ADDITIONAL INSULATION OF ROOFS

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SUMMARY

Additional insulation of roofs has proved to be very effective for economizing energy consumption. Depending on its performance, this additional insulation will change moisture and thermal conditions of the roof. In some cases severe moisture problems have resulted from incorrect execution. Since many of the parameters influencing the moisture balance of a roof are not yet sufficiently known, it is impossible to forecast the performance of a roof by calculation alone. Roof performance must be followed up after installation. The need for further research in this field is emphasized. Investigation shows, too, that every method of additional insulation has to be adjusted to the existing insulation against heat and moisture.

The quality of execution is of great importance, and this must be made clear. Good information is essential for improved results.

The need for energy conservation in the existing buildings has necessitated the formulation of programs of structural measures of variable scope. The object of these measures, combined with other property management measures, is to reduce energy consumption. Such a measure, which has proved especially cost effective, is additional insulation of attic floors and roofs in residential and similar buildings. The cost effectiveness is due mainly to the relative ease of placing additional insulation on a flat and readily accessible surface in existing constructions, and to the relatively slight extra work needed to apply additional insulation in conjunction with renovation and alteration. It is best to combine these measures with balancing the building's heating system so as to prevent excessive temperatures which would produce losses.

Additional insulation schemes have been carried out, although their scope has been rather limited. It has been found in some cases that the savings in energy do not meet expectations. In addition, these measures also have produced secondary damage such as damp, mould and frozen water pipes. It is these instances of unsatisfactory performance due to installation errors, that prompted a special study of the additional insulation technique with regard to structural, moisture and thermal effects.

This paper discusses how different methods of applying additional insulation in roofs change moisture and thermal conditions in the roof space. It also addresses the theoretical assumptions and the limitations of calculations. Experience gained in the course of a research project into additional insulation of roofs and the problems which this can cause also is presented.

MOISTURE AND THERMAL CONDITIONS

Depending on how they are ventilated, roofs are designated as cold or warm. The ventilated flat roof is an intermediate construction (*Figure 1c*).

Cold roofs are ventilated below the roof (*Figure 1a*). This slows the melting of snow. Any moisture which leaks into the roof space is removed by the ventilation air.

In warm roofs (*Figure 1b*) there is no ventilation, which also affects snow melting. Lack of ventilation requires a vapor barrier on the inside, unless the construction itself can cope with moisture. There is a certain amount of ventilation in the ventilated roof, but in practice it can be very little.

In principle, additional insulation can be applied below the roof space, inside the roof space, or on the outside of the roof (*Figure 2*). Aside from structural conditions, design, materials used and accessibility, the choice of insulation method is governed by architectural and town planning considerations, and often limited.

Whenever additional insulation is applied, climatic conditions in the roof are changed. If insulation is applied below the roof, the original construction will be colder. If it is applied inside the roof space, such as on the attic floor, the roof will be colder but the floor warmer. If it is applied on the outside, the whole construction will be warmer. When additional insulation is applied below the roof, and moisture from the rooms underneath continues to penetrate into the roof space after the additional insulation has been installed, this moisture will increase the relative humidity in the roof space, because the roof space is now colder, and there will be a greater risk of moisture damage. This is illustrated in Figure 3.

Insulation on the outside of the roof produces the opposite effect. The structure will be warmer than before, and in some instances will tend to dry out. At the same time the effect of thermal bridges is reduced. Ventilation in the roof space also is very significant for the moisture and heat balance. The general effect is that drying increases and the thermal insulation effect decreases as ventilation increases in the insulation layer. Theoretically, equations such as:

$$\text{Inflow} = \text{Outflow} + \text{Storage}$$

can be written for the heat and moisture balance of the roof before and after additional insulation.

However, several of the parameters which govern these equations are not yet sufficiently known. This means that the thermal and moisture conditions cannot be predicted with sufficient reliability by calculation alone. The uncertainties in these parameters may be due to:

- the actual construction of the building structure, such as the permeability to vapor and air, location of the insulation, and ventilation conditions in the roof space;

- living habits and activities in dwellings and non-residential premises, which produce moisture and temperature conditions, and pressure differences across the roof construction; and
- to some extent, material properties and outside climatic conditions.

Therefore it is necessary for the performance of the roof and the building as a whole to be carefully monitored after the application of additional insulation so that unexpected effects may be promptly eliminated. This also underlines the need for supplementary research in this field.

DESIGN AND MATERIALS

In Sweden, additional insulation of cold roofs preferentially has been carried out on the attic floor when accessibility allowed. In some, the insulation has been placed on the underside of the floor. Additional insulation in warm roofs preferentially has been placed on the outside, often in conjunction with renovation or renewal of the existing roof covering.

Some horizontal warm roofs, in conjunction with external additional insulation, have been given a new sheet metal cold roof at a slope of at least 1 to 16 in order that the roof may have proper fall for drainage.

In several cases, ventilated flat roofs, or cold roofs with a small ventilation space, have been given additional insulation by injection of insulation material into the ventilatin gap, partially filling it. A small number of the test roofs of the ventilated flat type and roofs with small ventilation space have been additionally insulated on the outside. In these test roofs, the existing ventilation openings are kept open until the existing structure has dried out to some extent. Then it is expected that the full insulation effect will be achieved. (*Figure 4.*)

Loose fill has captured an increasing proportion of the market for additional roof insulation. Using good equipment, it is relatively easy to apply, and at the same time it fills the spaces around struts and other obstacles. Mineral wool slabs and mats also are common materials. Other materials which are used include expanded polystyrene sheets or granules, extruded polystyrene sheets in upside-down-roof systems, and expanded polyurethane sheets. Sawdust or other loose filling is used to fill the gaps between the sheets and other materials.

The effect of additional insulation in reducing heat transmission through the roof, depends on the method of construction, the choice of material and the workmanship. In order that an additional insulation design be based on actual conditions, the designer should inspect the roof to be treated. This will help avoid difficult construction details, and make it possible to include in the specification any special measures required to assure good results.

WORKMANSHIP

Eaves are a difficult detail. They often are insufficiently insulated and sealed against moisture and wind. In view of this, additional insulation schemes alwasy should be preceded by adjustment of the original insulation, such as filling gaps between the insulation, boarding and joists to prevent air passages which, when in contact with cold outside air, reduce the effectiveness of the additional insulation (*Figure 5*).

Problems which often occur in the application of additional insulation mainly have to do with ventilation, such as blocking or restricting the ingress of air at the eaves, in the air gap between inclined attic ceilings and the roof, or unsatisfactory ventilation at gables and ridges (*Figure 6*).

Insufficient ventilation has caused moisture damage in the form of mould.

These workmanship problems often are attributed to lack of knowledge on the part of the workmen concerning the performance and properties of the different materials. Effective training probably would eliminate these construction defects. Control measures in the form of thermography can throw further light on the importance of workmanship to the end result.

CONCLUSIONS

The following conclusions can be drawn from this investigation.

- Different methods of applying additional insulation in roofs change the moisture and thermal conditions in the roof space. In some cases severe moisture problems have been the consequence of incorrect execution. This underlines the need for supplementary research in this field.
- Problems which often occur as a result of the application of additional insulation mainly are problems of ventilation.
- Quality of workmanship is of great importance.

REFERENCES

[1] Cornish, J.P. & Sanders, C.H., 1981, Parameters Affecting Condensation in Pitched Roofs. (Society of Chemical Industry 1982). Proceedings of The Second International Symposium on Roofs and Roofing, Vol. 2, pp 63-71, London.

[2] Höglund, I., Johnsson, B. & Lagerström, J. 1981, The Ulfsunda project. More Effective Use of Energy in Older Buildings. Stage I. (Swedish Council for Building Research.) T5:1981, Stockholm (in Swedish).

[3] Korsgaard, V., Christenson, G., Lohse, U., Prebensen, K. & Brandt, J., 1981, Additional Insulation of Flat Roofs. (COWI consult, Rådgivande Ingeniörer AS.) Publ. nr 418, Köpenhamn (in Danish).

[4] Larsson, L-E, 1979, Sandwich Panels with Foamed Polyurethane Insulation. (American Society of Heating, Refrigerating and Air-Conditioning Engineers, INC.) Proceedings of the ASHRAE/DOE-ORNL Conference on Thermal Performance of the Exterior Envelopes of Buildings, pp 638-650, New York.
Also published at Chalmers University of Technology, Div. of Building Technology, Publ. 81:9, Göteborg.

[5] Petersson, B-A, 1980, The Upside-Down Roof. Field and Laboratory Studies of Thermal Insulation, Moisture Conditions and Performance. (Chalmers University of Technology, Div. of Building Technology.) Publ. 80:6, Göteborg.

[6] Petersson, B-A, 1983, Additional Insulation of Roofs. Problems, Experience, Possibilities. (Swedish Council for Building Research.) R81:1983, Stockholm (in Swedish).

[7] Petersson, B & Axén, B, 1980, Thermography. Testing of the Thermal Insulation and Airtightness of Buildings. (Swedish Council for Building Research.) D5:1980. Stockholm.

[8] Tolstoy, N. & Persson, A., 1980, Faults and Shortcomings of Additional Insulation. (Svenska Väg-och vattenbyggares Riksförbund.) Väg-och vattenbyggaren, Nr 9, pp 29-33, Stockholm (in Swedish).

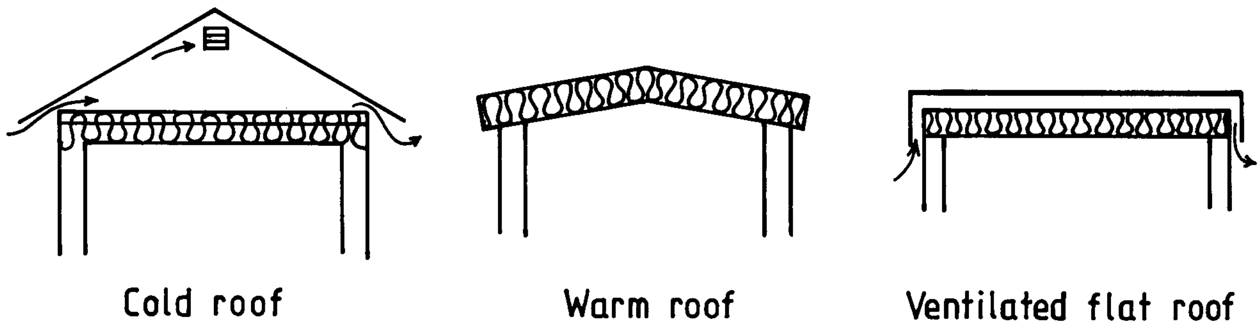

Figure 1 *Schematic difference between cold and warm roofs, and the intermediate form ventilated flat roof*

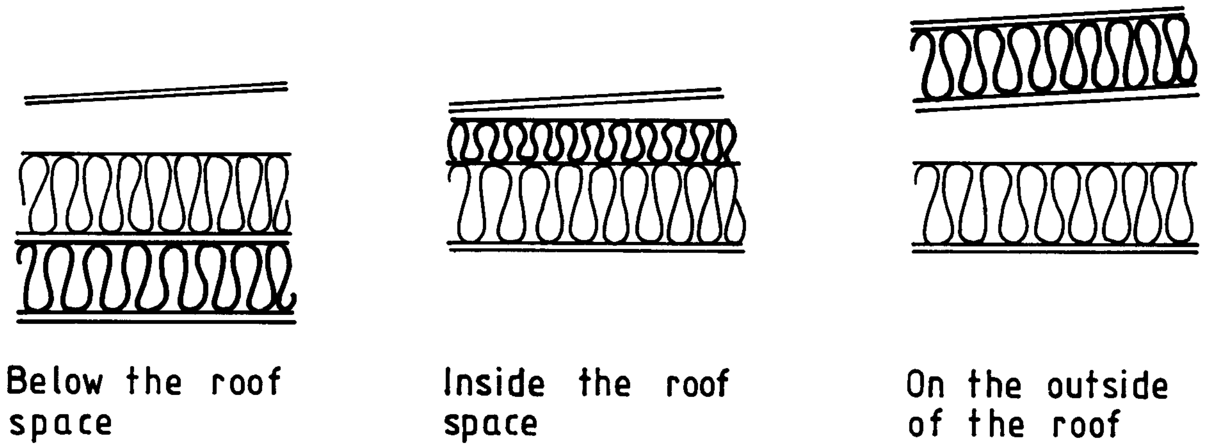

Figure 2 *Schematic arrangement of additional insulation in a ventilated roof*

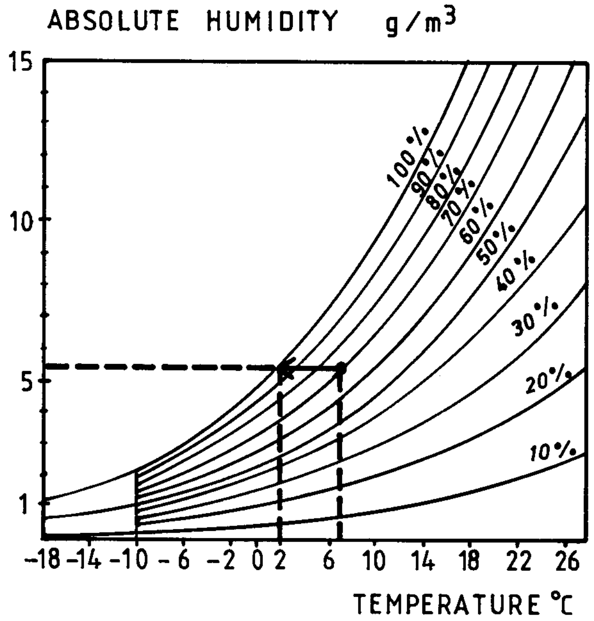

Figure 3 *Relationship between temperature, relative humidity and absolute humidity*

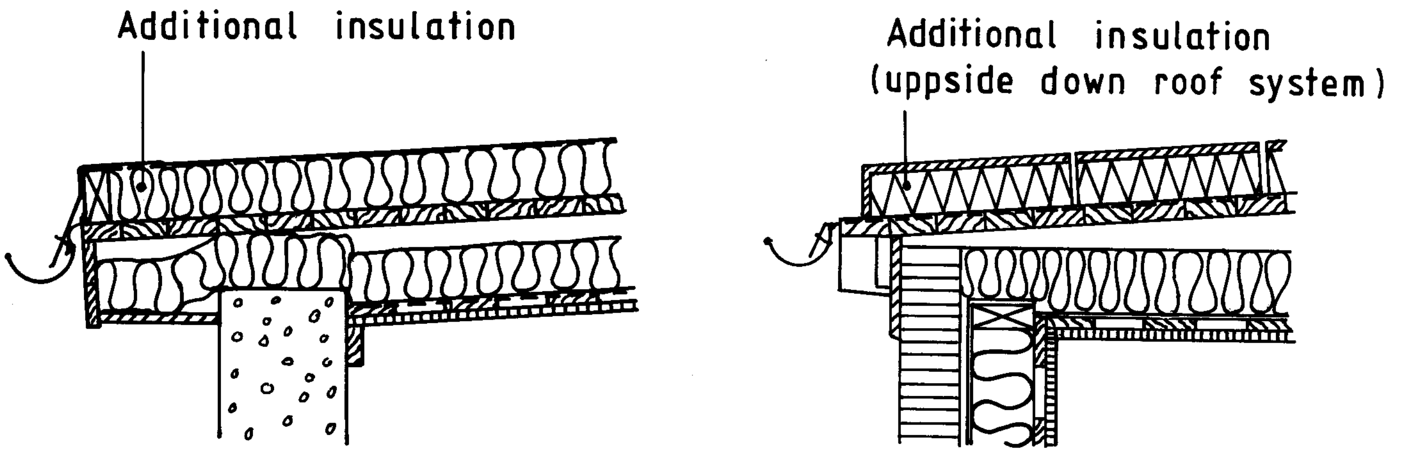

Figure 4 Example of external additional insulation of a ventilated flat roof

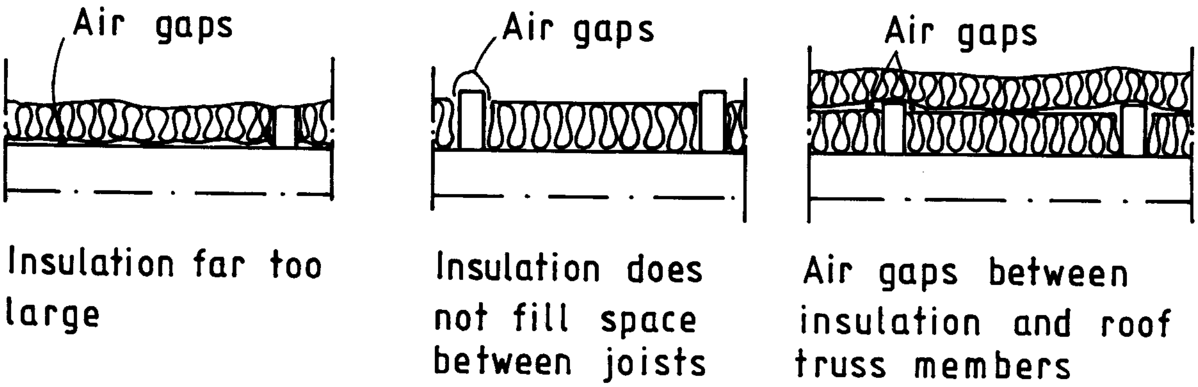

Figure 5 Examples of defects and application shortcomings which reduce the effect of additional insulation

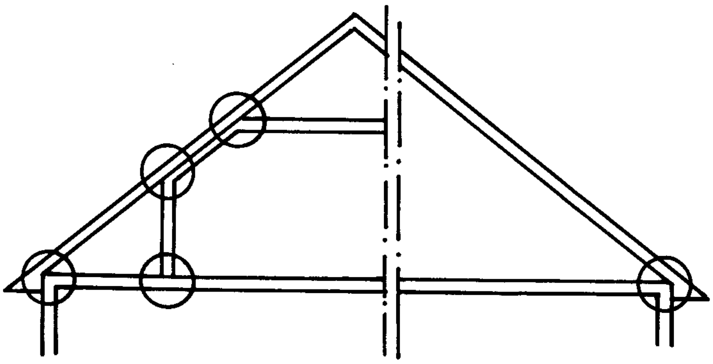

Figure 6 Sensitive construction details when applying additional insulation