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Numerically analysed applications of transparent insulations

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Abstract

Numerical simulation model TCCC2D (Transient Coupled Convection and Conduction in 2-Dimensions) has been used to study the thermal behaviour of building structures with and without transparent thermal insulations.

Use of transparent thermal insulations can decrease the conductive heat losses through a structure with about 50% during one year depending on the case. The ventilation heat losses will, however, remain unchanged in conventional applications. When applying dynamic insulation, where the outside air is taken through the building envelope, also the ventilation heat losses can be decreased and the total, weekly heat losses may be reduced even with 40% of the conventional case having the same u-value. The analyses are done using the hourly weather data of central Finland.

1. Simulation model TCCC2D

This model /1/ has been developed for the analysis of the hygrothermal behaviour of 2-dimensional, convective, multilayer structures including layers of transparent insulation. The model has been verified using measured data from field experiments also with applications of transparent insulation.

2. Analysed wall structures and results

2.1 Massive structure

The analysed 2.4 m high south facing structure had 50 mm outside insulation covered on both sides with 6 mm glasses, 50 mm closed air space and 250 mm massive aerated concrete wall bounded to inside surface. The inside air temperature was +20 C or the outside temperature value when it exceeds +20 C. The thermal conductivity of the insulation corresponded to that of a capillar transparent insulation and the total transmissivity was either zero (in reference case A) or dependent of the direction of the solar radiation (case B with transparent insulation). The u-value of the structure was the same in both the cases and the inclination of the walls were 70° (90° refers to vertical) in order to have more direct solar radiation to the surface.

According to calculations the maximum temperature values at the outside surface of the aerated concrete were in the reference case A about +40 C and in the case B about +130 C. In case B the heat flow values through the inside surface varied during the year from -12 to +34 W/m^2, while the outside air temperature varied in the range of -33 to +28 C.

Fig. 1 shows the calculated yearly and monthly heat flows (kWh/m^2) through the inside surface of the structure in cases A and B. The negative values refer to heat losses and the positive to heat gains. Use of transparent insulation has decreased the heat losses with about 45% (from case A to case B). The heat losses of the structures A and B are in the same level only from October to January. From February to April the monthly reduction of heat losses due to transparent insulation varied from 3 to 4 kWh/m^2.

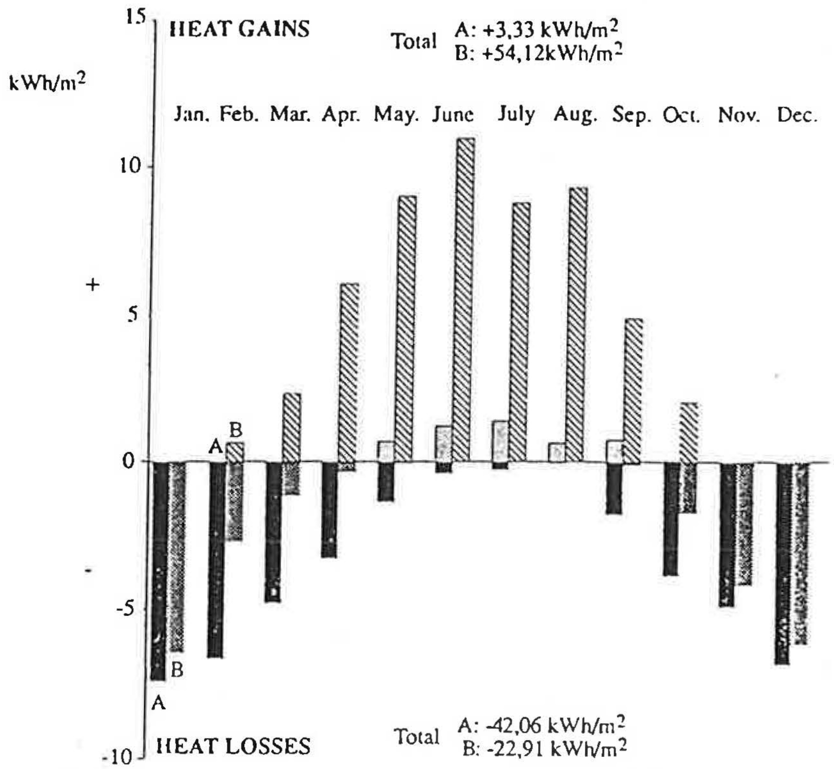

Fig. 1. Calculated monthly heat flows through south facing structures with non-transparent (A) and transparent (B) insulations.

In reference case the total yearly heat gains are only about 8% of the total heat losses while in the transparent application (B) the incoming heat flows are about 2.3 times higher than the heat losses. The heat gains in case B through April to September are high and they may cause problems by raising the inside air temperature of the room space. When the thermal capacity of the structure can't be increased and the application doesn't allow to transport the extra heat into cooler zones of the building, shading of the structure remains probably the only way to prevent overheating problems.

2.2 Dynamic structure

In typical applications of transparent insulations only the conductive heat flows are changed. When the outside air is taken through the wall into the inside air space, the incoming air warms up because of the heat recovery effect. The use of transparent insulation together with infiltrating air flow makes it possible to cut down also the ventilation heat losses. The air could also be used to transport the extra heat to those building zones, where heating is needed.

In this case the south facing vertical structure (Fig. 2) was 2,5 m high, it had transparent insulation and air space open to outside air from the bottom, 150 mm glass fibre insulation and

12 mm wood fibre board with air crack at the top of the structure. The outside air flows into the structure through the air space and glass fiber and then, in this case, through the air crack into the room space.

The inside temperature was constant +20 C and the outside boundary conditions were changed according to the weather data values during one week in March, when the temperature varied from -17 to +2 C and the daily mean total radiation to the surface was about 3,2 kWh/m^2.

The air flow rate through the structure was set to be constant 1,0 litres/sm^2, which corresponds the value 2,5 l/s per crack meter.

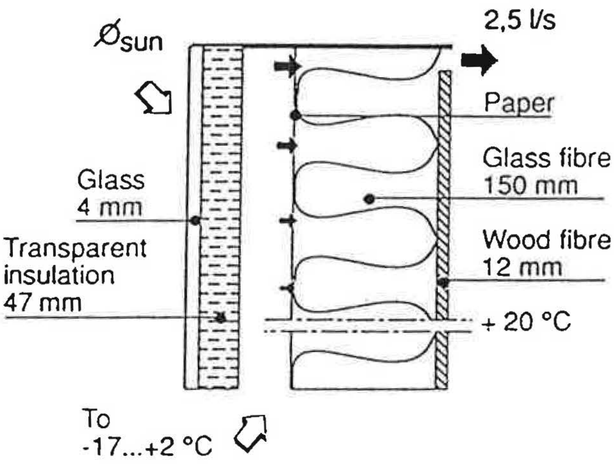

Fig. 2. Dynamic wall with transparent insulation.

Five different cases were analysed numerically:

I Outer insulation is non-transparent and the air flows (through an air inlet) to the inside air space at the outside air temperature.
II As case I but the outer insulation is transparent.
III Non-transparent insulation, the air infiltrates through the structure and warms up because of the heat recovery.
IV Transparent insulation, air infiltration.

The calculated mean conductive and convective (ventilation) heat losses through the structural area of the five cases are presented in Fig. 3.

Case I is a reference case. In case II the conductive heat losses are decreased with more than 50%, but while the convective losses are the same, the total relative heat losses ($Nu^* = q_{tot,II}/q_{tot,I}$) remain in 93% from the reference case. Heat recovery effect due to air infiltration in case III causes about the same total savings ($Nu^* = 0.93$), but now the ventilation heat losses have decrease with about 30% while the conductive heat losses have increased. When transparent insulation is used with dynamic structure, the total heat losses are decreased to 60% (case IV).

This example shows that if the transparent insulation cuts down only the conductive heat losses, the effect on total heat losses may remain relatively small. If the transparent insulation technology is used to warm up the incoming air thus decreasing the ventilation heat losses, the potentials for energy savings are much higher than in conventional applications.

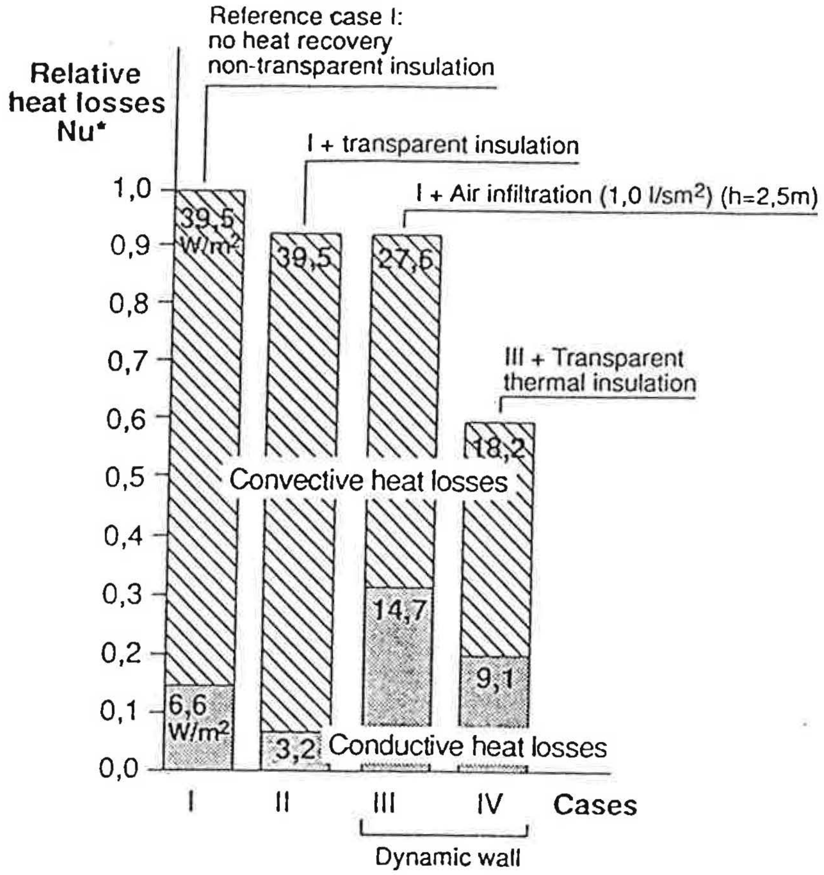

Fig. 3. Calculated heat losses with different assumptions of solar radiation, transparent insulation and heat recovery of air infiltration during one week in March.

3. Conclusions

Use of transparent insulations in south facing facades in Finnish climate can cause easily about 50% reduction in the yearly conductive heat losses through the structure. Problems of overheating may probably arise from April to September also with massive structures, if the direct solar radiation entering the wall surface isn't reduced by shading or other means.

The conductive losses are only part of the total heat losses. When transparent insulations are applied to warm up also the incoming air, the ventilation heat losses can be decreased and the effect on total energy consumption is significantly higher then in passive applications. Also the extra heat loads could be controlled better if the air warmed up by solar radiation could be blown to those building zones that need heating.

References

1. Ojanen, T., Salonvaara, M., Kohonen, R., Nieminen, J., Moisture transfer in building structures. Numerical methods. Technical Research Centre of Finland, Research report 595, Espoo 1989. 102 p. (In Finnish)