load and temperature variation in buildings there is little difference between self-switching and externally controlled systems. However, a distinction has been made here because the use of controlled systems result in attaining extremely low solar gain factors (if placed outside the insulation layer). On the other hand, additional constructional elements often give rise to a lower solar gain in the open state.

The advantages of externally controlled covering for TIMs are:
- reduction of solar gain only when necessary (at high intensities);
- excess solar heat is collected outside the insulating layer (only for outside sun shading);
- very low solar gain in closed state;
- it can be switched off.

Disadvantages:
- the cost of most constructions is inhibitive for use on walls;
- susceptible to failure and high servicing requirements;
- additional energy consumption for driving and control system;
- constructional and/or mechanical parts obstruct part of the solar gain in the open state;

- limitation of architectural freedom of designer.

5. Seasonal controlled shutters in front of the TIM-walls

The advantages to season controlled sun shading for TIMs are:
- reduction of solar gain only when necessary (outside the heating season);
- excess solar heat is collected outside the insulation layer (only if outside sun shading);
- very low solar gain in the closed state;
- it can be switched off;
- inexpensive constructions are conceivable;
- little susceptible to failure and low servicing requirements;
- no additional energy consumption for operation.

Disadvantages:
- constructional parts obstruct part of the solar gain in the open state;
- limitation on architectural freedom of the designer;
- additional cost for manual operation.

6. Mechanical venting of the cavity between TIM and mass wall outer surface

Because of the high temperatures in the cavity between TIM and the wall during sunny periods, ventilation in this place may very well serve to carry off heat. This can be done by mechanical means or in a natural way. In this only mechanical ventilation of the cavity will be discussed, since it can be better modelled in the Suncode program.

Advantages to ventilation in the cavity of the TIM wall:
- no obstruction by the TIM wall of solar gain;
- no influence on the appearance of the building;
- controllable;
- the heat in the ventilation air can be utilized for storage or other purposes.

Disadvantages:
- susceptible to failure and high servicing requirements;
- extra energy consumption for mechanical ventilation;
- additional investment cost;
- excess solar heat is captured inside of the insulation layer.

7. Increased venting rates for the indoor air of the building

Advantages to cooling by using elevated ventilation rates:
- no obstruction of solar gain through the TIM wall;
- no influence on the appearance of the building;
- controllable according to individual needs;
- very inexpensive;
- failure proof and no servicing;
- no additional energy consumption for operation.

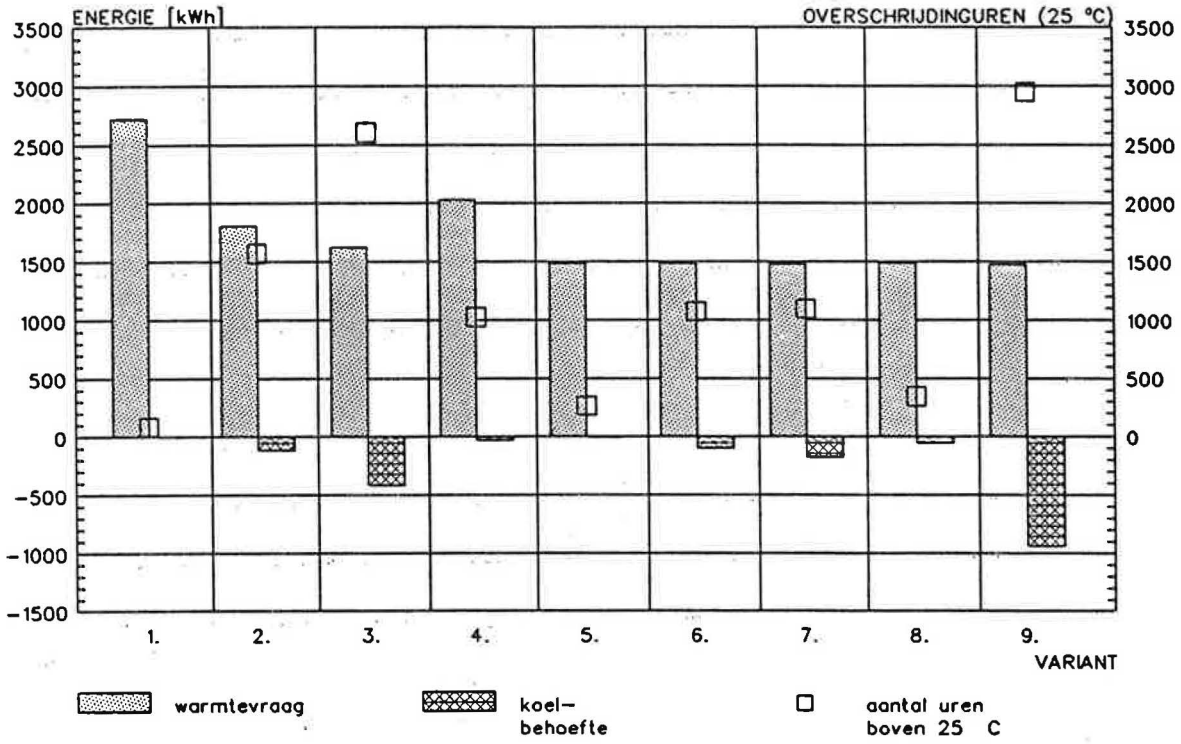
Disadvantages:
- throughout the cool season a number of windows must be open;
- sufficient ventilation is not always attained because of dependence on wind speed and difference in temperature between the inside air and the outside air;
- excessive solar heat is captured inside of the insulation layer;
- not all overheating can be vented off, since the outside air temperature may be higher than the upper limit for thermal comfort;
- possible discomfort caused by draught at low outside temperatures.

The first two disadvantages may be avoided by using a mechanical ventilation system, as a

result of which, however, the last three advantages would be sacrificed.

8. Calculation results and conclusions

The calculation results for the described variants are plotted in Figure 1. Of the options dealt with in this section the season-controlled shutters appear to display the most favourable performance. Overheating problems will be avoided and the shoebox model considered will not require mechanical cooling if throughout the summer period the TIM walls are completely covered on the outside (fixed or detachable).



1. reference case without TIM
2. overhangs above the TIM construction
3. intensity sensitive glazing as outer layer
4. intensity controlled shutters in front of the TIM-walls
5. seasonal controlled shutters in front of the TIM-walls
6. mechanical venting of the cavity between TIM and mass wall outer surface
7. increased venting for the indoor air (n = 3 ac/h)
8. increased venting for the indoor air (n = 5 ac/h)
9. TIM reference case

Figure 1: Simulation results for several cases

On the basis of climate data and calculations it may be concluded that for very well insulated houses a substantial saving on energy under thermally comfortable interior conditions can only obtained with TIM by using a system which during the heating season displays a higher solar gain than in the rest of the year, i.e. a system which is switchable as regards solar gain, for instance on a seasonal basis.
To prevent overheating the sun should for security be kept away from the TIM over a large part of the year, also at moments during the early and the late seasons when solar energy is very useful. It therefore makes sense to reduce the period over which the sun is to be kept out and to prevent the resulting overheating problems in the early and late seasons by applying a cooling option. This additional option is directed to less serious overheating problems than encountered in the summer time. It should also be realized that this additional option must function when the TIM wall transmits energy. Consequently, in order to prevent over-heating preference is given to rapidly responding options which are of direct influence on the inside climate. In that case cooling by extra ventilation would be a very obvious choice.