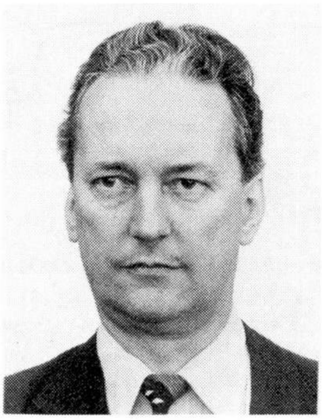
Insulated roofs with two layer steel sheets

Insulated Roofs with Two Layer Steel Sheets

Toitures composées de deux tôles profilées en acier

Isolierte Dächer mit zwei Schichten von Stahlblech

Germund JOHANSSON
Assistant Prof.
Chalmers Univ. of Technology.
Göteborg, Sweden



Germund Johansson, born 1937, received his civil engineering degree at Chalmers Univ. of Technology in 1962. After some years at a consulting firm for geotechnical problems he joined the Dep. of Steel and Timber Structures at Chalmers Univ. of Technology. His research interests are, among others, steel structures, roofs, and structural damage (due to snow, wind).

SUMMARY

A roof type consisting of two layers of profiled steel sheets is described. Between the two layers a thermal insulation is placed. Usually mineral wool or fiber glass with low unit weight is used. Due to the rise of energy cost and the need for thicker insulation this type of roof has been more commonly used during the last five years. Different factors influencing the function of the roof are discussed, e.g. moisture, heat transfer and air tightness. Results from field investigations on nearly 40 different roofs are discussed.

RÉSUMÉ

Il s'agit de la description d'une toiture constituée de deux couches de tôle profilée. Une isolation thermique est placée entre les couches. Habituellement, on utilise de la laine minérale ou de la fibre de verre à faible densité. Par suite de l'augmentation du coût de l'énergie et du besoin d'une isolation plus importante, ce type de toiture a été plus souvent utilisé au cours des cinq dernières années. Différents facteurs influençant l'efficacité de la toiture sont mentionnés comme par exemple l'humidité, le transfert de chaleur et l'étanchéité à l'air. Les résultats d'observations in situ sur environ 40 toitures différentes sont analysés.

ZUSAMMENFASSUNG

Eine Dachkonstruktion, die aus zwei profilierten Stahlblechen besteht, wird beschrieben. Zwischen den beiden Blechen liegt eine Isolationsschicht aus Steinwolle oder Glaswolle. Infolge der erhöhten Energiepreise und der Nachfrage nach dickeren Isolationen ist diese Art von Dach in den letzten fünf Jahren häufig gebaut worden. Verschiedene Faktoren, die die Funktion des Daches beeinflussen, werden beschrieben, z.B. Feuchtigkeit, Wärmetransport und Luftdichtigkeit. Ergebnisse einer Felduntersuchung von etwa 40 verschiedenen Dächern werden angegeben.

1. INTRODUCTION

The double steel deck with thermal insulation between the two layers of steel sheets has to a certain extent been used i Sweden during the last twenty years. During the end of the 1970´s and in connection with increasing energy prices this type of roof has become more extensively used. There are several different types on the Swedish market. They differ among other things with respect to the degree of ventilation under the exterior steel sheet. Until now more than two million m^2 of such roofs have been built in Sweden. The main advantage is that insulation with lower density (and with lower costs) can be used in this type of roof than in a conventional built-up roof. Very thick thermal insulation is used in the roof. Thicknesses of 220 or 250 mm are common.

The investigations described here have been performed in close cooperation with Swedish steel sheet manufacturers and insulation manufacturers.

2. DESCRIPTION OF THE ROOF

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, fig.1. The plastic sheet provides air tightness and prevents moisture penetration from the inside of 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, fig.2.

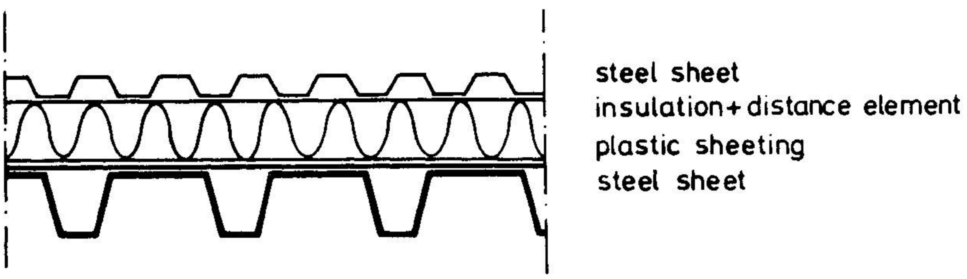


Fig.1 Cross section of a two layer steel sheet roof. Sketch showing the design principles.

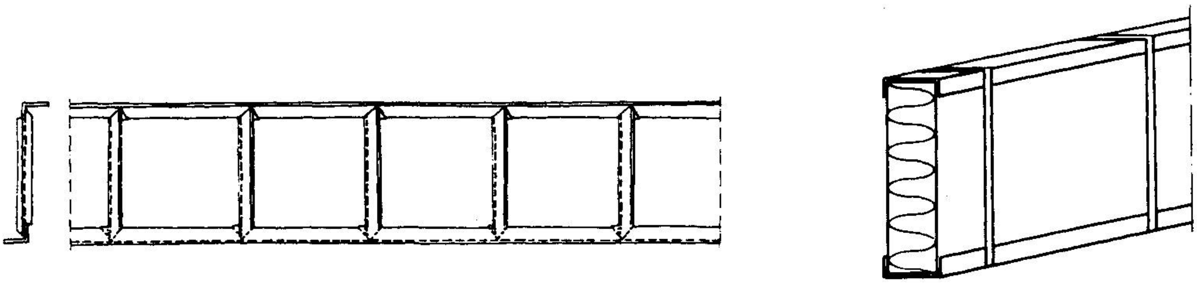


Fig.2 Different types of spacer elements, especially designed to minimize heat loss.

3. THERMAL INSULATION

This type of roof is used mostly with mineral wool or fiber-glass thermal insulation at least 150 mm thick. A thickness of 250 mm is also common. With these thick insulations thermal bridges play a great role in the thermal behaviour of the roof. Figur 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 1.5 mm steel plate. The U-value for a roof with 150 mm insulation and distance element with holes as in Figure 2 corresponds to a roof with 250 mm 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 roof with no spacers. A roof with 270 mm mineral wool and spacers with holes, c.f. fig.2, had a measured U-value of 0.172 to 0.176 W/m^2 ^{o}C if the spacing is 0.95 m. With another type of perforated spacer, with a spacing of 1.45 m, and 150 mm mineral wool, the measured U-value was 0.27 W/m^2 ^{o}C.

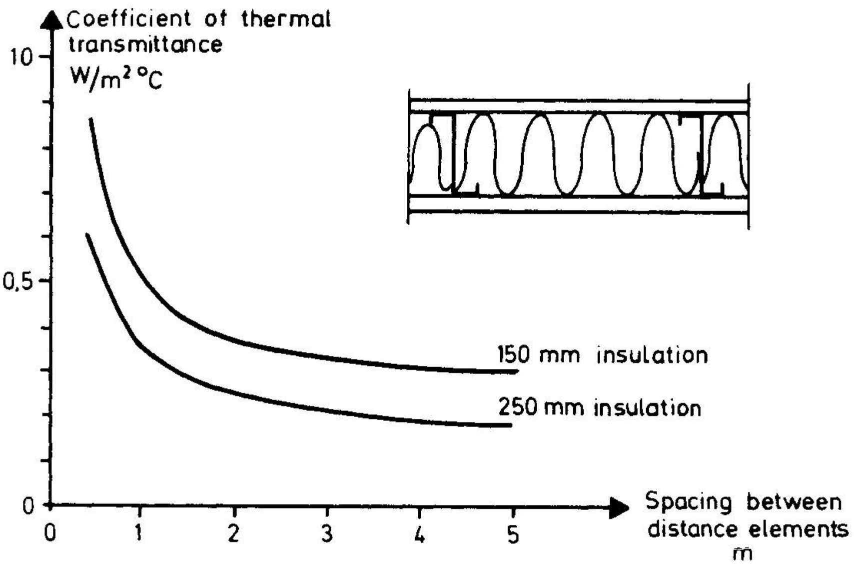


Fig.3 Calculated value of the coefficient of thermal transmittance U. Influence of spacing between the spacer elements. (Common Z-purlins, t = 1,5 mm).

4. DESIGN PHILOSOPHIES

There are roof designs based on different 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 are more or less ventilated. Both these types have advantages and disadvantages.

The advantage of 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 is also thought to be easier to waterproof the roof when it is non-ventilated.

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.

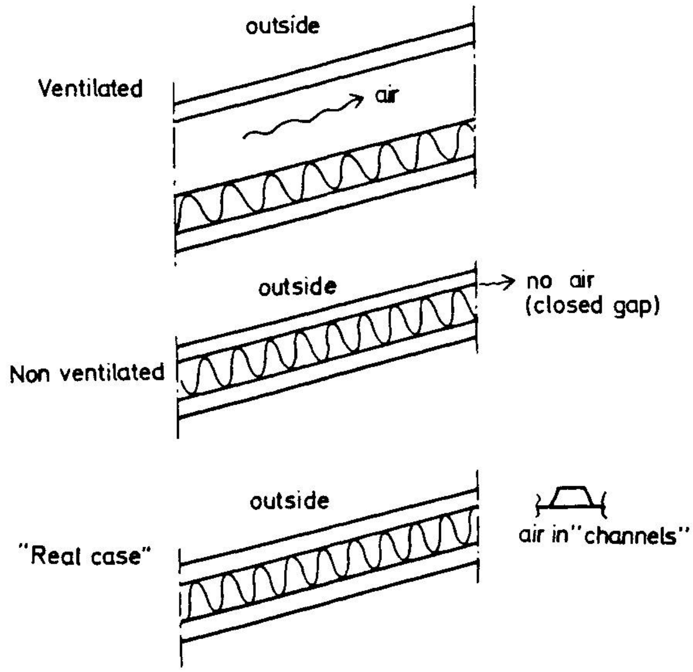


Fig.4 Different design principles for insulated roofs

5. WATER

A roof has to be tight against rain and water. For certain poorly designed roofs, rain can leak into the structure. Wind in combination with rain makes the water penetration more severe. The wind presses water into the structure.

There may be a static water pressure caused by ice walls. Ice can form dams near the eaves, or near warm gutters and drains.

6. CONDENSATION

There will always be moisture transportation through the roof. This will not cause any problem if the side laps of 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 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. But, just a small mist in the plastic layer will not cause trouble - the amount of air is not enough.

With a very poor design with big inside openings leading air into the structure, there must be moisture problems, fig.5.

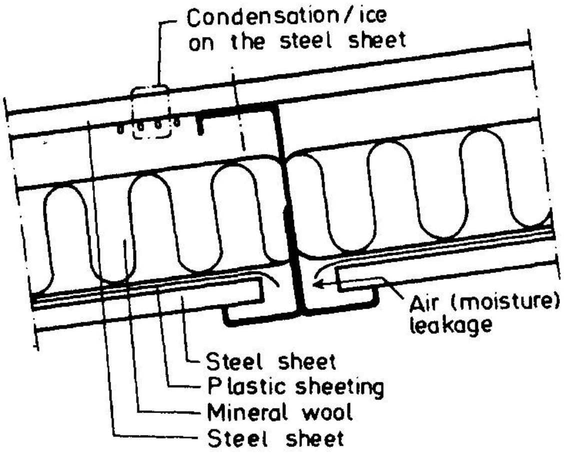


Fig.5 A very poor design leading to condensation problems

During the last years we have met with a few roofs with condensation problems, depending on mechanical ventilation. In one case there was an overpressure inside the building caused by ventilation fans. The measured pressure-difference was not large, just a few Pa. However, this low, but rather constant, difference was enough to force air from inside into the roof. When some of the exterior steel sheets and some of the insulation were removed the plastic film blow up like a ballon.

In another case there was air coming from the outside causing serious trouble with condensation on the inside of the outer steel sheet. Also in this case air was forced into the structure by fans. The condensation probably occurred mainly during the nights when the steel sheet may be about 10 °C colder than the air due to the heat radiation.

We have also looked at a leaking roof where everybody involved were convinced that there was a condensation problem. It was, however, possible to follow the way taken by coloured water from the outside, through the structure and into the office. That was not condensated water.

A very important rule is this:

- Do not arrange the ventilation fans to create over-pressure inside the building. Make sure that there always is a lower pressure inside than outside the building.

7. MINERAL WOOL HOLDS WATER

If significant moisture quantities 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. The specimens (0.15 x 0.15 x 0.1 m), density 25 kg/m^3, of mineral wool were kept under water. They were repeatedly slightly compressed 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 20 ^oC. The results of these measurements are shown in Figure 6. It can be seen that after six weeks the water content is still 150 kg/m^3 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). From Figure 6 it can also be seen the difference between horizontally and vertically stored specimens.

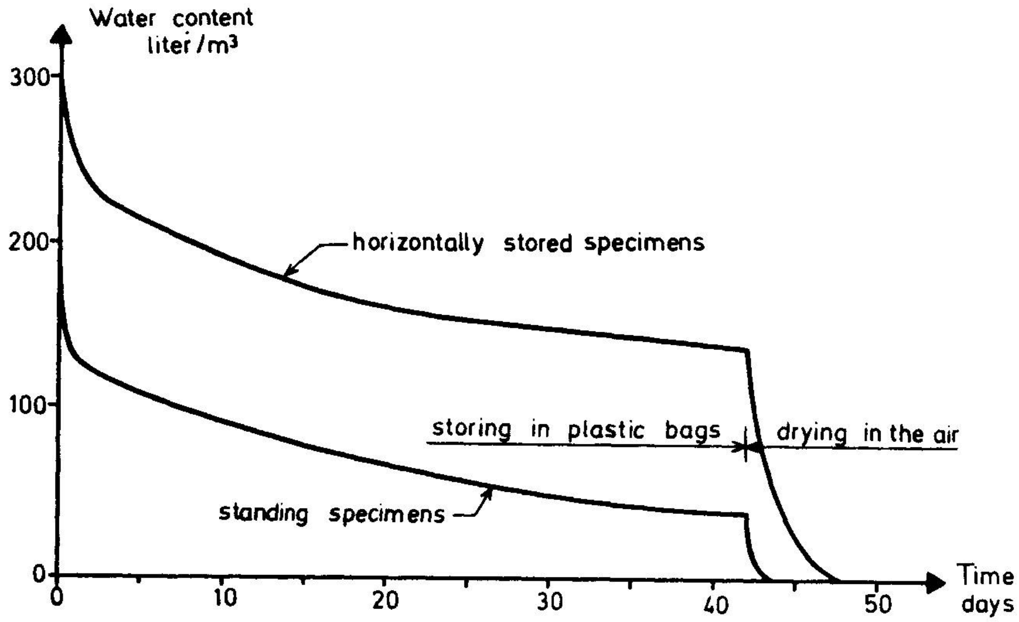


Fig.6 Laboratory tests of the drying process. Measured variation of the water content of initially wet rock wool. Each curve represents the mean value of 3 different tests.

8. 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 m^2 to 3700 m^2. The roofs have a total area of 33300 m^2. The slope of the roofs vary between 3.6 (1:16) 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. Most of the buildings had ventilation with underpressure inside (22) and five had overpressure ventilation. The rest had no fans at all or they had so called balanced ventilation which means that under certain condition and at certain points there is thought to be no pressure difference between the inside and the outside of the building. The real case might be "under-" or "over-" pressures ventilation.

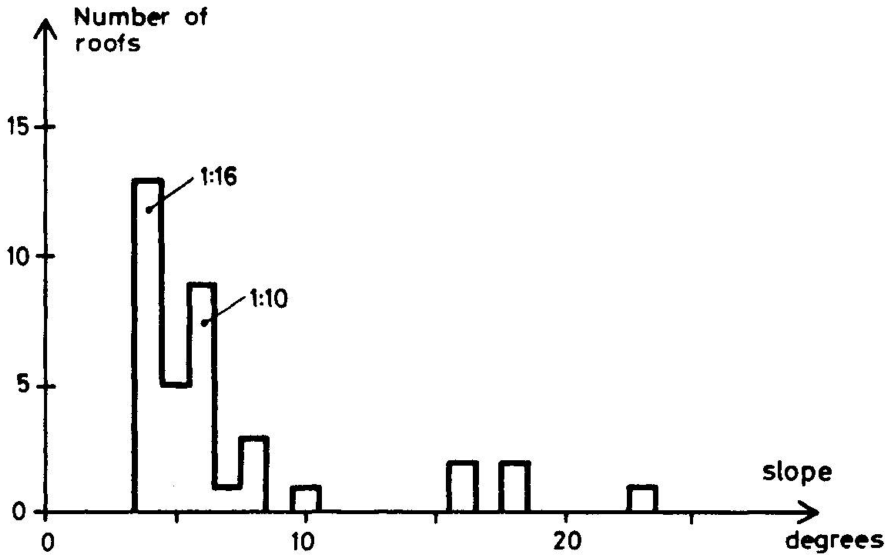


Fig.7 Roof slopes for investigated roofs

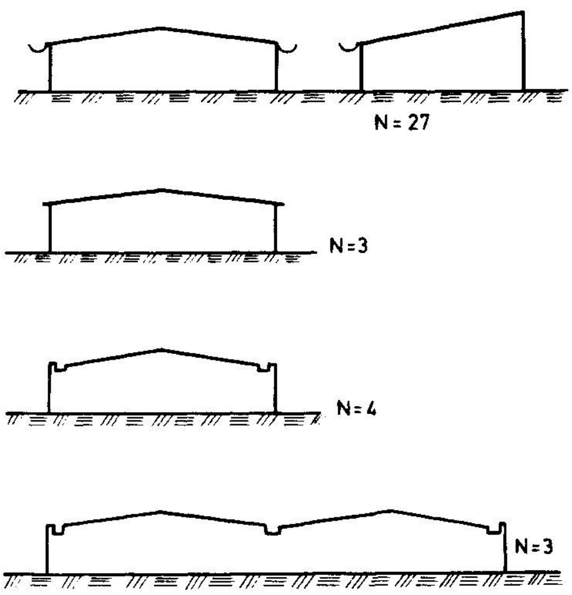


Fig.8 Investigated roofs. N is the number of roofs for each type

Figure 8 shows sketches of the different types of buildings investigated. In approximately half of 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 penetrations has to be minimized. Also the leaks found were very often the result of poor workmanship and not of the roof design. There were drilled holes without screws or rivets. We also found skew screws which made leakage easier. The general impression of this type of roof was good, however.

One of the companies involved has performed moisture measurements on more than 10 roofs. Moisture variation is rather high but the roofs dried out during the summer. Figure 9 shows some results. When looking at Figure 9 remember that the insulation can hold more than 50 kg 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.

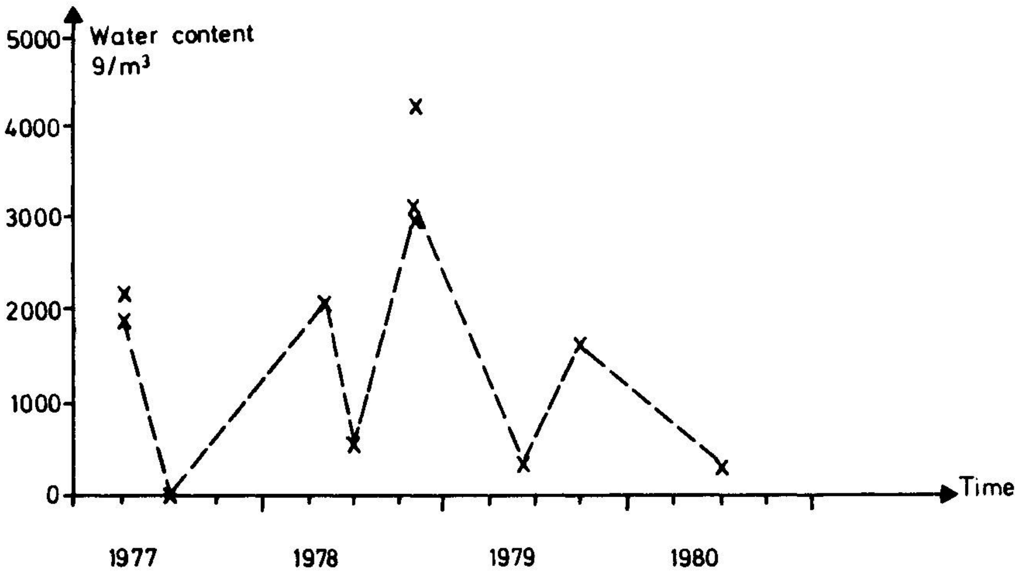


Fig.9 In situ tests. Measured variation of moisture content for a double steel sheet roof. The moisture disappears during the summer period.

9. REFERENCES

1. JOHANSSON G., Double Steel Decks (in Swedish).
Report R98:1984, Swedish Council for Building Research, Stockholm 1984.