VI–3. Additional Thermal Insulation of Existing Buildings. Technical Consequences.

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ABSTRACT

Additional thermal insulation of an existing building component causes a change in the moisture balance and temperature conditions. An insulation on the outside of, for example, an outer wall is mostly favourable from this point of view. Internal insulation is, however, likely to cause technical problems. The most important of these problems, with which the paper will deal, are:

1. *Influence of thermal bridges (for example joist connections) on heat losses in the building, and possible surface condensation.*
2. *Condensation risk in the existing wall. This risk is increased if there is an existing vapour barrier, which will be on the cold side of the additional insulation.*
3. *The influence of driving rain on a wall, and the possible risk of increased damages due to frost, after internal insulation.*
4. *Temperature stresses and movements.*

Additional thermal insulation of an existing building component always causes a change in the balance with the surrounding climate. FIG 1 shows schematically how additional insulation on the outside and on the inside of an exterior wall will affect the temperature (wintertime) and the conditions at a thermal bridge such as for instance a joint connection to the wall.

Insulation on the inside of a wall is likely to cause problems, mainly because of the temperature-decrease in the wall. The most important of these problems are:

a) condensation in the building component
b) possible decrease of frost resistance
c) possible increase of thermal stresses and/or movements

The paper deals with these problems and, in addition, the influence of thermal bridges on energy saving with internal insulation.

THERMAL BRIDGES

Thermal bridges will in many cases considerably affect the energy savings that can be made with additional insulation. A great number of thermal bridges have been investigated with two-dimensional stationary computer-calculations, Andersson (1978). In FIG 2 a part of an exterior wall is shown. The wall is made of 38 cm massive brick masonry. The thermal bridges in this wall are a window splay, a concrete floor and a connection to an internal brick wall. The heatflow through the wall has been computed at inside temperature 20°C and outside temperature −20°C. This is shown in TAB 1. The window has not been included in the calculations.

The great increase of the heatflow due to thermal bridges, Q_e, is partly due to the definition of this heatflow. Q_e is defined as the difference between computercalculated heatflow through a part of the wall including thermal bridge, and the heatflow through an equally large part of the wall without thermal bridge.

The obvious conclusion from TAB 1 is that thermal bridges should be considered when energysaving with additional insulation is discussed.

Another problem, caused by thermal bridges, is that temperatures at internal surfaces decrease, and the risk of surfacecondensation consequently increases. This problem can be especially serious at window splays, since there is seldom any room for insulation to be placed at the surfaces of the splays.

CONDENSATION IN THE BUILDING COMPONENTS

If the internal insulation is made without a vapour barrier on the inside, or the performance of this vapour barrier is poor, the condensation risk will be great in wintertime. The amount of moisture accumulated will be especially great if there is an existing vapour barrier in the building component. To investigate how internal insulation can affect the moisture balance in a building component, calculations were made with a computer program developed by Sandberg (1973). In this program the onedimensional nonstationary temperature and moisture conditions are computed under simulated climatic conditions. FIG 3 shows an example for a 38 cm brick wall, situated in the south of Sweden. The inside temperature was assumed to be 20°C, and the difference between indoor and outdoor vapour concentration $3 \cdot 10^{-3}$kg/m^3 throughout the year. Another important boundary condition is the radiation coming in to the surface. In the cases in FIG 3, no radiation was assumed to be absorbed by the surface, this being the most dangerous case.

The curves show the mean moisture content in the wall without additional insulation, with 10 cm mineral wool on the inside, with 10 cm cellular plastic, and with 10 cm insulation with new vapour barrier. The heat conductivity was assumed to be 0.04 W/mK for all insulation materials.

In the case with vapour barrier, no moisture exchange is assumed to take place with the inside air. After internal insulation with mineral wool, the moisture content increases during wintertime, due to condensation in the inner part of the wall. w_{100} is a fictitious point, marking the end of the sorption curve in the calculations. It is also seen, from FIG 3, that the mean moisture content of the wall does not increase from one year to another. All moisture that accumulates during wintertime can dry out in summer. This means that condensation could perhaps be accepted, provided that the temporarily increased moisture content does not damage the building materials. Generally, it is however wise to recommend that vapour barriers are used with internal insulation, since there are many uncertain factors that cannot be accounted for in this type of calculation.

POSSIBLE INFLUENCE OF INTERNAL INSULATION ON FROST RESISTANCE OF EXISTING FACADE MATERIALS

The lowered temperature in an internally insulated wall will have the effect that the rate of drying out of moisture supplied will decrease. This, in combination with a somewhat increased possibility for freezing, could possibly increase the risk of frost damage to the facade.

The interesting source of moisture is in this case driving rain. For a brick wall, most of the driving rain that strikes the surface is absorbed into the wall, and the moisture content could be far higher than in connection with condensation only.

In FIG 4, an example of a onedimensional nonstationary computercalculation is shown. The wall is, as before, a 38 cm brick wall. During one year, driving rains of each 2,5 mm occur five times, and are totally absorbed into the wall. Four cases are studied. In two of these, one without and one with 10 cm internal insulation, no radiation is absorbed by the wall. In the other two cases, the wall is assumed to be a south wall, with a surface absorption coefficient equal to 0,7. In all four cases, no moisture exchange with the inside air was assumed to take place.

In the cases with radiation to the wall, the difference between the insulated and the uninsulated case is very small. When there is no radiation, the rate of drying out is considerably slower and there is a distinct difference between the walls with and without internal insulation. From this, one can draw two conclusions:

1) Internal insulation can affect the rate or drying out to a noticeable degree.
2) Variations in the climatic conditions can have greater influence than the insulation rate.

Although the conditions in the internally insulated wall are more severe than in the uninsulated one, the difference is not drastically great. One must, however, bear in mind that when climatic conditions are severe, the risk of frost damage to the facade materials can increase due to the insulation.

THERMAL STRESSES

Thermal stresses in a homogenous, linearly elastic, isotropic material will arise when movements due to temperature changes are restrained, or when the temperature field is nonlinear, even if there is no external restraint. The latter can be the case when there is sun-radiation absorbed by the surface. Thermal stresses can be relatively large, as is shown in FIG 5. Two structural models were used here for the wall. It was treated as a plate with fixed and with free edges, respectively. The right part of FIG 5 shows the normal stress, far from the edges, at the surfaces and in the middle of the wall. The outside climate is a sunny winter day in Stockholm. Inside temperature was assumed to be constant, 20°C. The wall is a 38 cm brick wall facing south with a surface absorption coefficient of 0,7. The left part of the figure shows the computed temperature distribution in the wall. The extreme normal stress in the wall always arises at the outside surface, since the extreme temperatures are here. The internal insulation will hardly affect the surface temperatures, and therefore the maximum stresses and movements will be much the same for a wall if it has additional insulation or not. The stress distribution in the wall will however be quite different when it is internally insulated. This could possibly be of importance, depending on how other loads affect the wall.

When two different parts of the building structure are forced to interact, stresses arise if these have different temperatures. Interaction between interior walls and exterior walls with insulation on the inside is an example of a case where thermal stresses could be a greater problem due to the insulation.

REFERENCES

1. Andersson, A–C, Thermal bridges in exterior walls with insulation on the inside. (In Swedish) Swedish Council of Building Research, Report 46:1978.
2. Sandberg, P I, Moisture balance in building elements exposed to natural climatic conditions, Div of Building Technology, Lund Institute of Technology, Report 43, Lund 1973.

TABLE 1—Heatflow through part of exterior wall in FIG 2. Heat conductivity of insulation material is assumed to be 0,047 W/mK.

Internal insulation (cm)	$Q_A(U \cdot A \cdot 40)$ (W)	Q_e (W)	$Q_{tot}(=Q_A+Q_e)$ (W)	Q_e/Q_{tot} (%)	U_{nom} (W/m²K)	U_{eff} (W/m²K)
0	533,8	34,3	568,1	6,0	1,20	1,28
5	226,6	120,1	346,9	34,6	0,51	0,78
7	186,8	130,5	317,3	41,1	0,42	0,71
10	146,8	144,4	291,2	49,6	0,33	0,65
12	129,0	149,2	278,2	53,6	0,29	0,63
15	111,2	151,7	262,9	57,7	0,25	0,59

A= wall area
Q_A= onedimensional heat flow through the wall
Q_e= sum of computercalculated heatflow due to thermal bridges
U_{nom}= "nominal" U-value, disregarding thermal bridges
U_{eff}= "effective" U-value, including thermal bridges.

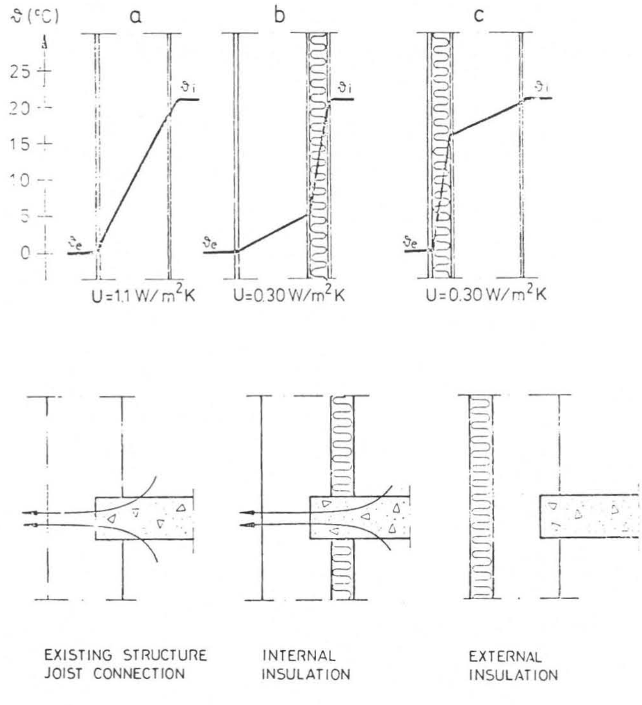

Figure 1. Influence of additional insulation on temperature distribution and thermal bridge effects in a wall.

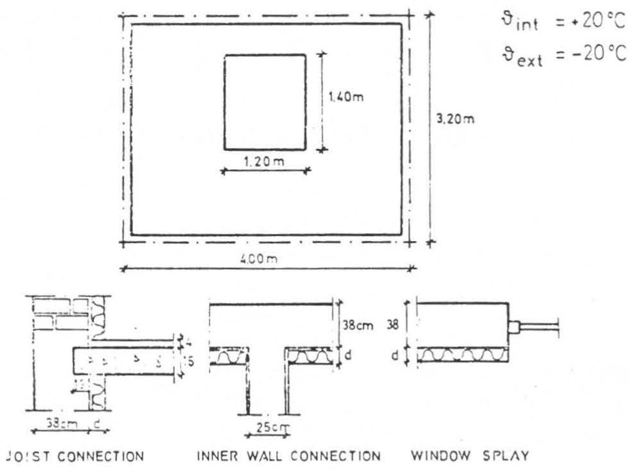

Figure 2. Part of exterior wall with thermal bridges.

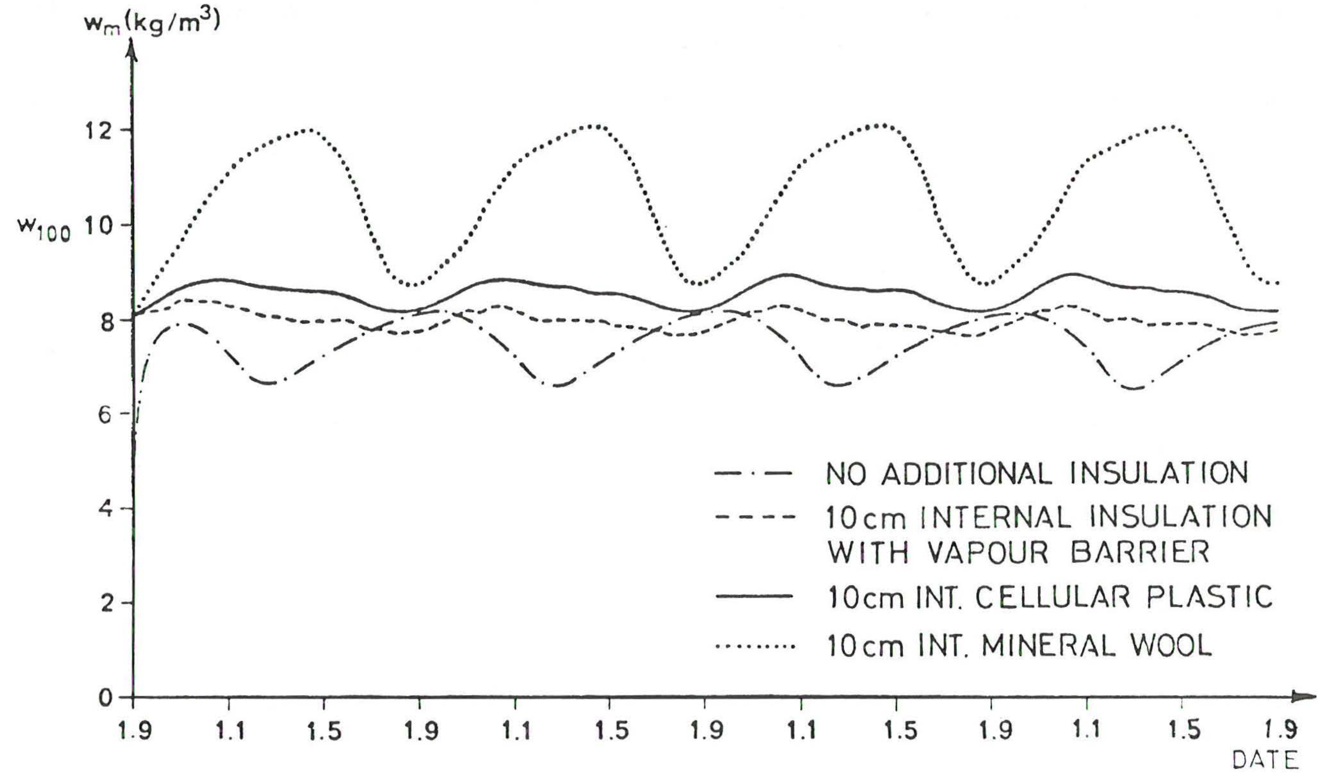

Figure 3. Mean moisture content (w_m) in a 38 cm brick wall with and without additional insulation.

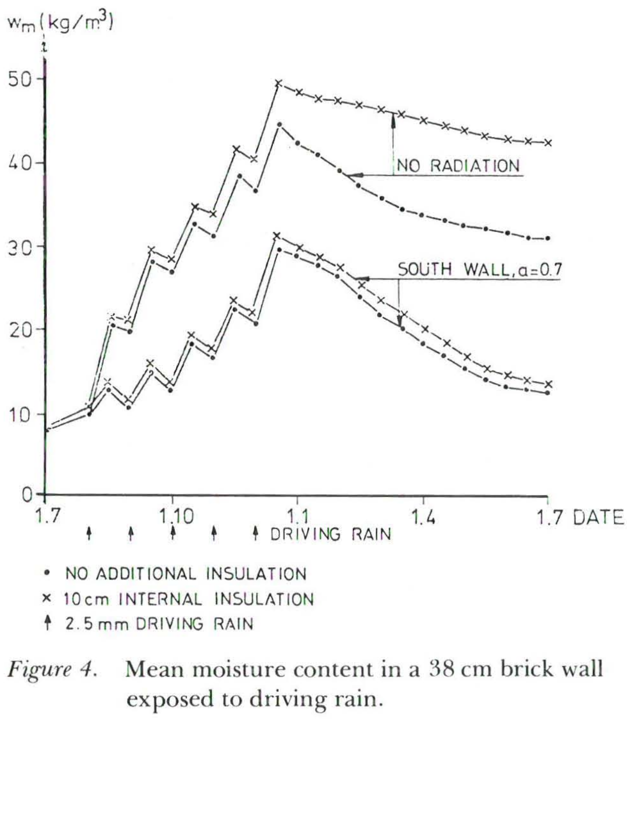

Figure 4. Mean moisture content in a 38 cm brick wall exposed to driving rain.

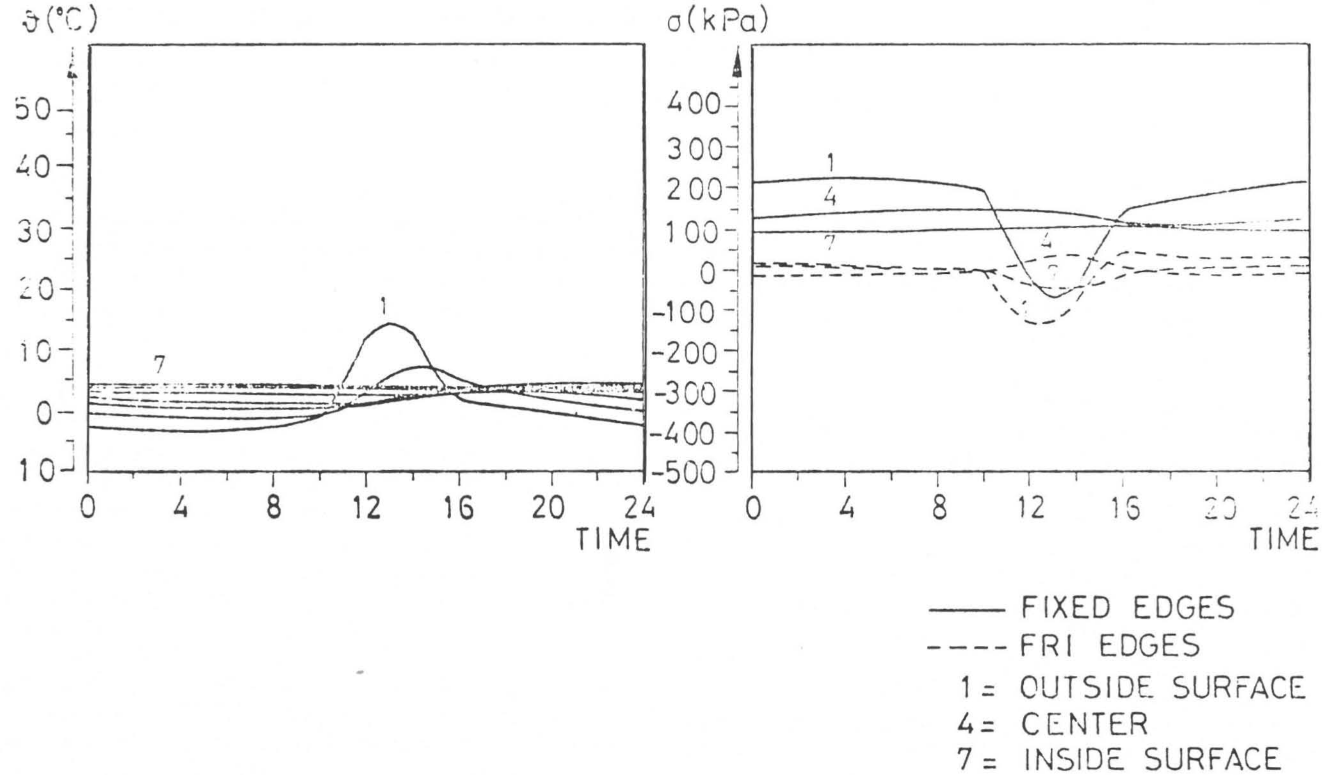

Figure 5. Temperature distribution and normal stress in a 38 cm brick wall. Modulus of elasticity 2000 Mpa, Poisson's ratio 0,3, coefficient of thermal expansion $6 \cdot 10^{-6}$.