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VENTILATION OF TIMBER FLAT ROOFS

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Reviewed here is a major co-operative investigation in Denmark into the effect of ventilation of timber flat (cold) roofs to combat condensation and moisture accumulation. Field measurements of moisture content in a number of test roofs over long periods and under different conditions are evaluated and conclusions drawn. They include the advice that, where moisture accumulation is a problem, it can be aggravated if roof vents are installed.

Cet article porte sur une étude très importante menée en collaboration au Danemark sur les effets de la ventilation des toitures-terrasses (froides) en bois pour lutter contre l'accumulation de condensation et d'humidité. Les auteurs donnent les résultats des mesures in situ de la teneur en eau pour un certain nombre de toitures de ce type sur de longues périodes et dans différentes conditions et en tirent des conclusions; dont celle-ci: lorsqu'il y a un problème de condensation, il risque d'être aggravé par la pose de bouches d'évacuation dans la toiture.

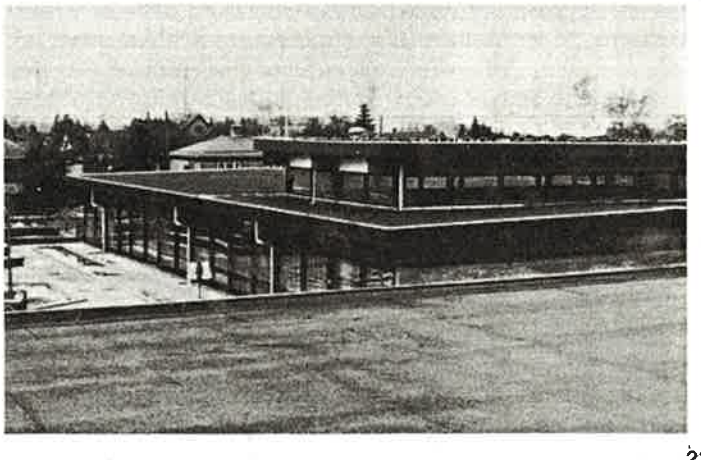
Over recent years it has become apparent that ventilated timber flat roofs of the cold roof type with a covering of roofing felt are, due to excessive moisture content in the roof decking, subject to decay and fungal attack. The cause is primarily the permeation of warm, moist air from underlying rooms into the roof cavity, where it can condense on timber roof structures and roof decking.

No investigation had, however, previously been carried out in Denmark to determine the extent to which ventilation, possibly supplemented by roof vents, will improve or aggravate the prevailing moisture conditions in such roofs. A major investigation of actual conditions has therefore been carried out (ref. 1) where ventilation was determined in advance, in order to ascertain the influence of various factors. The programme has been financed by the Danish Technological Advisory Council, the Danish Ministry of Energy and the Danish Building Research Institute (SBI).

BACKGROUND

It has long been accepted practice to ventilate timber roof structures with outside air. Ventilation openings, having an area of not less than 1/500 of the roof area, were normally located along the eaves.

The changes in building design have, however, made the establishment of edge-to-edge ventilation difficult or impossible, for example where roof panels span in different directions, as in the corner of an L-shaped house, or where the roof area is too large to enable ventilation openings of 1/500 along the eaves. Attempts have therefore been made to provide for ventilation with vents on top of the roof. To our knowledge there has been no prior investigation of the extent to which roof vents affect moisture conditions within the roofs. Similarly, the effect of many joints between roof panels on air transport into ventilated roofs, compared to the joint-free plastered ceiling, has not previously been determined.



Thus, the factors under investigation were:

1. The design and dimension of ventilation openings
   a. ventilation along roof eaves,
   b. ventilation by roof vents.
2. The significance of moisture conditions in the underlying rooms.
3. The significance of airtightness of ceilings.

Investigations were also carried out concerning moisture conditions in non-ventilated roofs (warm roofs), provided with pressure-equalising roof vents. This article, however, deals primarily with the results of the investigation of ventilated timber roofs. The Technological Advisory Council publication (ref. 1) includes the investigations of warm roofs and the resulting conclusions.

THE PROBLEM

Moisture can be transported from underlying rooms into cold roof voids by vapour pressure through permeation (diffusion) or air penetration of joints (moisture convection). For many years great emphasis has been attached to the prevention of moisture transport or permeation by the use of vapour barriers having a high vapour resistance. However, the same stress has not been placed on airtightness. Figures 1a, 1b and 1c illustrate three situations which may be considered in connection with the evaluation of air flow and correlated moisture conditions in the roof cavity of a ventilated roof.

In figure 1a an airtight and reasonably vapour-resistant barrier is assumed located in the ceiling. A ventilation of 1/500 of the roof area will, based on experience, be sufficient here to remove the small quantities of moisture which penetrate the vapour barrier. The relative air pressure conditions in and around the house, caused by wind, are also indicated. As the ceiling is assumed airtight, an upward flow of room air will not take place although there is a pressure difference between the roof cavity and the underlying room.

A similar situation is illustrated in figure 1b, but with some leaks in the vapour barrier. It is apparent that, due to pressure conditions, there is a tendency for the room air on the lee side of the house to be drawn into the roof cavity and out to the open air. When the roof is cold, the moisture contained in the room air may condense on the roof decking (plywood, chipboard, boards) and cause detrimental accumulation of moisture.

Figure 1c shows roof vents used when the roof cavity cannot be ventilated from edge to edge. Due to wind pressure conditions, a pressure difference will occur above the roof. If the ceiling, *ie* the vapour barrier, is not airtight, then the roof vents will function as extractors and draw large quantitites of room air into the roof cavity.

The natural stack effect in houses, as illustrated in figure 1b and 1c will under winter conditions greatly increase the transport of air, which at this time of year will be warm and moist.

The investigations studied moisture conditions in these typical situations, of which there are, of course, several variations.

MOISTURE MEASUREMENT

The moisture content in the cold (upper) part of the roofs investigated was observed through one or several winters using the SBI-moisture gauges. These gauges were developed in connection with an earlier investigation of moisture conditions in the roofs of houses in Albertslund, as described in references 2 and 3.

The gauges exploit the relationship between the moisture content of wood and its electrical conductivity. A plywood disc of

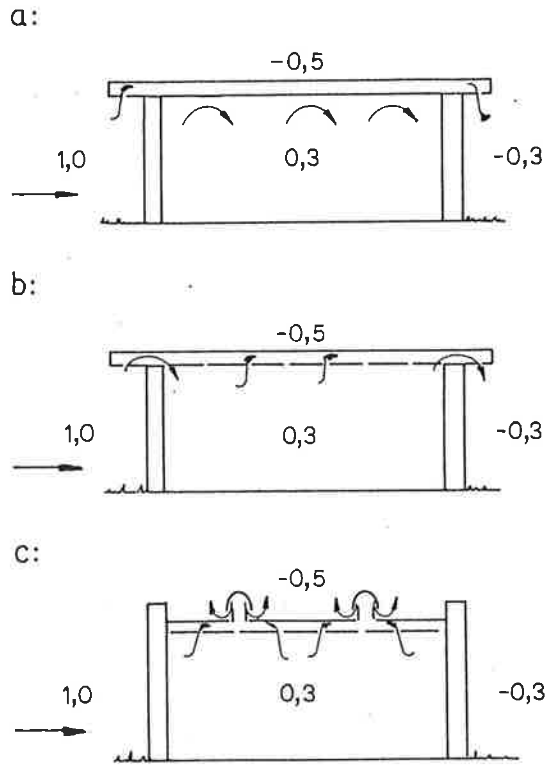


Fig. 1. Relative pressure conditions (shown by numbers) resulting from wind flows in and around a flat-roofed house
(a) ventilation of roof cavity when ceiling is airtight, (b) how room air can permeate into the cavity when the ceiling is not airtight, and (c) how room air can stream out through roof vents when there is no airtight vapour barrier in the ceiling.

diameter 50 mm has 2 electrodes built in between which the resistance can be registered (see figure 2). The electrical resistance is measured with a digital datalog. The relationship between electrical resistance and moisture content is illustrated in figure 3. The electrical resistance is to some extent dependent on temperature and therefore a temperature correction must be made. In all the investigations these gauges where built into the roof decking, with wires running to positions with ease of access for recording the measurements.

Measurements are normally accurate and capable of duplication, but the following factors may cause errors.

1. Severe frost with temperatures below – 5 °C.
2. Extremely moist outside air may result in current leakage from the wires. Measurements should therefore not be undertaken in very wet or foggy weather.
3. Direct solar radiation will, when the measuring gauge is located directly beneath the roofing felt, cause a temperature gradient through the gauge, whereby the moisture content in the disc (and also in the roof) will be unevenly distributed. Measurements should therefore not be carried out when the roof is exposed to direct solar radiation.
4. When moisture content exceeds 30 per cent, short circuiting will occur between the two electrodes and readings will be uncertain. Moisture content in excess of 30 per cent is therefore always registered as 30 per cent.

Many years' experience has shown that the moisture contents indicated by the SBI-gauges are equivalent to the moisture contents found in roofs made of wood or plywood which are determined by the traditional drying and weighing method.

Criteria for determining whether moisture content of timber is too high have been described (ref 3). Suffice to state here that, for timber not previously attacked by fungal decay, a moisture content of less than 20 per cent by weight is normally assumed to provide assurance against attack. If the timber has previously

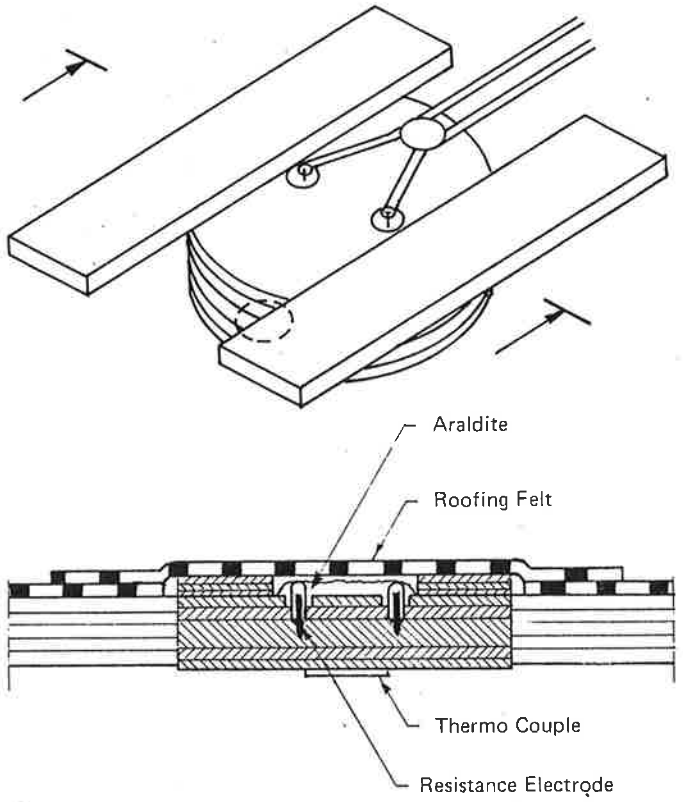


Fig. 2. SBI moisture-measuring gauge (isometric and cross-section)
The gauge is built into the roof decking. The electrodes, insulated except at the tips, measure the electrical resistance of the plywood. The thermocouple helps to correct resistance measurements for temperature

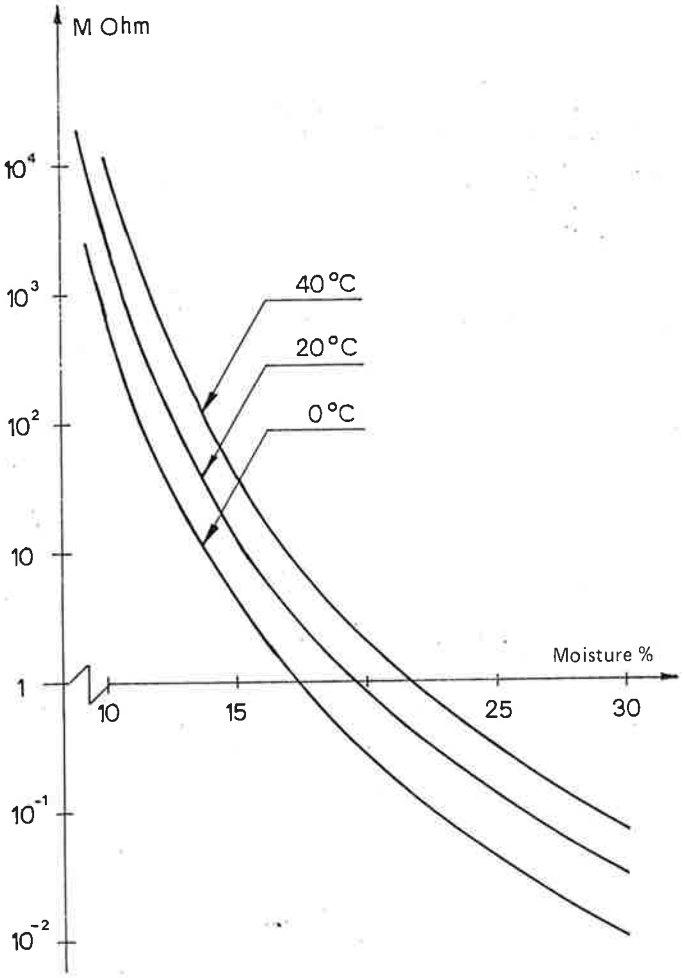


Fig. 3. Relation curves of electrical resistance and moisture content in the measuring gauge
As resistance is slightly temperature-dependent, correction must be made

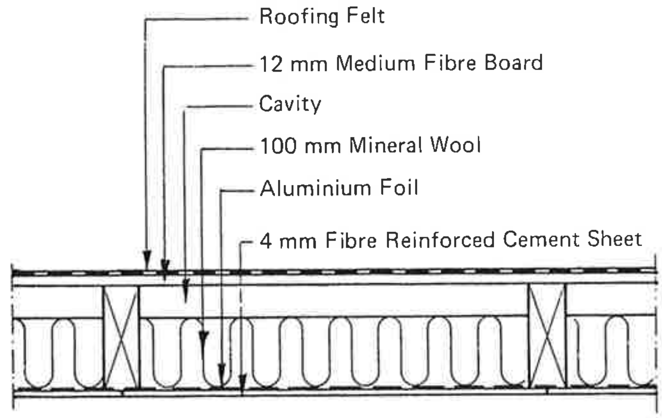


Fig. 4. The original roof construction of the swimming pool building investigated

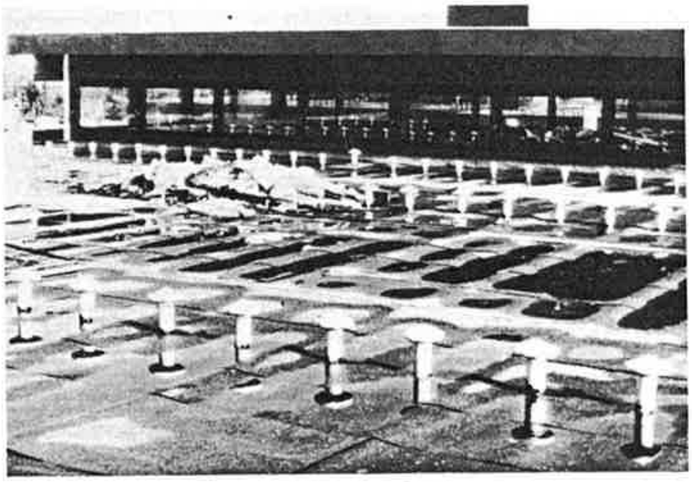


Fig. 5. The many and varied vents which had been placed on the swimming pool roof to try to improve ventilation

been attacked, then a limit of 15 per cent by weight should be ensured. At temperatures below 5 °C growth of fungi will not occur as the necessary growth conditions do not exist. Subequent mention of moisture content of timber will always refer to percentage by weight.

INVESTIGATIONS UNDERTAKEN

Roof above swimming pool

The 10-year old roof of an indoor swimming pool consisted of roof panels with a top skin of medium wood fibre board and mineral wool insulation between the timber ribs. A vapour barrier of aluminium foil and an asbestos cellulose board formed the underside (see fig. 4). There had been moisture problems with the roof for a long time and, to alleviate this, roof vents had been placed in several areas of the roof, but the problems had worsened. Figure 5 shows the large number of vents employed.

In connection with the necessary replacement of the roof, the municipality willingly allowed an area to be used for experiments with various forms of ventilation of the roof panels. This section of about 150 m^2 was divided into 7 test zones.

The temperature in the swimming pool was 26-28 °C, and the relative humidity was 50 per cent. This reduced to 40 per cent, however, when outside temperatures were lower than − 10 °C.

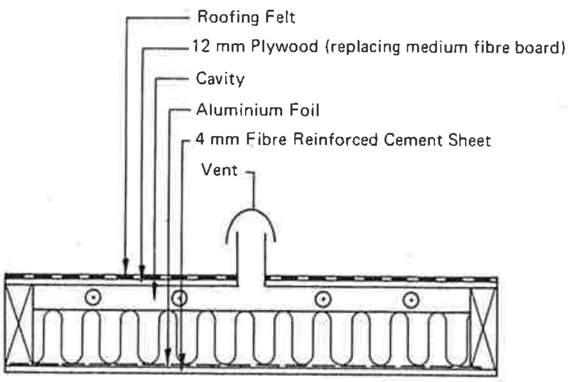


Fig. 6. Test roof panels used for experiments with the roof prior to its replacement
Cavity above the insulation could be closed or ventilated by either roof vents or edge-to-edge ventilation

The test roof panels were as shown in figure 6. The method of ventilation of the roof panels was varied in each zone and moisture content was measured in the upper skin at the points illustrated in figure 7. The test zones, consisting of 2 or 4 roof panels, may be described as follows:

- Zone 1: designated the reference zone; the original edge-to-edge ventilation of 1/500 was retained.
- Zone 2: as zone 1, but with the complete closure of edge ventilation openings.
- Zone 3: O-energy units (*ie* sandwich panels) with rigid mineral wool (on edge) between plywood skins, not ventilated (differing in construction from figure 6).
- Zone 4: as zone 1, but supplemented by two vents in the middle of the roof.
- Zone 5: as zone 2, but with vents provided at the edges and middle of the roof.
- Zone 6: as zone 2, but with mechanical ventilation of the roof cavity.
- Zone 7: as zone 2, but with great care taken to achieve airtightness at the underside of the panels with the help of projecting edges of the plywood sheets. Joints were taped from above.

Results

Moisture content in excess of 30 per cent was measured in the upper plywood decking in zones 1, 2, 4 and 5 during the major part of the winter period. As drying out began in May-June it was clear that there was a very long period with temperatures above 5 °C, together with a moisture content of the upper skin in excess of 20 per cent, resulting in great risk of fungal attack. Only in zone 4 employing edge-to-edge ventilation supplemented by roof vents did a complete drying out to 10 per cent occur during the summer.

Timber edgings of the O-energy units in zone 3 reached 23-25 per cent moisture content due to a badly designed joint. Mechanical drying of the joint was later effected to improve airtightness of the joint, but it became apparent that joints towards adjoining panels were not airtight, allowing moist air rapidly to re-enter and re-moisten the units.

In zone 6, the forced ventilation kept the moisture content of the wood reasonably low. However there were difficulties in maintaining continuous operation of the ventilators. Even a stoppage of a few days resulted in substantial moisture accumulation.

In zone 7, a gradually increasing moisture content was observed during the winter despite the attempts to provide a very effective vapour barrier. Not until June-July did moisture content fall to 10-15 per cent.

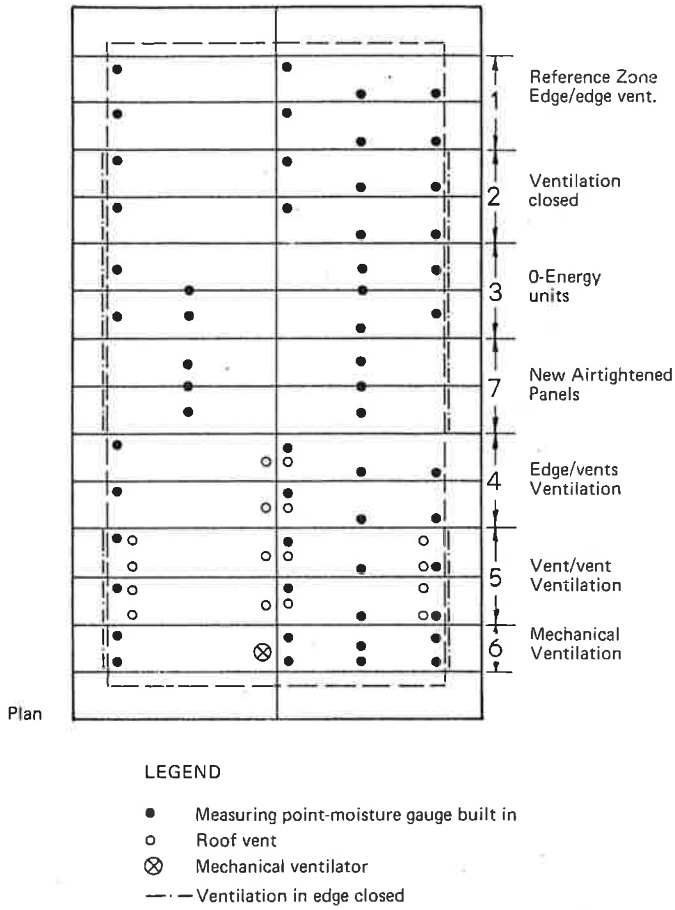


Fig. 7. Plan of the swimming pool roof investigated, showing section in zone 4

Evaluation

Neither natural ventilation through roof eaves (edge-to-edge ventilation) nor roof vents are capable of keeping the moisture content in the roof decking of a cold roof sufficiently low when the underlying room has a moisture loading such as a swimming pool. Despite considerable efforts, it proved impossible to fashion a sufficiently airtight vapour barrier in a traditionally-designed roof panel having soft mineral wool between the ribs. It can not, therefore, be recommended that a ventilated cold roof be employed over swimming pools or other buildings having a similar moisture load. A warm roof should be used instead.

It should be mentioned that a warm roof was employed to renovate the roof over the swimming pool (shown in figures 8 and 9). Subsequent measurements in the plywood decking below the new layer of insulation showed completely satisfactory moisture conditions. Regarding calculation of the relationship of moisture to thermal resistance of the two layers of insulation in similar warm roofs, see reference 3.

Roof over canteen building

The roof over a canteen building was constructed as shown in figure 10, *ie* traditional timber roof panels which, as a starting point for this investigation, were completely closed.

There was accordingly no ventilation along the roof eaves. The roof panels of 1.80 × 1.80 m were supported by a steel space frame. Roof panels were connected by a loose tongue placed in a groove in the edges of each panel, supplemented by a strip of mineral wool encased in sheet plastic. The roof panels were supported at each corner on a space frame joint plate to which a bolted connection secured four adjacent panels.

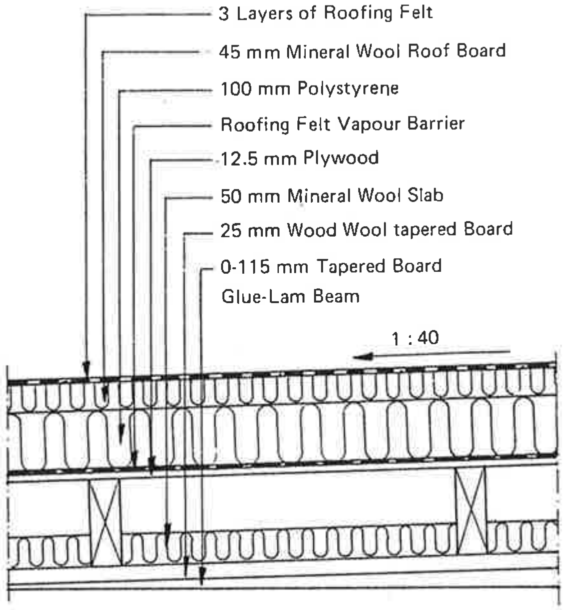


Fig. 8. The new roof eventually built over the swimming pool; it is a 'warm' roof with the main part of the insulation above the vapour barrier

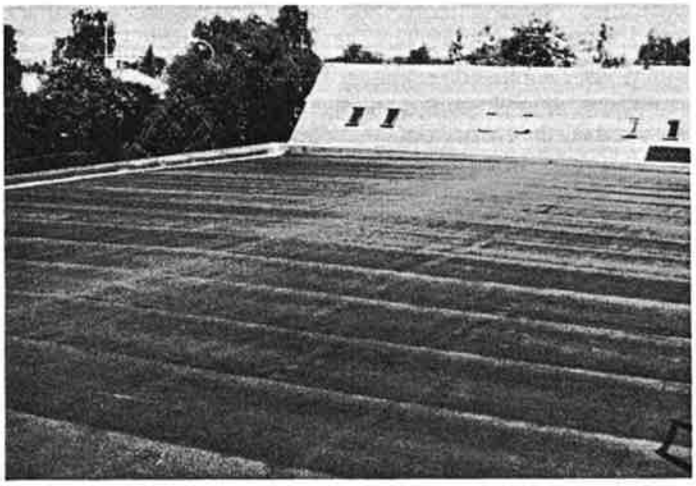


Fig. 9. View of the new 'warm' roof: all roof vents have now been removed

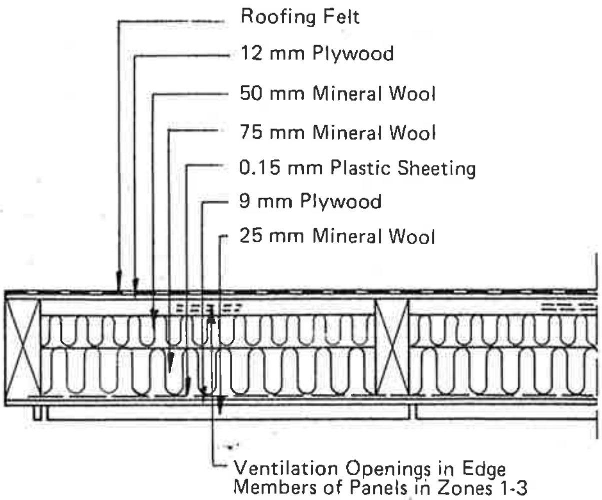


Fig. 10. The roof of the canteen building investigated

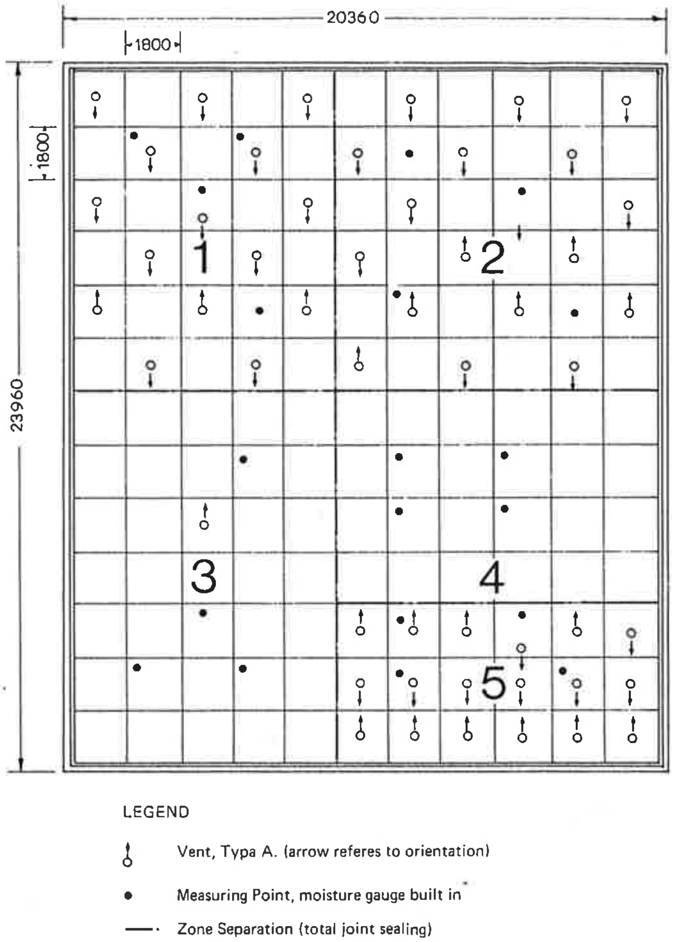


Fig. 11. Plan of the canteen building roof for purposes of the investigation, period 1979-81

The aim of the investigation was to evaluate the influence of various forms of ventilators or simple forms of pressure equalisation, either above the roof or towards the room below, on moisture accumulation in the upper plywood skin of the roof panels. The climate of the room during the winter period was 20°-25 °C and 40-60 per cent RH. The 20 × 20 m roof was divided into five independent test zones as shown in figure 11. The zones may be characterised as follows:

- Zone 1: ventilation openings were found in the upper part of edge members of the panels forming a continuous interspace within the zone. Edge members towards adjoining zones had no openings. The zone was ventilated by one roof vent in every second panel, corresponding to 4.6 cm^2 per 1.80 × 3.60 m.
- Zone 2: as zone 1, but the ventilated area was reduced to 1.2 cm^2 per 1.80 × 3.60 m.
- Zone 3: as zone 1; ventilation was further reduced to one vent having an area of 3.0 cm^2 per 9.0 × 12.60 m. This modest ventilation should rather be considered as pressure equalisation.
- Zone 4: there were no links here between the cavities of the 1.80 × 1.80 m roof panels. There were no vents in the roof, but a hole of area 1.2 cm^2 had been drilled in the underside of each panel to allow pressure equalisation towards the underlying room.
- Zone 5: as zone 4, but with pressure equalisation through a vent with an area of 1.2 cm^2 in the topside of each panel.

The described ventilation conditions were monitored over the two years 1979-81.

As the differences in moisture content of the upper skins were not as divergent as anticipated, conditions in 1981-83 were changed as follows:

- Zone 1: ventilation was substantially increased by adding one large vent having an area of 10 × 10 cm in every second roof panel around the perimeter of the zone.
- Zone 2: the reduced cavity ventilation was closed completely.
- Zone 3: part of the roof was covered by a newly developed special roofing felt having fibres projecting from the underside which raised the felt slightly above the roof surface. This should result in an increase in thermal insulation value that could perhaps contribute to keeping the moisture content of the upper skin low.
- Zone 4: no change.
- Zone 5: all pressure-equalising vents were closed.

Results

First test period 1979-81

Moisture accumulated more or less equally in zones 1, 2 and 3. The accumulation of moisture started in October and continued until April, reaching a moisture content at most measuring points in excess of 30 per cent. Thereafter the drying-out period started until by the middle of the summer all areas had dried out to 15 per cent moisture content.

Moisture accumulation in zone 4 took place at a slower rate, only reaching about 25 per cent. Drying-out also took place at a slower rate, reaching a minimum of about 15 per cent by the middle of the summer. Moisture accumulation in zone 5 took place in a similar fashion to zones 1, 2 and 3, but occurred more rapidly. The maximum moisture content was 25-30 per cent, reaching a peak of about 30 per cent in April.

Second test period 1981-83

The increased ventilation in zone 1 did not substantially alter moisture conditions. The moisture content again reached about 30 per cent. Closure of the already-reduced cavity ventilation in zone 2 had no effect on the moisture conditions, as moisture content again reached 30 per cent.

The newly-developed roofing felt laid in zone 3 had similarly no effect on moisture conditions. In zone 4, where no changes in ventilation conditions were carried out, measurement showed a slightly reduced moisture accumulation compared to the previous winters. The closure of all pressure-equalising vents in zone 5 proved to have a beneficial effect, as moisture content remained under 18 per cent.

Evaluation

In zones 1, 2 and 3, in which all inter-zone roof panels had ventilation openings between adjoining panels, the moisture content reached 30 per cent during winter regardless of the degree of ventilation. Apparently air flowed from the underlying room into these panels, depositing part of the contained moisture before being extracted through the ventilators.

The vents were closed in zone 2 in the second period to prevent the above mentioned flow. As moisture accumulated despite this, it was assumed that an internal circulation occurred between the panels as air entered through joints between components and out through other joints owing to differences in pressure below the ceiling. This flow is called internal convection and may result in moisture accumulating in the cold timber components.

In zones 4 and 5, where each panel was a closed unit, moisture accumulation was considerably less than in the other zones. When the pressure-equalising vents in the roof in zone 5 were closed, moisture accumulation was further reduced. This was probably due to a reduced suction above the vapour barrier when the vents were sealed, as the negative pressure zone above the roof was no longer transplanted to the cavity in the roof panels.

The investigations thus showed that roof cavity ventilators had no beneficial effect on moisture conditions in the roof. For closed panels, into which air permeation is strictly limited, it was only during the winter period that a very limited moisture accumulation took place.

Finally, smoke tests were carried out to determine the location of leaks in the ceiling construction. This showed that smoke which was blown into joints from above exited at the corner joints between four panels. Filling the joints with polyurethane foam had no significant effect.

OTHER INVESTIGATIONS

Similar investigations of other flat roofs were carried out (ref 1). These also utilised SBI-moisture measuring gauges through longer periods. The types of buildings involved were as diverse as a town hall building, many types of terraced atrium garden houses, a block of flats and several detached houses. The extent to which adding external insulation could help alleviate already existing moisture problems was also investigated. Findings confirmed earlier conclusions concerning these upgraded constructions (as published in ref 3).

The general impression is that roof vents do not improve moisture conditions; edge-to-edge ventilation of 1/500 seems to function satisfactorily in typical detached houses of normal width and moisture load when the ceiling construction is reasonably airtight. It was also found that in warm roofs, in this case concrete units with polystyrene insulation and roofing felt, there is a real risk of moisture problems if skylight linings and joints between units are not airtight.

PRESSURE MEASUREMENTS IN ROOFS

Concurrent with the aforementioned investigations, SBI undertook a project entitled 'Pressure conditions in flat roof constructions'. The aim was to establish through actual measurement the magnitude of pressure differences between the roof space in a ventilated roof construction and the underlying room. Measurements were carried out using very sensitive pressure transducers connected to a datalog.

Measurements took place in the previously mentioned test zones in the roof over the swimming pool. A detailed report is given in SBI Report 152, 'Pressure conditions in flat roofs' (ref 4).

Measurements showed that during long winter periods the wind created a negative pressure in the roof space of 5-10 Pa relative to pressure in the underlying room. This means that considerable quantities of room air could be drawn into the cavity through leaks in the ceiling construction. It was also recorded that, using a mechanical input ventilator, it was possible to maintain a modest positive pressure of 0-50 Pa in the roof space and this was sufficient to prevent this air flow. Experience showed, however, that the ventilator often stopped, *eg* because of power failure, and that due to current safety regulations it could not automatically start again. To ensure the feasibility of mechanical solutions to moisture problems it is necessary continuously to monitor their running.

CONCLUSIONS

Warm roof-cold roof

The vital factor for maintaining ideal moisture conditions within a flat roof is the ability of the vapour barrier to prevent the penetration of moist air from underlying rooms into the roof cavity.

In most cases, it is not possible to solve moisture problems in cold roofs by increased ventilation of the roof space; introducing roof vents will only aggravate the problems.

For warm roofs, it has similarly been demonstrated that augmented ventilation of the insulation layer (pressure equalising) cannot solve moisture problems. If the increased ventilation is brought about by roof vents then it may, as with the cold roof, aggravate the problems.

The investigation showed that there are numerous factors influencing moisture conditions in flat roofs. They are:

- airtightness of the vapour barrier (especially at joints, connections and penetrations)
- type of vapour barrier (aluminium foil may corrode if exposed to an alkaline environment)
- room climate
- room ventilation (positive pressure ventilation in underlying rooms aggravates moisture conditions)
- method of roof ventilation (edge-to-edge or vents)
- degree of roof ventilation (size of openings)
- possibility of air permeation
- sun/shade conditions on the roof (shade limits drying conditions)
- wind conditions (shape of roof, roof eaves, surroundings, and so on).

The primary factor, however, with regard to moisture conditions in a roof is as previously mentioned, namely that the moisture barrier is airtight at joints, connections and penetrations. The consequences of a defective moisture barrier cannot be redressed by increased ventilation. More emphasis should be placed on using a vapour barrier for cold roofs which can be installed airtight, rather than a vapour barrier with a high vapour resistance. Airtightness can often be achieved by using an airtight sheet material with tight, taped joints.

In warm roofs it is possible to establish a very effective vapour barrier, as this can be laid from above and thereafter checked for tightness at penetrations and joints before thermal insulation and roofing are laid on top.

Room climate

Moisture accumulation in a roof will depend on the climate in the underlying rooms. This can vary enormously depending on the function of the room and the type of ventilation used. Positive pressure ventilation in a room with high humidity will in particular have a most detrimental effect.

A classification

The moisture loading on a roof construction can be deduced from moisture conditions in the underlying rooms. The investigation has shown that the moisture loading may be determined from the absolute humidity of the room air, as follows:

Room climate Class 1. Moisture content in the room air during the heating period is less than 5 g/m^3, which means that the dew point is below 0 °C.

Dry rooms such as the following may be classified under class 1:

— factory premises where processesproduce moisture

— storage rooms

— sports halls (without spectators).

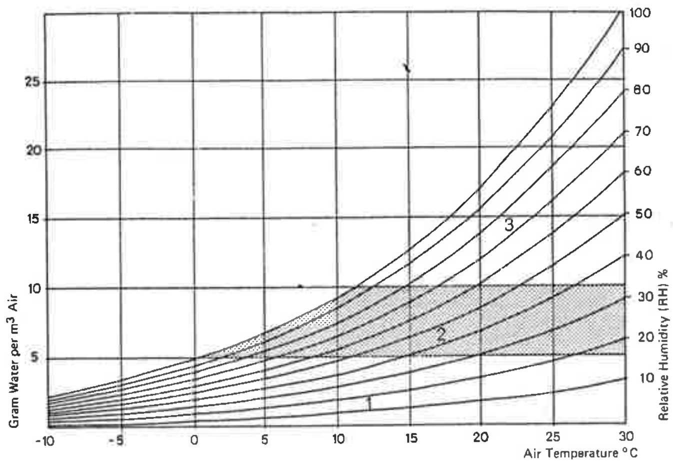


Fig. 12. Room climate classification (classes 1, 2 and 3) for evaluating moisture loading on roof constructions

Room climate Class 2. Moisture content in the room air during the heating period is less than 10 g/m^3. This means that the dew point of the air is below 11 °C.

Normally ventilated rooms, having neither substantial production of water vapour from manufacturing processes nor open water surfaces, such as the following, may be classified under class 2:

— schools

— houses

— offices

— shops

— institutions

— sports halls (with spectators).

Room climate Class 3. Moisture content in the room air during the heating periods is in excess of 10 g/m^3. This means that the dew point is above 11 °C.

Rooms in which substantial humidity is to be found, such as the following, can be classified under class 3:

— swimming pools

— laundries

— bathrooms

— factory premises with moisture producing processes.

The three classes of room climate are illustrated in relation to humidity levels in figure 12.

It should be noted that the above classification of rooms is purely for orientation purposes. The class of room climate to which a building belongs must be considered in each particular case, particularly for houses, where room climate conditions can be of great diversity, *eg* where insufficient ventilation or an impermeable climatic shield may put such dwellings in class 3.

DESIGN OF VENTILATION

The optimum form of roof ventilation is edge-to-edge ventilation, as this provides an air stream in the roof space without giving rise to any substantial negative pressure which could draw room air into the roof construction.

The use of vents in flat roofs should be avoided, since they will almost certainly cause a negative pressure in the roof cavity as wind pressure on the building causes a negative pressure zone above the roof.

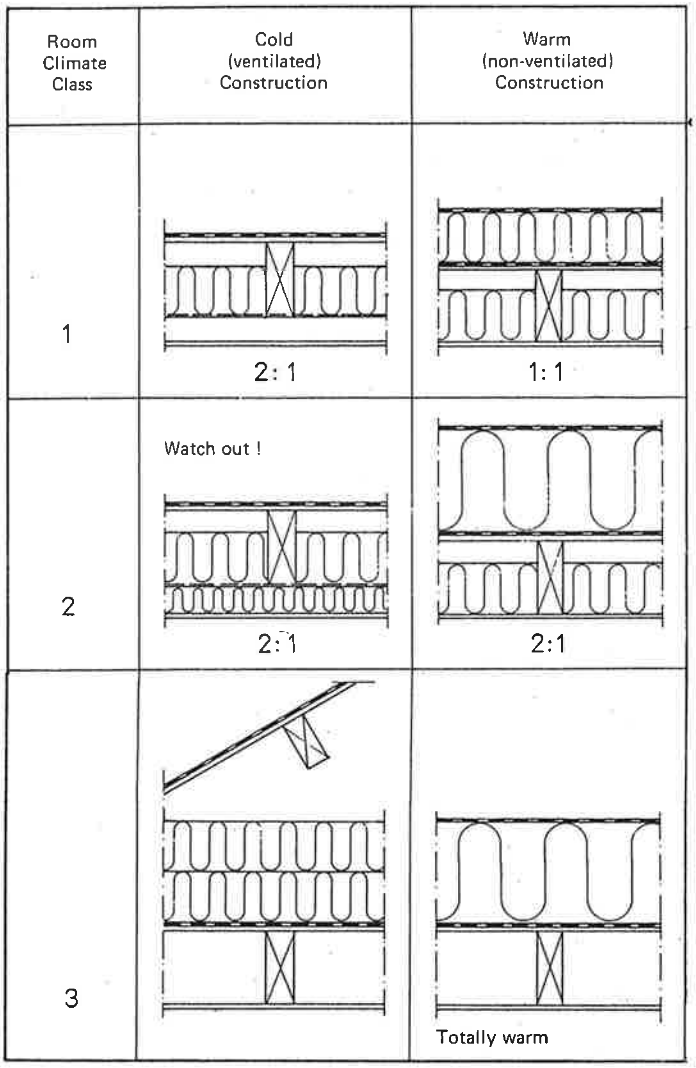


Fig. 13. Outline of choice of roof construction, assessing conditions related to thermal insulation above and below vapour barrier depending on room climate classification

The Danish Building Code states that a ventilation area of 1/500 of the roof area is considered sufficient to assure satisfactory moisture conditions in a roof construction. The investigations have shown that this is only so if the outside air has direct and unhindered access from roof edge to roof edge.

This method of ventilation is based on an open cavity above the insulation of at least 45-50 mm. In practice it has proved difficult to achieve such unhindered ventilation in the corner of L-shaped houses or when the roof cavity is obstructed *eg* by skylights.

OTHER CIRCUMSTANCES

Roofs which are constantly in the shade have difficulty in drying out during the summer, and extra care must be taken in their execution.

As ventilation conditions are dependent on the wind, the effectiveness of ventilation will depend on the location of the building relative to neighbouring houses and vegetation, as well as on the configuration of the building.

AREAS OF APPLICATION

Based on the measurements and investigations in this project and including the previously executed project for the Technological Advisory Board: 'Additional insulation of flat roofs', it is possible to formulate the following limitations for the use of warm and cold roofs as schematically represented in figure 13.

- Warm roofs may be utilised above all room climate classes. In classes 2 and 3 it is essential that the vapour barrier is constructed airtight and with a reasonable vapour resistance.
- The vapour barrier should normally be placed on the warm side of the insulation, but in room climate class 1 it may be placed so that up to half of the insulation is on the warm side of the vapour barrier. In class 2, the vapour barrier may be placed so that up to one-third of the insulation is located on the warm side of the barrier. In class 3, the insulation should normally be placed so that it is entirely on the cold side of the vapour barrier. However, if a moisture calculation (as described in ref 3) is carried out, this may show that a limited amount of the insulation can be placed on the warm side of the vapour barrier.
- Cold roofs can always be utilised above room climate class 1. Such roofs may only be utilised in class 2 if a vapour barrier is installed which is airtight at all joints and connections. Ventilation area may be set at 1/500 of the built area and should be established from roof edge to roof edge (eaves-to-eaves).
- Ventilation using roof vents should be avoided. Roofs that are so large that they cannot do not be ventilated from edge-to-edge should be designed as warm roofs. Cold roofs should not be utilised above room climate class 3 unless the vapour barrier consists of roofing felt bonded to the decking, *eg* plywood and unless the joints have been checked for airtightness by a water test for example.

For cold roofs it is a prerequisite that the vapour barrier is placed on the warm side of the insulation. The barrier may however, in room climate classes 1 and 2, be placed so that up to 1/3 of the insulation is on the warm side of the barrier.

WARM ROOFS AND PRESSURE EQUALISING

The project included moisture measurements in warm roofs with and without pressure equalisation in the insulation through vents. It can be concluded that the circulation of air through vents cannot alleviate moisture problems in warm roofs which have a defective or unsatisfactory vapour barrier. If there are leaks in the barrier through which the room air may be drawn into the roof construction, then the negative pressure created by the vents may increase moisture accumulation in the upper parts of the warm roof.

During execution of warm roofs there is a risk that a considerable amount of moisture will be trapped within the insulation layer. This built-in moisture must be allowed to escape through pressure equalising openings at the edges of the roof. With large roofs, it may be necessary to provide pressure equalising vents at a rate of 1 vent per 300-500 m^2 depending on roof design.

VENTS

The use of vents in a roof will always be questionable, since both wind and thermal updrift will seek to draw room air into the roof construction. This is true both for ventilation vents and pressure equalising vents.