

INSULATED ROOFS WITH TWO-LAYER STEEL SHEETS

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This investigation was performed in close cooperation with steel sheet and insulation manufacturers.

The double steel sheet roof with thermal insulation between the two layers has been used in Sweden to a certain extent since the 1960s.

During the 1970s, with increasing energy prices, this type of roof became more extensively used. There are several different types on the Swedish market. They differ, among other things, in the degree of ventilation under the exterior steel sheet. More than two million square meters of such roofs have been built. The main advantage is that lower density and lower cost insulation can be used in this type of roof than in a conventional built-up roof. Very thick thermal insulation is used. Thicknesses of 220 or 250mm (9 or 10 inches) are common.

The roof consists of a load carrying, trapezoidal steel sheet supported on main girders or purlins. A thin sheet plastic moisture barrier is placed on this steel sheet. On the top there is a waterproofing steel sheet placed on spacers. Thermal insulation is placed between the two layers of steel sheet. (Figure 1). The plastic sheet provides air tightness and prevents moisture penetration from inside the building. The spacers between the two layers of steel are of various designs. Most are designed to minimize heat loss. The most extreme spacing element is made of mineral wool and cold formed steel. (Figure 2).

THERMAL INSULATION

This type of roof is used mostly with mineral wool or fiberglass thermal insulation at least 6 inches thick. Ten inches is also common. With these thick insulations thermal bridges play a great role in the thermal behavior of the roof. Figure 3 shows the coefficient of thermal transmittance (U-value), as influenced by the spacing of the spacer elements. In this example the spacers are assumed to consist of Z-purlins made of 1.5mm steel plate. The U-value for a roof with 6-inch insulation and distance elements with holes as in Figure 2 corresponds to a roof with 10-inch insulation having ordinary Z-purlins. U-value measurements show that spacers with holes are very effective. They increase the U-value very little over that of roofs with no spacers. A roof with 270mm mineral wool and spacers with holes 0.95m on centers had a measured U-value of 0.172 to 0.176 W/m² °C. With another type of perforated spacer, spaced 1.45m on centers and 150mm mineral wool, the measured U-value was 0.27 W/m² °C.

DIFFERENT DESIGN PHILOSOPHIES

There are roofs based on different design philosophies on the market. There are systems with ventilated exterior steel

sheet and systems without ventilation. In the former, moisture that may enter the roof is supposed to be vented away. In the latter, moisture penetration is prevented. However, real roofs (Figure 4) are more or less ventilated. Both these types have advantages and disadvantages.

The advantage of the ventilated design is that water built-in or having leaked into the roof can be vented away. Under certain weather conditions the ventilating air introduces moisture rather than taking it away. This can happen with melting snow on the roof and humid air outdoors.

In the non-ventilated design, moisture cannot be brought into the roof by ventilation air. The risk of moisture entering from outside is minimized. It also is thought to be easier to waterproof than the ventilated design.

The real roof always will be partly ventilated. Even a roof designed as a ventilated roof will behave as a non-ventilated roof during much of the winter, because snow plugs the ventilation channels.

CONDENSATION

There always will be moisture transmission through the roof. This will not cause any problem if the side laps in the load carrying steel deck are tight enough. If you have a poor design which permits inside air to come in close contact with the exterior steel sheet you may have some problems, especially if it is cold outside and the humidity in the building is high. Air transmission, which also means moisture transmission, depends on the pressure difference between the inside and the outside. A small mist in the plastic layer will not cause trouble; the amount of air is not enough.

MINERAL WOOL HOLDS WATER

If significant moisture penetrates into the roof during short periods or on single occasions, it is important that the insulation is able to absorb the moisture and then release it when exterior conditions have changed. This quality is probably one of the reasons for the good experience with this type of roof in Sweden.

Some laboratory tests have been carried out to estimate the amount of water that the mineral wool can hold. Six-by-six-by-four inch specimens of mineral wool were kept under water under slight pressure in order to make the water go into the wool. After a while the specimens were removed and placed on pieces of wood in a plastic bag. During a period of six weeks the weight of the specimens was measured. At the end of the period the specimens were allowed to dry in the air at 20C. The results of these measurements are shown in Figure 5. It can be seen that after six weeks the water content is still 150 kg/m³ for horizontally stored specimens. This is to be compared with

the maximum measured water content in a roof, which is about 5 kg/m^3 (0.5 percent of the volume).

FIELD INVESTIGATIONS

A lot of field investigations have been made in Sweden during recent years. More than 35 different roofs involving four different manufacturers have been investigated by Chalmers University of Technology. The roofs have an area ranging from 145 square meters (1560 square feet) to 3700 square meters (39800 square feet). The roofs have a total area of 33300 square meters (358000 square feet). The slope of the roofs vary between 3.6 and 23 degrees. The building period was 1977 to 1982. Most of the roofs are on single span buildings with outer gutters and drains. Just a few had warm interior drains.

Figure 6 shows sketches of the different types of buildings investigated. In approximately half the roofs there has been some water leakage. The leak mainly occurred at roof windows and ventilation ducts. However, there is no major difference in waterproofing between roofs with steel deck and roofs with roofing felt. The weak points are much the same. In order to minimize the risk of water leakage, the number of pipe flashings has to be minimized. Also the leaks found were very often the result of poor workmanship and not the roof design. There were drilled holes without screws or rivets. We also found skewed screws which made leakage easier. The general impression of this type of roof was good.

One of the companies involved has conducted moisture measurements on more than 10 roofs. Moisture variation is rather high but the roofs dried out during the summer. Figure 7 shows some results. When looking at Figure 7, remember that the insulation can hold more than 50kg of moisture per cubic meter. At eleven roofs some of the outer plates were removed and examined. All but one had hoarfrost on the inside of the outer plate. However, the roofs dried out during the summer. None of the roofs examined showed any signs of leakage or problems with condensation. The U-value was not examined, but no excessive heat loss has been reported.

The moisture is usually concentrated in the area near the top plate and it does not observably affect the U-value when the insulation is thick. We did not measure the U-value in the field investigation, nor did we find any signs that the thermal conductivity was influenced by moisture.

SUMMARY

A roof consisting of two layers of profiled steel sheets is described. Thermal insulation is placed between the two layers, usually mineral wool or low density fiberglass. This type of roof has been used in Sweden during the last two decades. Because of rising energy prices and the need for thicker insulation, this type of roof has been used more commonly during the last five years. Results from field investigations of nearly 40 different roofs show that this type of roof is performing well in practice.

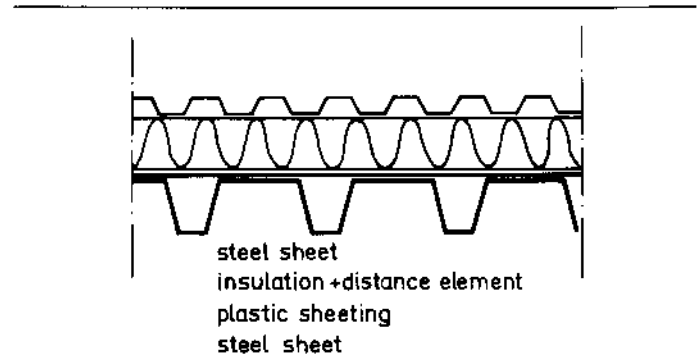


Figure 1 Cross section of a two-layer steel sheet roof. Sketch showing the design principles.

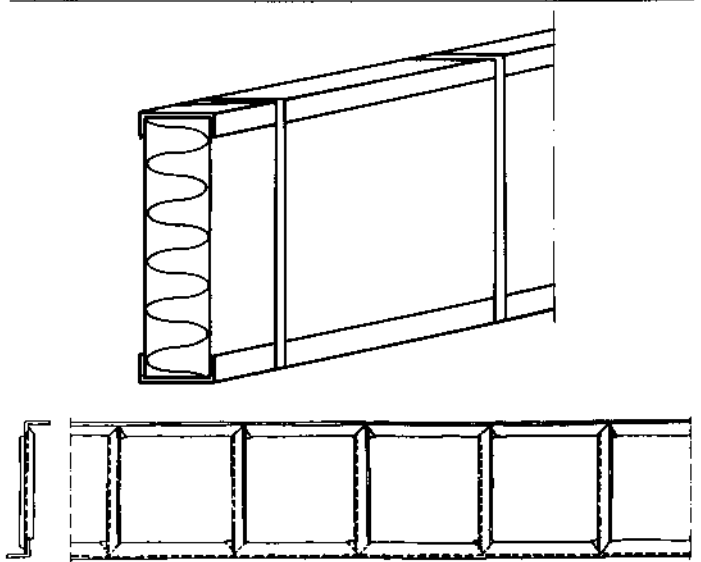


Figure 2 Different types of spacer elements, especially designed to minimize heat loss

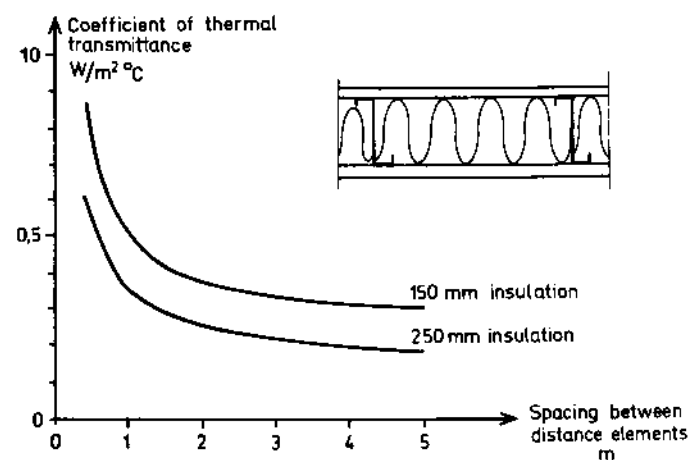


Figure 3 Calculated value of the coefficient of thermal transmittance U . Influence of spacing between the spacer elements. (common Z-purlins, $t = 1,5 \text{ mm}$).

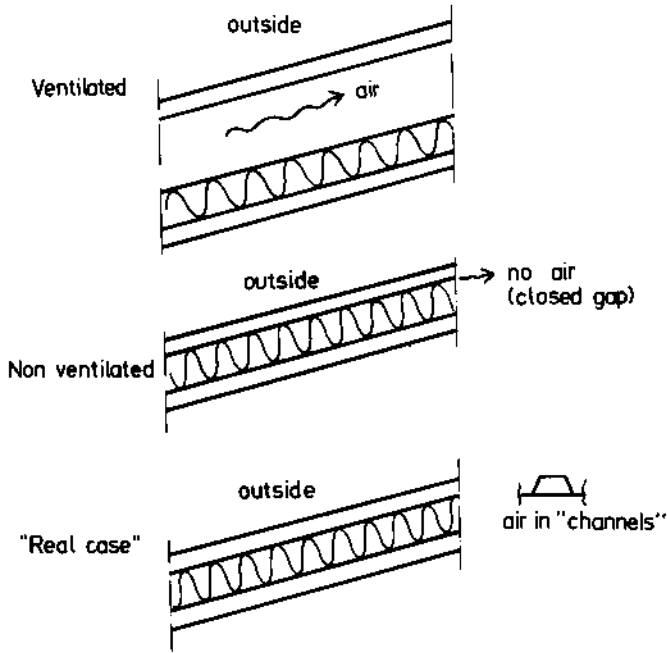


Figure 4 Different design principles for insulated roofs

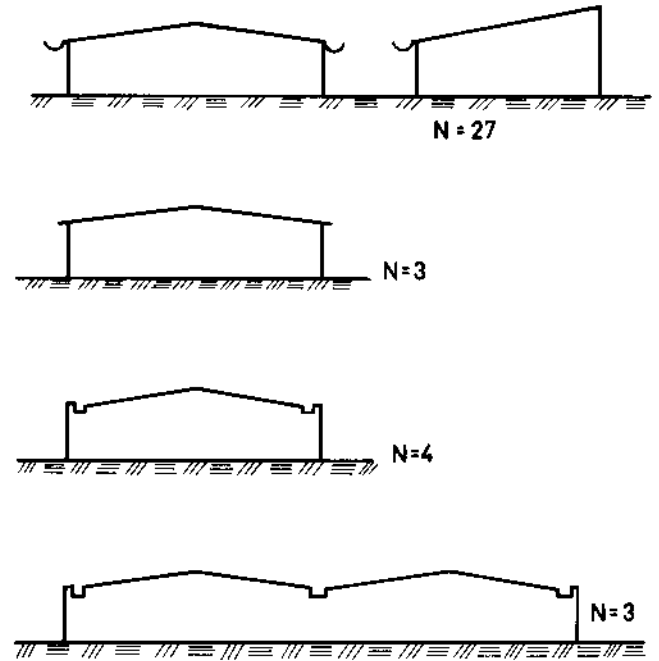


Figure 6 Investigated roofs. N is the number of each type of roof.

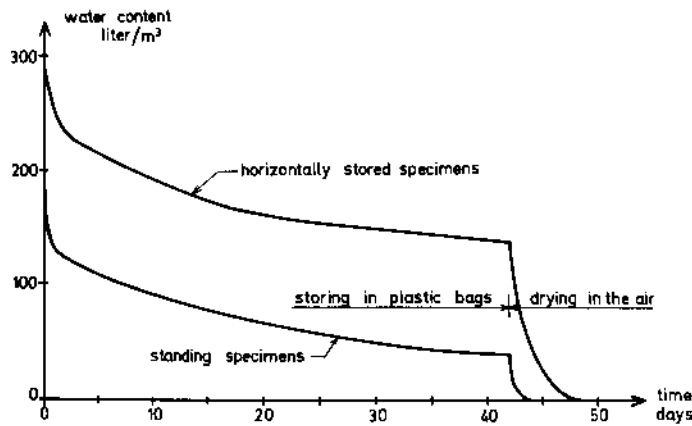


Figure 5 Laboratory tests of the drying process. Measured variation of the water content of initially wet rock wool.

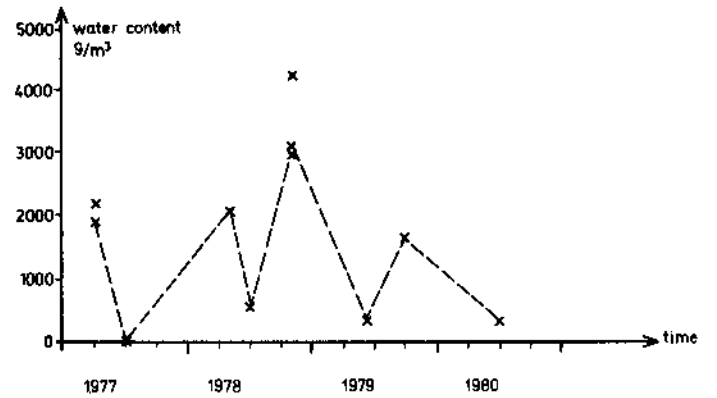


Figure 7 In-situ tests. Measured variation of moisture content for a double steel sheet roof. The moisture disappears during the summer periods.