EXPERIENCE WITH INSULATED SLOPED ROOFING IN WEST GERMANY

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Energy saving is not a new concept in the Federal Republic of Germany. The difference is that in past decades energy saving was not a priority consideration because of relatively low energy costs.

The so-called "energy-crisis" of 1970 to 1973 changed this attitude. People became increasingly aware that the supply of raw materials in the world was limited and were forced to recognize that energy costs represented an ever increasing and significant factor in the overhead costs in the use of residential and office buildings. It was recognized that there was ample potential for saving in the use of heating energy in buildings.

Until 1973 approximately 50 percent of the energy consumption in the Federal Republic of Germany was by households and other small users. About 85 percent of this was used for heating. This led to the realization that the biggest opportunity for saving energy lay in the construction field and in the erection of residential buildings. The energy saving resulting from improved thermal insulation is considerable. Simply replacing all conventional-type windows with special, insulated, airtight windows, already has produced an annual saving of 12 percent in energy consumption. A further 5 percent can be saved by improving the heat insulation in roofs and ceilings.

Recognizing the special "energy-situation," a legally binding "order" was issued. The "Thermal Insulation Order" of 1977 was markedly improved in 1982 and 1984 when the need for further energy-saving measures was acknowledged. The latest revisions of 1984 have relevance to the extension of existing buildings, the addition or replacement of windows and French windows and other construction elements such as external walls and extension work on the roofing. Increased thermal insulation will have to be carefully considered in the future, even when roofs are renovated. The requirements of the standard DIN 4108 with regard to thermal insulation in structural engineering in 1974 had to be revised and finally were released with extensive modifications in March 1982.

This considerably increased thermal insulation presents no problem to the professional. However, certain considerations relating to construction are necessary. These were given only slight consideration in the past by the professions associated with the building trade.

Basic physical principles pertaining to construction had to be determined. Simplified methods of calculation for a practical application of these thermal insulation measures had to be devised and made generally understandable. This was accomplished through extensive research work by various institutions.

The pressing requirements for increased thermal insulation make stringent demands, particularly for the thermal insulated sloped roof.

It now is essential to incorporate considerably thicker layers of insulating materials in the construction of roofs. Vapor retarders, preparatory roof sheeting, lumber and preparatory roof structures must be planned, relative to the type of construction and the requirements.

DETAILED DISCUSSION

The German standard *DIN 4108 "Thermal Insulation in Structural Engineering"* of 1969 was reformulated to raise standards pertaining to improved thermal insulation and protection against humidity in the construction of building elements. This revision of the standards was published in August 1981 and became accepted guidelines in practice in March 1982.

The new DIN 4108 takes protection against atmospheric humidity into account. This refers to pelting rain on outer walls and protection of building sites and construction elements from condensation. Also new is a series of suggestions on thermal insulation in summer.

This revision of DIN 4108 is subdivided into five parts:

Part 1: Thermal insulation in structural engineering—sizes and units

Part 2: Thermal insulation and storage of heat with requirements and recommendations concerning planning and execution

Part 3: Protection against atmospheric humidity with requirements and recommendations for planning and execution

Part 4: Technical values for calculations relating to heat and protection against humidity

Part 5: Methods of calculation

The important fact is that this standard sets out the minimum values for effective thermal insulation, heat energy storage and protection against atmospheric humidity, provided that the rooms are adequately heated and ventilated according to their use.

DIN 4108 applies to the following buildings and parts of buildings:

- living rooms, bedrooms and side rooms,
- kitchens,
- classrooms and day rooms,
- office buildings, business premises and workshops, and
- shopping complexes and administrative buildings.

Thermal insulation in structural engineering, within the context of DIN 4108, refers to all measures which reduce the transfer of heat through the connecting surfaces of a building and through walls and ceilings which separate

rooms of different relative temperatures. Thermal insulation in buildings is significant for the maintenance of a hygienic room climate, in order to protect the entire building against the effects of atmospheric humidity and to ensure a limited energy consumption when heating and cooling.

The following summarizes the minimum requirements of DIN 4108 for heat conservation and protection against humidity with roofs having an inclination of more than 10 degrees.

Thermal Insulation in Winter with Sloped Roofs
DIN 4108, Part 2

The thermal resistance $1/\Lambda$ is a measure of the insulating value of a construction element.

For constructions of single and multiple layers, the thermal resistance $1/\Lambda$ is calculated from the thickness of the layers of the building materials, in meters and the values of thermal conductivity. λR in $W/m(\cdot K)$

$$\frac{1}{\Lambda} = \frac{S_1}{\lambda_{R1}} + \frac{S_2}{\lambda_{R2}} + \frac{S_3}{\lambda_{R3}} + \cdots + \frac{S_n}{\lambda_{Rn}} \text{ in } m^2 \cdot K/W$$

where W is heat displacement, $W/(m\cdot k)$ is the coefficient of heat conductivity and K is the temperature difference.

DIN 4108 requires a minimum thermal resistance $1/\Lambda$ for roofs with inhabited rooms beneath them of $1.10\ m^2 \times KW$, with a maximum value at any point (e.g. roof penetrations) of $0.80\ m^2 \times K/W$. The coefficient of heat penetration K is a measure of the amount of heat loss through conduction. It is directly related to the thermal resistance. It is calculated:

$$k = \frac{1}{\frac{1}{\alpha_i} + \frac{1}{\Lambda} + \frac{1}{\alpha_a}} \text{ in } W/(m^2 \cdot K)$$

DIN 4108 stipulates an average heat penetration coefficient k for roofs of $0.79\ W\ (m^2 \cdot K)$ and a maximum value at any point of $1.03\ W\ (m^2 \cdot K)$.

These values for *minimum thermal insulation* and *protection against humidity* take into consideration the health of inhabitants and of those who use a building as well as the protection of the entire building.

This means that, under unfavorable climatic conditions, there is no accumulation of condensation on the surface of the construction elements provided that there is normal heating and ventilation.

In order to guarantee the energy saving, a binding, legal "order" was made by the state, on the basis of this DIN 4108 standard. The "Thermal Insulation Order" which was published in February 1982[2] stipulates significantly higher values of thermal insulation. It applies not only to new buildings, but under certain conditions, to old buildings be-
• ing renovated.

For example, the maximum heat penetration coefficient, K, for ceilings over inhabited rooms is, at any point, 0.30 $W/(m^2 \cdot K)$. This is a 343 percent reduction in the maximum heat penetration coefficient compared to the minimum requirements of DIN 4108, Part 2.

By taking constructive steps in conjunction with suitable insulation materials, this improved thermal insulation can be guaranteed.

The DIN 4108 requirements for thermal insulation placement within various types of sloped roofs, are:

Heat conductivity W/(m·K) according to DIN 4108	Thickness of the insulation material S in mm	Arrangement of the insulation layer
0.030	120	between the rafters
0.030	95	under the rafters
0.030	85	on the rafters

Table 1 Polyurethane (PUR) solid foam insulation

Protection Against Atmospheric Humidity (Protection Against Condensation on Building Elements and Construction Work in Sloped Roofs)
DIN 4108, Part 3

Protection against atmospheric humidity means *protection against condensation* on the outer and inner surfaces of roofs and outer walls, as well as protection against pelting rain on walls.

Protection against condensation is directly related to thermal insulation. The thermal insulating function of building elements decreases when humidity content increases. In addition, there is an increased chance of condensation on the surface of building elements if the insulation is inadequate and the dew point has been exceeded. The dew point is defined as the temperature at which the water vapor in the air reaches saturation when the air is cooled.

In addition to possible danger to building elements themselves from the effects of humidity, there is further danger of corrosion and of damage caused by microorganisms and fungus. The hygienic conditions inside the building also are endangered.

It should be mentioned that the standard DIN 4108 does not always prevent condensation on the inside of the building elements, but only when such condensation will be detrimental to the thermal insulation and other building elements.

In order to eliminate this possibility, the DIN 4108 requirements are designed so that any humidity which collects on the inside of building elements is completely reevaporated into the surrounding atmosphere.

To accomplish this DIN 4108, Part 3 recommends that:

A. A condensation mass of 1000 grams per square meter should not be exceeded when constructing roofs and walls.

B. To prevent condensation from appearing on surfaces which cannot absorb it and to prevent flowing or dripping, a condensation mass of 500 grams per square meter should not be exceeded. This addresses fibrous insulation layers or air spaces beneath vapor retarders or concrete layers.

C. An increase in the moisture content of solid wood of more than 5 percent by weight is not permitted. For wood derivative materials such as particleboard the increase can be no more than 3 percent by weight.

Observing these maximum values will, as a rule, ensure that humid areas dry out during the drying phase, provided there is sufficient ventilation of the construction area.

When these requirements are not met, it is necessary to calculate the extent of condensation.

In order to produce such evidence mathematically, DIN 4108, Part 3, section 3.2.2.2 uses normal indoor and outdoor conditions. These are:

For the period of condensation:
Outdoor atmospheric conditions: $-10C$, 80% relative humidity
Indoor conditions: 20C, 50% relative humidity
Duration: 1,440 hours (60 days).

For the period of evaporation (roofs with occupied rooms directly below):
Outdoor conditions: 12C, 70% relative air humidity
Temperature of the roof surface: 20C
Indoor conditions: 12C, 70% relative air humidity (in the region of condensation)
Temperature: refers to drop in temperature from the outside going towards the inside
Relative humidity: 100%
Duration: 2160 hours (90 days)

In the case of extreme weather conditions or swimming pools and air-conditioned rooms the actual, relevant values must be measured and used in the calculation. Condensation water mass is a function of time and the surface area of the diffusing water vapor.

Ventilation

Ventilation above thermal insulation layers in a sloped roof is absolutely essential for most types of construction according to DIN 4108, Part 3 (Figure 3.) The professional rules of the roofing trade require efficient ventilation under the roofing elements. Necessary cross-sections must meet the new requirements of DIN 4108. The reason for these measures is to prevent increased humidity in roofing materials, such as earthenware roof tiles and to avoid damage to construction elements from freeze -thaw action in winter. Figure 1 shows the four most common forms of sloped roof construction.

Figures 1a, 1b and 1c show the most common forms of sloped roof construction. Thermal insulation is placed between or below the rafters. The most commonly used insulating materials are glass fiber or mineral wool with a built-in vapor retarder on the inside. This means that the thermal insulation fibers are exposed on the upper surface, without protection or lamination.

Due to the limited protection provided by flat roofing tiles, concrete roofing tiles and cement fiber blocks, it is possible to prevent moisture, such as from snow drifts, from entering only by means of additional waterproofing measures. These include:

Preparatory roof sheeting (A1) of polyethylene with lattice armouring, artificial fibers bathed in bitumen, glass-fiber felt, etc.

Timber boarding (A2) consisting of a rigid wood base with a layer of nailed roof sheeting with glass-fiber bitumen, loosely covered, but not glued.

Preparatory roofs (A3) with a continuous thermal insulation installed under the rafters. As a rule, rigid polyeurythane or polystyrene are used, perhaps in combination with gypsum plaster boards serving as sandwich elements.

When a roof is below the minimum slope, only the following types of preparatory roof structures are permitted. A rigid timber support with 1) a layer of torch-on sheet nailed and concealed in the upper regions of the roof and completely welded at vertical and horizontal overlaps, or 2) an upper covering strip consisting of two layers of bitumen roof sheeting in which the first layer is hidden and covered and the second layer is adhered with hot bitumen, or 3) a layer of high polymer sheeting with sealed vertical and horizontal overlaps.

With all these types of construction, the professional rules of the roofing trade require laying 24×48mm counterbattens in before laying the support-battens for the various roofing parts.

This construction with a separating layer between the thermal insulation and the roofing requires *two* ventilation levels. This is because of the barrier effect that the separating layer has on the diffusion of water vapor. There are, however, preparatory roof sheeting products on the market which have a moisture vapor transmission value of $Sd = 2.0$m, obtained, for example, by using perforated polyethylene. These prevent the formation of condensation in the construction work between the thermal insulation layer and the lower side of the separating layer.

Material	S_d (Average value)
Polyethylene-foil 0.20mm	4.0m
Polyethylene-foil, perforated	2.0m
Artificial fiber bathed in bitumen	3.0m

Moisture vapor transmission rates (S_d) of preparatory roof sheeting

A further problem of this type of construction lies in the absolutely essential gap between the separating layers at the ridge. This is indispensible for reliable ventilation at the lower levels. Since the thermal insulation layers are unrestricted here, water which penetrates through ventilation openings at the ridge or surface covering can cause moisture damage to thermal insulation materials and building elements below.

Figure 1d has a continuous thermal insulation layer on the rafters. Here there is only one ventilation space, above the thermal insulation. It is less difficult to create ventilation flow around the eaves, than in the other systems in Figure 1. Water intrusion through ventilation openings at the ridge and in the region of the roof surface will not affect the efficiency of the thermal insulation layer when rigid polyurethane or polystyrene are used. Regions near the joints can be constructed to resist the entrance of water and rigid foams do not absorb moisture.

These construction methods are all ventilated construction. There is an air space between the thermal insulation layer with a separating layer and an air space above the separating layer towards the roofing or with only one air

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space between the thermal insulation layer and the roofing. The ventilation areas are connected to the outside through openings in the eaves, on the surface of the roof and near the ridge.

The ventilation passage allows humidity to pass from the inside of the house to the outside without special preparation of the roof surface in the winter. It reduces thermal strain of the roof surface resulting from the sun's rays.

An efficient exchange of air currents depends on the effects of wind and thermal currents as well as moisture vapor transmission values S_d.

An investigation of the movement of currents in ventilated roofing constructions revealed that out of 6,000 insulated, inclined roofing constructions measured, 54 percent of the cases showed that air entering at the ridge exited at the opposite end of the eaves. The rate of movement depended on the air currents that impinged on the building. Seventeen percent showed a movement of air currents which entered at one side of the eaves, left through air holes at the region of the ridge, and left again in part at the eaves on the opposite side of the roof. These air movements depended on wind direction. Only 28 percent displayed the conventional air movements noticed in earlier years, wherein air entering at both sides of the eaves left only around the ridge through ventilation openings.

These measurements, together with other investigations, showed that contrary to previous belief, a considerably smaller free movement of air is needed for efficient ventilation around thermal insulated roofing. This observation led to reduction of the customary large ventilation cross-sections in roofing construction.

It must be said that these experimental measurements were carried out on a dual-pitched construction. Problems occurred when trying to design ventilation space as well as coping with onward and outward moving air currents. This is particularly true of area hipped end roofs and at valleys where roofing surfaces meet. DIN 4108 requires ventilation along the entire roof surface which lies above the insulation layers.

Because of this requirement, special so-called ventilation eaves and ventilation hips were developed. These ensure the necessary ventilation cross-section, alone or in combination with the single points of ventilation.

The revised standard DIN 4108 stipulates the following free minimum ventilation cross-sections:

1. Ridge region 0.5 per mille of the related roof surface
2. Eaves region 2 of the related roof surface
3. Hip region and valley region 0.5 per mille of the associated roof surface

An additional condition for efficient moisture ventilation is by ensuring an essential moisture vapor transmission rate S_d. Moisture emanates from building elements in the lower part of the ventilation area, independent of the length of the roof rafters. It is calculated from the value of the vapor diffusion resistance of the building elements used and the thickness of the layers.

Roof length	Incoming air cross-section	Outgoing air cross-section	Adequate vapor barrier
Eaves - ridge	Eaves	Eaves and hips as well as valleys	*Inner* parts of the roofing S_d in m
Length of rafters in metres	Ventilation cross-section in cm²/m	Entire cross-section in cm²/m	
up to 10m	200	100	2.0
11.00m	220	110	
12.00m	240	120	
13.00m	260	130	5.0
14.00m			
15.00m	300	150	
16.00m	320	160	
17.00m	340	170	10.0
20.00m etc.	400	200	

Table 2   Roof slope over 10°

These values also indicate whether the vapor transmission rates of the building layers lies within the minimum values, so that diffused moisture is not prevented from moving along the air stream towards the outer regions of the roof, thereby avoiding condensation from appearing on the inside of the construction work and the layers of the building elements.

When these stipulated values are not attained, a vapor retarder must be installed under the thermal insulation on the side towards the room to prevent over-burdening the ventilation space with humidity resulting from diffusion.

The following are moisture vapor transmission rates S_d for the vapor retarder materials[5].

Material	S_d (m)
Bitumen roofing felt V 11 (Fibrous strip 110 grams)	80 - 160
Bitumen roofing felt V 13	60 - 130
PVC soft plastic web sealing systems (PVC—Polyvinyl chloride)	80 - 120
PIB plastic web sealing systems (PIB—Polyisobytulene)	600 - 3000
ECB plastic web sealing systems 2.00mm (ECB—Ethylene copolymerisate bitumen)	100 - 160

Table 3

Due to the increased requirements for material thickness as prescribed by the Thermal Insulation Order, generally speaking it is no problem to meet the required adequate vapor barrier with rafter lengths up to 10.00m when using rigid foam. An S_d of 2.00m is attained without any problem (*Table 4*). Rigid foams are used in conjunction with thermal insulating layers in construction systems on and under the roof rafters, as polyurethane laminated slabs and unlaminated polystyrene.

A moisture vapor transmission rate of S_d 2.00m cannot be attained with unlaminated fibrous insulating materials. The extremely low water vapor diffusion value, μ1.0, clearly shows the importance of a manufactured vapor retarder. Since it is extremely difficult to render joints and connections at roof penetrations absolutely impervious to diffusion, one is well advised to include an additional vapor retarding layer with no joints, such as Polyethylene foil with a minimum thickness of 0.20mm.

The following table gives an idea of the relationship between the effect of thermal insulation, water vapor resistance value and moisture vapor transmission rate with currently used thermal insulation materials (6).

SUMMARY

The West German standard DIN 4108 stipulates the following requirements for roof constructions with a slope of over 10 degrees:

1. Adequate thermal insulation (increased by the rules of the countries' Thermal Insulation Order).
2. Efficient moisture vapor control in keeping with climatic conditions by adequately sizing ventilation space, while maintaining an adequate moisture vapor transmission so that harmful condensation within the roofing construction and building elements can be avoided.

The planning and construction of sloped, thermal insulated roofing structures has undoubtedly become more complicated with these guidelines. Nevertheless, the result has been prevention of the kinds of problems that originally appeared, though it involves greater costs. This was particularly true just after the Thermal Insulation Order of February 1982 first came into force, and where problems can be directly related to a neglect of these guidelines. (See documentation around the sketches).

These guidelines should make it possible to get an overall picture of the effects of using thermal insulation in sloped roofing over occupied rooms in structural engineering, when these are kept at normal indoor temperatures (at least 19C).

REFERENCES

[1] Publisher: Norming panel for construction work in the DIN German Bureau of Standards.
[2] Publisher: German Ministry for the Economy, "Thermal Insulation Order" of Feb. 24, 1982.
[3] Professional standards of the Organization of German Roofers' Trade-Guidelines for roofing tiles and concrete roof tiles-Central Organization of German Roofers' Trade, 5000 Cologne 51.
[4] Liersch, K.W.: "Thermal and humidity insulation in the roof and fascades according to the new DIN 4108 norm," Mueller Publishing Co., 5000 Cologne 41.
[5] Bernhardt, P. and Kuenzel, H., "The water vapour permeability of roof sealing systems and vapour barriers," a short report from research into building techniques, Nr. 12/79.
[6] Board for Technical and Economic Counseling of the German Building Trade, 6236 Eschborn, Construction and modes of application of energy-saving measures in sloped roofing, Technical document 64/1984, Nr. 826.

Photographic documentation of case studies

Subject matter
Terraced house—used for apartments

Roof covering
Single-lap tiles for flat roofs, provided with folded seam

Roof shape
Duo-pitched roof

Tilt of roof
30 degrees

Length of rafters
7.45m (each side of the roof)

Roof level
Built-up. Thermal insulation between the rafters (glass fiber mats). Continuous insulation layer on the side towards the room (polystyrene).

Roof covering
Spruce wood, tongue and groove

Use of room
Living room (average temperature during period room is heated 18C)

Roof construction from inside towards the outside
Ceiling surface: (panelling)
1) Spruce-wood, tongue-and-groove, 12mm thick and laid on counter-battens (24mm thick), (integrated in the room ventilation).

Thermal insulation I:
2) Polystyrene PS 20, with thickness of 30 mm acting as a *continuous* thermal insulation layer on the side towards the room. Thermal conductivity 0.040 W/m × K. These glass fiber plates are combined with border strips, which fix the plates laterally at the rafters. The strips have the verified width of 3 to 7mm at the joints. These joints make possible the convection of inner and outer compartments. An additional, inner "steam or wind barrier" does not exist.

Thermal insulation II:
3) Glass fiber insulation mats laminated on the lower surface with aluminum foil (0.07mm thickness) with edge strips of 150mm average thickness. Heat conductivity 0.040 W/m × K. (Rafter cross-section 140 × 70mm)

Roof covering:
4) Support-battens: cross-section 24 × 48mm
5) Roof tiles-with overlaps on all sides
   Single-lap tile for flat roofs
   Overlapping portion of tile (length) 340mm
   Overlapping portion of tile (width) 202mm

Defects
A) Damage to the ceiling on the side towards the room caused by humidity as a result of condensation during the winter months with outdoor temperatures at about −10C over a period of 120 hours (5 days) (Photo 2)

B) Also humidity penetration of the glass-fiber insulating mats, where the diffusion humidity has frozen to a depth of 5cm (measured from the outside towards the inside) (photos 5 + 7 + 8)

C) Penetration of humidity on the sides of the rafters (Photo 9)

D) Condensation at the base of the roof tiles, with the formation of ice (Photos 5 + 6)

Causes

1) Insufficient inhibition of vapors on the side towards the room in the vicinity of the glass fiber mats laminated with aluminum foil resulting from non-waterproof joints and insulating layer at the adjoining edge, as well as mechanical damage done by electric cables, etc.

2) An inadequate air ventilation space above the glass-fiber insulating layer towards the lower side of the roof tiles (Photos 5 + 7)

Diagnosis

The condensation humidity which has diffused into the construction layers is greater than the water mass displaced during the period of evaporation (Refers to DIN 4108, part 3 + part 4).

Remedy

1) Removal of the wood panels on the ceiling on the side towards the room.

2) Installing a vapor inhibitive layer, for example, polyethylene sheets of at least 0.1mm ($S_d = 100$mm).

3) Reinstallation of the ceiling panels.

4) Removal of the roof covering and the support battens.

5) Installation of counter-battens (parallel to the rafters) at least 30mm in thickness.

6) Creating ventilation openings at the eaves, with minimum cross-section of the eaves being 200 cm²/m.

7) Creating ventilation openings near the ridge. Minimum total cross-section 74.5 cm² per m of the ridge (entire cross-section).

8) Reinstall the support-battens and the roof covering. (It is recommended that the preparatory roof sheeting also be put in position).

Thermal insulation material	Thermal conductivity W/m × K)	Water vapor diffusion resistance value 1) m	k-value 2) in W/m²·k) and adequate vapor barrier 3) of various thicknesses									
			6 cm		7 cm		8 cm		9 cm		10 cm	
			k	Sd	k	Sd	k	Sd	k	Sd	k	Sd
Mineral wool unlaminated 6)	0.045	1	0.65	0.06	0.57	0.07	0.50	0.08	0.45	0.09	0.41	0.10
Glass fiber unlaminated 6)	0.040	1	0.58	0.06	0.51	0.07	0.45	0.08	0.41	0.09	0.37	0.10
Polystyrene hard foam, expanded	0.040	20	0.58	1.20	0.51	1.40	0.45	1.60	0.41	1.80	0.37	2.00
Polystyrene hard foam, extruded	0.035	80	0.52	4.80	0.45	5.60	0.40	6.40	0.36	7.20	0.33	8.00
Polyeurythane hard foam 4) + 6)	0.030	30	0.45	1.80	0.39	2.10	0.35	2.40	0.31	2.70	0.28	3.00

1) Values according to DIN 4108, in the case of normal material humidity
2) K-values only for roofs ventilated from below
3) The most unfavorable value is applied here in each case
4) In the case of elements which are impermeable to vapors on all sides, the value of heat conductivity can be reduced to 0.025 W/(m² × K)
5) 5mm thick roofing layers of sandwich slabs with PS-hard foam cores are not considered for calculation purposes
6) S-values only for the material in question. Laminated slabs or webs must attain the given Sd-values when used, *without* additional measures
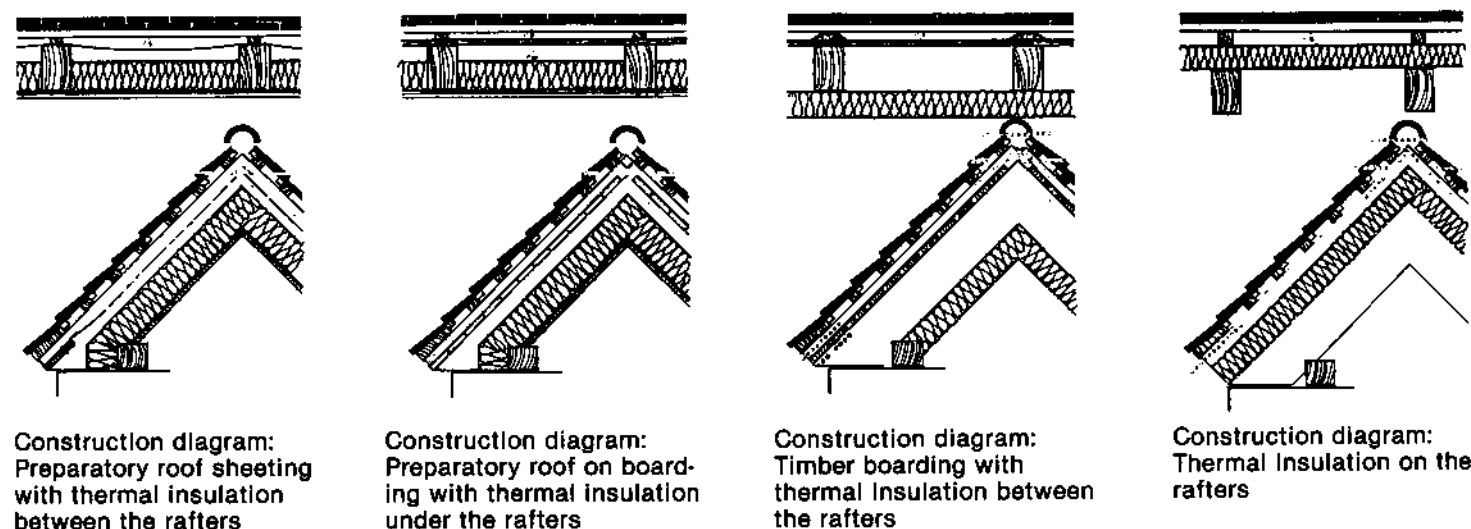
Table 4

Construction diagram: Preparatory roof sheeting with thermal insulation between the rafters

Construction diagram: Preparatory roof on boarding with thermal insulation under the rafters

Construction diagram: Timber boarding with thermal insulation between the rafters

Construction diagram: Thermal insulation on the rafters

Figure 1   *Types of construction for thermal insulated, sloped roofs*

Eaves

Ridge and hip

L_f at least 20/00 of the related roof surface never-theless 200cm²/m eaves, at least

L_f at least 0.50/00 of the relevant roof surface

Roofing Area

Building elements below the ventilation cross-section

L_f At least 200 cm²/m however at least 2 cm unobstructed height

L: unrestricted ventilation cross-section
a: length of rafters
S_d: adequate vapour barrier

a	≤	10m	sd	≥	2m
a	≤	15m	sd	≥	5m
a	>	15m	sd	≥	10m

In residential office build-ings without air-condition-ing as well as buildings used for similar purposes and with a roof inclination of more than 10°, the following simplified values can be applied. These values are minimum values and should be exceeded wherever possible

Figure 2 *Ventilation cross-section for thermal insulated roofs according to DIN 4108*

Photo 1 *View of the building*

Photo 2 *Inner view—living room. Wood paneling of the ceiling discolored through condensation.*

Photo 3 *View of the roof ridge. A) Humidity penetration of the mortar due to condensation. B) As a result of the low outdoor temperatures (– 10), the condensation which has settled between the roof tiles has frozen on the lower side of the overlaps arranged lengthways (ice has formed) (see arrows indicating the spot).*
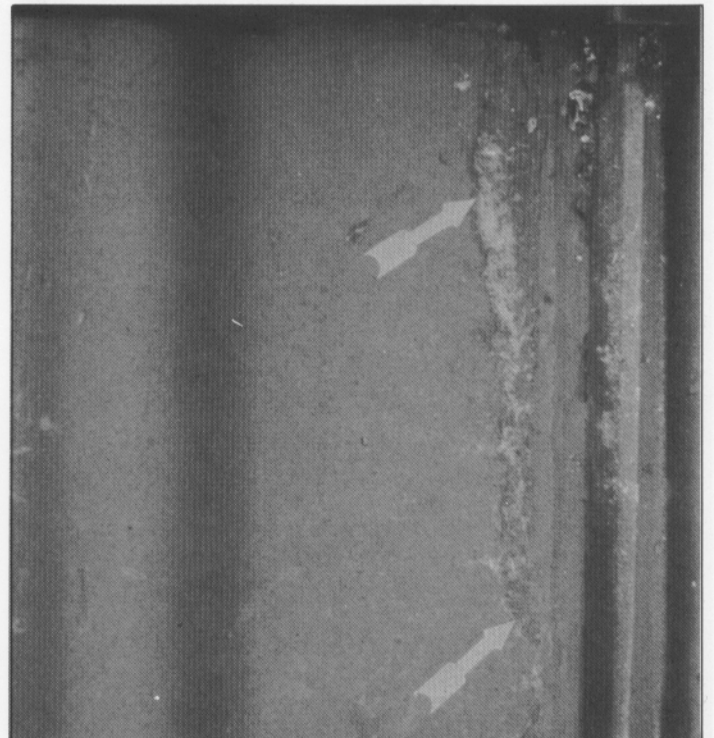

Photo 4 *Detailed view of photo 3. After removing a tile the arrows indicate where the ice has formed. Further condensation cannot escape towards the roof exterior. Result: dripping into the building layers.*
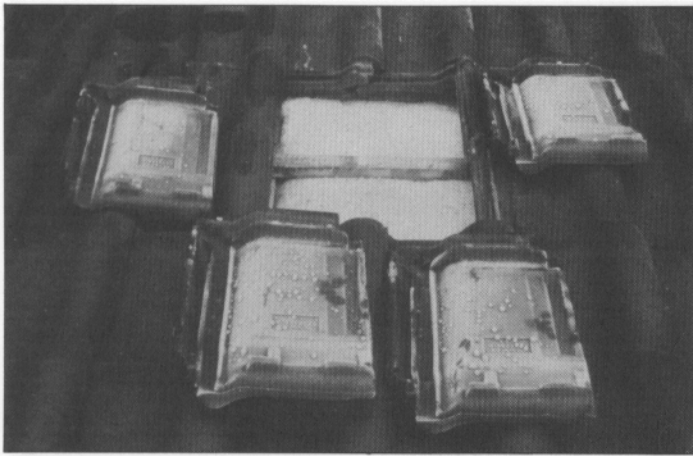
Photo 5 View of the roof after removing the roof tiles. The areas of the rafters are tightly packed with insulation material. There is not possibility of ventilation and the lower surfaces of the roof tiles show frozen condensation humidity.
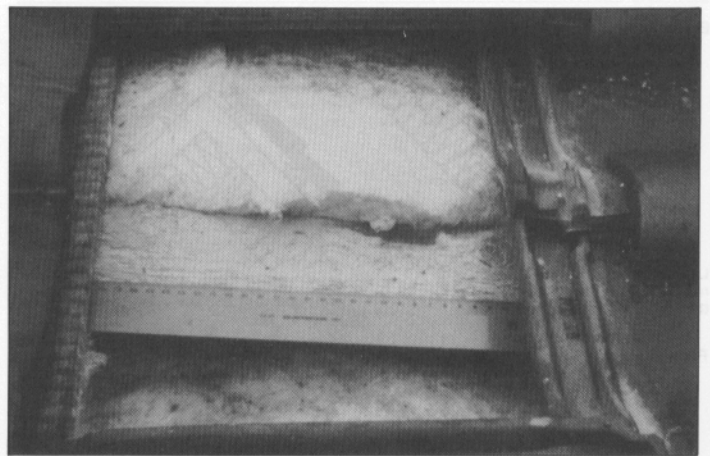

Photo 7 View of the upper construction surface after removing the roofing tiles near the rafters. Formation of ice on the upper surface of the insulating glass fiber mats.
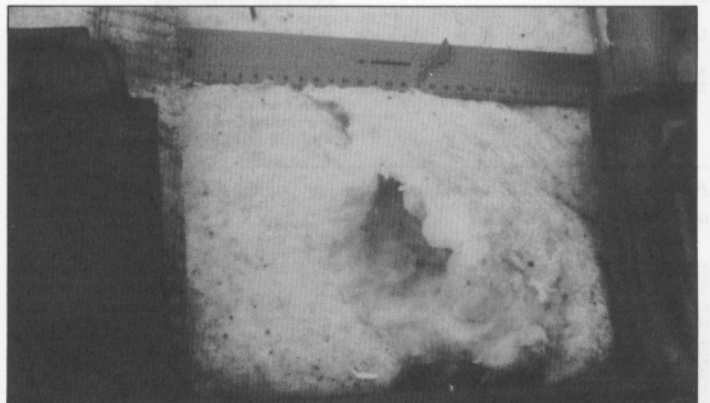

Photo 8 By manual removal of the insulating glass-fibre mats, the "degree to which freezing has penetrated" is clearly visible

Photo 6 Detailed view of the lower portion of a roofing tile. Frozen condensation humidity.

Photo 9 Complete view of the construction layers, seen from the ouside looking towards the inside. The arrow indicates the thermal insulating layer on the side towards the room, consisting of polystyrene particle-foam. The rafter sides are heavily impregnated with humidity on the upper surface. (Depth of penetration of humidity, up to 5mm on the average).