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Autor: Vaes, Felix / Hens, Hugo
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Condensation in Roofs with Thin-Walled Metal Sheets

Condensation dans les toitures avec tôles profilées en acier

Kondensation in Dächern mit dünnen Metallprofilblechen

Felix VAES
Civil Engineer
ESSA nv
Diest, Belgium

Hugo HENS
Prof. Dr.
K.U.-Leuven
Leuven, Belgium

Felix Vaes, born 1956, received his civil engineering degree at the Katholieke Universiteit Leuven, Belgium. For almost 6 years he was involved in research concerning hygrothermal problems in .roofs. At present he is co-manager of ESSA nv, a consulting firm specialized in low-energy technology and building physics.

Hugo Hens, born 1943, received his civil engineering degree at the Katholieke Universiteit Leuven, Belgium. Doctor in applied sciences, 1975. Professor in building physics at the university since 1981. Involved in research on roof systems, energy use in buildings, a.o.

SUMMARY

The paper deals with condensation problems in roofs with thin-walled metal sheets. The buildings concerned covered a wide range of indoor climates ranging from storage buildings with very low moisture content to swimming pools.

RÉSUMÉ

Cette contribution traite des problèmes de condensation dans les toitures avec tôles profilées en acier. Les bâtiments concernés couvrent une gamme étendue de climats intérieurs: des dépôts avec faible degré d'humidité jusqu'aux piscines.

ZUSAMMENFASSUNG

Dieser Artikel behandelt Kondensationsprobleme in Dächern mit dünnen Metallprofilblechen. Die Untersuchungen betreffen Gebäude mit sehr unterschiedlichem Innenklima: von der Lagerhalle mit sehr geringer Feuchtigkeit bis zum Hallenbad.

1. INTRODUCTION

At several times during the past five years, we have been confronted with severe leakage, caused by condensation in roofs with thin-walled metal sheets. The damage varied from water dripping out of the roof, to degradation of preserved goods and deterioration of the roofing system. Problems occurred not only in buildings with a high vapour load, but also, as treated here, in buildings with a rather low inside vapour concentration. See also (1).

2. SOME CASE STUDIES

2.1. Cheese storage building

2.1.1. Construction.

The building consisted of two large storage rooms, both with walls and ceilings of sandwich-panels 'steel-PU-steel', the joints between the panels were sealed with a PVC-packing. The roofs were covered with metal sheets, the loft space between ceiling and sheets being ventilated with outside air: figure 1. Both cheese storage rooms were conditioned, one at 6°C and 90% R.H., the other at 12°C and 90% R.H.

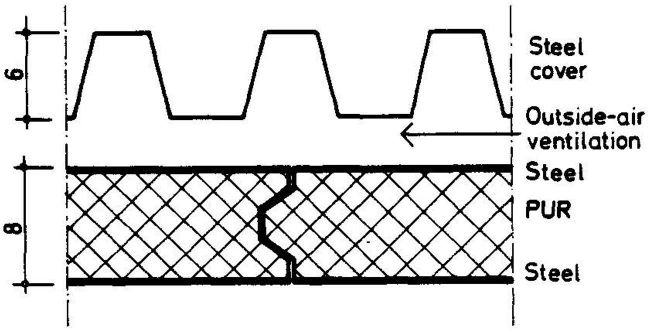

Fig. 1.

2.1.2. Damage.

In the loft spaces above both rooms (fig. 1) there was severe surface condensation against the metal sheets. The water, dripping on the ceiling, penetrated the joints between the sandwich-panels and damaged the stored cheese.

2.1.3. Causes.

By long wave radiative losses to the open sky, the night-time surface temperature of a roof may drop 6 to 10°C below air temperature. Having a very low thermal resistance and inertia, the underside temperature of the sheets equals the upside value. So, each time the outside surface temperature falls under the outside dewpoint, condensation goes on, not only at the sheets outside surface but also

- as far as the loft space is ventilated with outside air
- or/and a vapour transport by convection/diffusion exists from the inside to the roof space,

at the sheets inside surface.
In the case of the cheese storage building, convection of vapour to the loft space was very likely: there was an overpressure in both rooms, and the ceiling wasn't airtight. Otherwise water penetration through the joints wasn't possible! With that reality in mind, condensation against the inside sheet surface was a fact, each time the temperature of the sheets dropped below 10°C, the dewpoint of the air in the 12°C-room. A sheet temperature lower than 10°C is, considering the Belgian climate, possible each season. Because of lack of capillarity of the metal sheets, dripping begins shortly after the condensation starts.

2.1.4. Solution.

Here, it was necessary

- to raise the inside surface temperature of the covering;
- to reduce the vapour transfert by convection;
- to improve the capillar suction of the coverings inside surface.

This was realised by

- spraying, at the inside of each room, an elastic air- and vapourtight layer against the sandwich-panels;

- putting a new roof on top of the loft space, composed of an inside capillar cement bound fibre board, a vapour barrier, thermal insulation and an outside metal sheeting.

2.2. Sugar terminal

An immense hall (∿ 300.000 m^3) for sugar storage, was built with load bearing wooden arches, the outside walls and roof composed of an inside PU-board, vented air space and an outside thin metallic sheet cladding (fig. 2). The PU-boards were mounted very carefully, as to realise an air- and vapourtight inside leaf and ceiling. The vapour load of the inside air was rather low:

θ = 15 - 25°C
RH = 30%

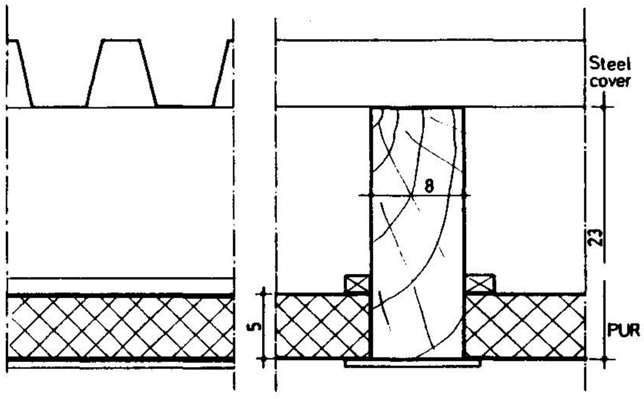

Fig. 2.

2.2.2. Damage.

Water drips out of the roof at several places, causing damage to the sugar.

2.2.3. Cause of the damage.

To avoid dust penetration from the outside, the storage building must always be in overpressure. Therefore 25.000 m^3 of fresh air is blown through the sugar into the hall, after climatisation. The only way-out is the ceiling that isn't airtight, in spite of the good workmanship. That was clearly observed by endoscopic control, white dust (sugar) floating inthe vented air space between PU-boards and sheeting. The reality of condensation was observed during a cold winter period, when ice was formed against the sheeting in the air space. During the following thawning period, the ice melts, giving dripping water. Calculations, using the measured climatic data, showed that the amount of condensate raises from some 0,1 gr/m^2h without airflow (diffusion only) to 20 gr/m^2h with the measured airflow. Because of long wave radiation and, coupled, the sheetings temperature drop, the problem may appear each season.

2.2.4. Solution.

A very important financial claim for each day the terminal would be out of use made it impossible to empty the building. Therefore, after sealing all joints between the existing sheets, a new roof was built over the old one, using a PU-thermal insulation and a new metal sheet covering. The extra thermal insulation was taken thick enough to be sure the temperature of the old sheet would always be higher than the dewpoint of the inside air. Because of the increase of the airtightness of the building after the retrofit, it was also necessary to change the air-conditioning.

2.3. High school

2.3.1. Construction (fig. 3).

The roof of the entrance hall and restaurant of a high school were constructed as indicated in fig.3:

- perforated steel sheet;
- acoustical insulation: mineral wool (2,5 cm);
- thermal insulation: mineral wool (8 cm);
- aluminium sheet.

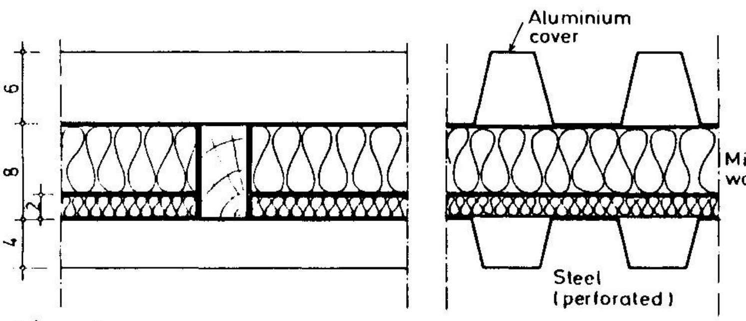

Fig. 3.

Slope: 27°
Orientation: NW

2.3.2. Damage.

In wintertime, several times, water dripped out of the roof.

2.3.3. Cause of the damage.

In Belgium interstitial condensation usually is calculated with monthly mean climatological data. This is justified, because of the hygric inertia of most constructions being high enough to blot out peaks in moisture production. However, here, because of the non-existing thermal and hygric inertia of this roof, the momentaneous temperature and vapour pressure situation becomes important. For that reason, the vapour production of 200 students in a hall of 3.000 m^3 is large enough to cause, after some hours, transient interstitial condensation against the alu-sheets. When the temperature of these stays lower than 0°C for several days (frost or long wave radiation), in view of the lack of absorption of the sheets severe leakage problems may occur during thawy weather.

2.3.4. Solution.

A vapour barrier was built in between the two insulating layers.
This experience once again proved that the thermal and acoustical function of a ceiling, should be separated.

3. CONCLUSIONS

The examples and theoretical reflections show three parameters, which play an important role in condensation problems with light-weight, metal sheeted roofs:
- lack of airtightness of the ceiling, especially when the building is in overpressure, with, as a result, a 'moist' air flow from the inside of the building to the roof space;
- negligible thermal resistance and inertia of the metal sheets, coupled to a very low outside surface temperature, caused by long wave radiative losses to the open sky;
- absence of capillarity of the metal sheets.

Many problems may be solved using sandwich-panels with a core of foamed insulation. However, attention has to be paid avoiding thermal bridging at the edges. Also the vapour and air tightness of the joints should be studied carefully.

(1) LABORATORIUM BOUWFYSICA, K.U.-Leuven, Condensatieproblemen (in Dutch), unpublished, 1981-1985.