Building Research
Design Guides
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Pitched wooden roofs with cold lofts

0 General

01 Contents

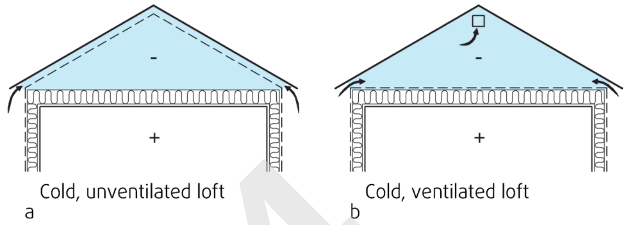
This Design Guide describes the structure and design details for two alternative solutions for pitched wooden roofs with cold lofts. Cold lofts can either be designed as a cold, unventilated loft space with all ventilation coming between the roof underlay and the roof covering, see Fig. 01 a, or in the traditional way as a cold, ventilated loft space with an air stream flowing through the loft itself, see Fig. 01 b. Having a cold, unventilated loft space is a relatively new solution, but experience with it is good so far.

This Design Guide deals with interior air and vapour tightening, thermal insulation, ventilation and exterior tightening against wind, rain and snow.

The Guide also provides structural measures that will delay fire spreading to cold lofts.

02 References

The Planning and Building Act (PBA)
Technical (TEK) Regulations Pursuant to the PBA with guidelines
Standards:
NS-EN ISO 6946 Building components and building elements – Thermal resistance and thermal transmittance – calculation method
Layout:
321.075 Fire safety design of residential housing
321.090 Fire safety design of buildings with cold lofts
Building Research Design Guides:
471.013 U-values. Roofs
524.305 Dividing walls between terraced houses
525.002 Roof structures. Choice of design and materials
525.101 Insulated pitched wooden roofs ventilated below the roof underlay
525.102 Insulated wooden roofs with a combined roof underlay and wind barrier
525.107 Sloping wooden roofs with living spaces in part of the loft
525.831 Prefabricated roof trusses
525.861 Timber Guide decking
525.866 Roof underlays
573.121 Materials for air and vapour barriers
Group 544 concerning roofing
Building administration:
701.401 Mould in buildings. Presence and effects on the indoor environment
720.311 Improving the fire safety of buildings with cold lofts



Figs 01 a and b
Roof with cold loft
a. Cold, unventilated loft space with all ventilation between the roof underlay and roof covering
b. Cold, ventilated loft space with air stream flowing through the loft itself

725.117 Repairing damage to pitched wooden roofs with cold lofts

1 Ventilation principles and choice of design

11 General

Pitched wooden roofs with cold lofts are primarily suitable where the load-bearing structure, room size and access to the loft limits the ability to make use of the loft space. The solution is suitable for smaller buildings with roof-truss frames, and generally consists of prefabricated W-shaped roof trusses spanning from outer wall to outer wall. All thermal insulation should be laid horizontally between and over the bottom chords with a cold loft space above it.

12 Reasons for ventilating the roof

Pitched wooden roofs with external downpipes are ventilated for two reasons:

– In order to transport moisture away from the roof structure and thereby prevent mould and other types of damage caused by dampness
– In order to allow heat to escape and thereby prevent unwanted snowmelt and icing at the roof base (eaves) and in gutters

13 Cold, unventilated loft spaces

131 *Ventilation principles.* All of the ventilation is at roof level, with air flowing in through a gap between the roof covering and underlay, see Fig. 01 a. The loft space itself is unventilated and without any openings to the outside air.

The solution requires the use of vapour-permeable roof underlay (breather type), see Section 51.
The structural principles are described in greater de-tail in Section 5.

132 *Areas of use.* Cold, unventilated loft spaces can be used for most types of buildings, including detached houses and buildings with several fire compartments, such as terraced houses, schools and institutional buildings, ref. Layout 321.090.

The solution can also be used in areas exposed to driving snow, such as mountains, and exposed coastal areas.

133 *Advantages.* This solution reduces the risk of fires spreading via lofts, and provides good protection against driving snow and cold air penetrating into the insulation. A properly installed roof underlay with sealed joints and terminations will help ensure that the roof is airtight. Any driven-in snow that melts to water or rain entering through the ventilation gap will be drained out again.

134 *Disadvantages.* The solution has a somewhat poorer drying-out capability than a ventilated loft, especially when the temperature is below freezing.

14 Cold, ventilated loft spaces

141 *Ventilation principles.* The roof structure is ventilated in the traditional way by air flowing into the loft space itself via ventilation gaps at the roof base (eaves) and ridge and/or gables, see Fig. 01 b. Ventilation of the loft itself is essential if the roof underlay forms a vapour barrier, which it does if you e.g. use bitumen felt on under-roof boarding. The design principles are described in greater detail in Section 6.

142 *Areas of use.* Cold, ventilated loft spaces can be used for detached houses and other small buildings with only one fire compartment without special measures being taken against the spreading of fire to cold lofts. The solution should not be used for larger buildings with several fire compartments.

143 *The advantage* of having ventilation gaps at the roof base (eaves) and ridge is that it facilitates drying-out of the roof and there is little risk of damaging ice formation and water retention at the roof base (eaves) and gutters.

144 *Disadvantages.* Snow can easily blow into the loft through ventilation gaps and vents in places exposed to drifting snow, e.g. in mountain areas and exposed coastal areas. In these areas you should choose a cold, unventilated loft space or a roof structure that does not involve a cold loft, see Design Guide 525.002.

The design may allow fires to spread rapidly to the loft through the ventilation gaps at the roof base (eaves), unless special precautions are taken, see Section 65. Once the fire has spread to the loft it becomes difficult to extinguish, and there is a high risk that it will continue to spread.

2 Loadings and requirements

21 Fire

The best way of preventing fire from spreading via the roof is by having a completely insulated roof. These designs are discussed in Design Guides 525.101 and 525.102.

The notes to TEK specify that in buildings with cold lofts and several fire compartments, the roof base (eaves) must in principle be sealed, and the loft must be ventilated in some other manner, see Section 5. However, you can have ventilation gaps at the roof base (eaves) if the ventilation gaps are at least 1.8 m from a fire compartment wall, see Section 65.

Over cold lofts that require a particularly low risk of fire spreading, the roof underlay must provide at least 10 minutes of fire resistance against fire spreading from the outside, see Section 51. Fire should be prevented from spreading from the inside by having highly fire resistant loft flooring/joisting.

22 Mould on the roof underlay

Wherever there is condensation on the roof underlay or there are long periods of high relative humidity (RH) and temperature, there is a risk of fungus and mould growing on the surface, see Building Administration 701.401. Wood and wood-based materials that have not been treated with a fungicide provide a fertile environment for mould, and are generally more vulnerable than plastic roof-underlay materials.

23 Snowmelt, icing

Snow on the roof provides additional insulation. The surface of insufficiently ventilated roofs may become so warm that the snow melts, even if the ambient tem-perature is several degrees below freezing. The melt water will freeze and form harmful deposits of ice and icicles on the cold parts of the roof, such as the eaves, gutters and downpipes. The risk of snowmelt and icing is greatest if the ambient temperature is a few degrees below 0 °C and the risk diminishes with falling temperatures.

Warm indoor air leaking into the cold loft will increase the risk of snowmelt.

The thicker the layer of insulation, the lower the risk of snowmelt and icing on the eaves. Increased thickness of insulation is particularly recommended for large roofs in cold and calm (windless) inland areas where the risk of icing is greatest.

Ventilation systems and ventilation ducts should not be located in cold lofts. They release heat into the loft, thus increasing the risk of snowmelt and icing, as well as forming condensation in the ducts and a cooling of the supply air.

24 Condensation

Warm, moist indoor air leaking up into the loft constitutes the greatest risk of harmful dampness building up in the roof. It is therefore important that the ceiling forms a good and continuous seal, so that air leaks are kept to a minimum, see Section 4.

25 Sound

The sound insulation properties of the roof are important for buildings located in noisy areas. Cold, unventilated loft spaces provide much better sound insulation than cold, ventilated loft spaces. Roof underlay consisting of felt on timber Guide decking provides better sound insulation than simple roof underlay, see Building Details 525.422 *Sound insulation properties of roofs*. Thin rolled-out roofing felt, if not supported by timber Guide decking, can be noisy as it will flutter in strong winds.

3 Thermal insulation

31 U-values

Table 31 shows the U-values of wooden roofs with cold lofts and various thicknesses of insulation. Design Guide 471.013 contains more detailed tables. On cold lofts it is easy to insulate more than that required by the regulations. This allows you to redistribute the thermal insulation between the roof and other parts of the building; see. Design Guide 471.018 *Documenting the anticipated energy consumption of buildings*. Requirements for each individual part of the building.

Table 31
Estimated U-value (W/(m²K)) for wooden roofs with cold lofts. The roof beam dimensions in the table refer to the bottom chords of ruff trusses, solid wooden beams and L-beams. A spacing of 0.6 m be-tween the centres of beams/bottom chords has been used.

Insulation thick-ness, d	Bottom chords or beam dimension	Thermal conductivity, λ, of insulation W/(mK)			
mm	mm x mm	0.034	0.037	0.040	0.043
250	48 x 98	0.14	0.15	0.16	0.17
	48 x 148	0.15	0.16	0.17	0.18
	48 x (148 + 98)	0.16	0.17	0.18	0.19
	L-beam	0.15	0.16	0.17	0.18
300	48 x 98	0.12	0.13	0.14	0.15
	48 x 148	0.12	0.13	0.14	0.15
	48 x (148 + 98)	0.14	0.15	0.16	0.16
	L-beam	0.12	0.13	0.14	0.15
350	48 x 98	0.11	0.11	0.12	0.13
	48 x 148	0.11	0.12	0.12	0.13
	48 x (148 + 98)	0.12	0.13	0.14	0.14
	L-beam	0.11	0.12	0.12	0.13
400	48 x 98	0.09	0.10	0.11	0.11
	48 x 148	0.09	0.10	0.11	0.12
	48 x (148 + 98)	0.11	0.12	0.12	0.13
	L-beam	0.10	0.10	0.11	0.12
500	L-beam	0.08	0.08	0.09	0.10
600	L-beam	0.07	0.07	0.08	0.08

32 Mineral-wool insulation

Specially-designed mineral-wool slabs are available for insulating roofs with cold lofts. These slabs make it easy to insulate over the bottom chords of the roof trusses. The insulation can also be laid in two layers, with the bottom layer being as thick as the height of the bottoms chords, see Fig. 32. It is important that there are no gaps in the insulation, and that it is laid right up against the roof truss web to prevent cold air from flowing down through joints and poor transitions in the insulation layer. If the insulation is more than 300 mm thick, it is recommended that you use insulation material with a building-paper covering on top in order to reduce the risk of natural convection.

33 Blowing of loose mineral wool, cellulose or wood fibre

In practice this method provides a better seal around the roof truss web and chords than insulation boards. In order to compensate for settlement, the insulation should have an excess thickness of approx. 5 % for mineral wool and approx. 20 % for cellulose and wood fibre.

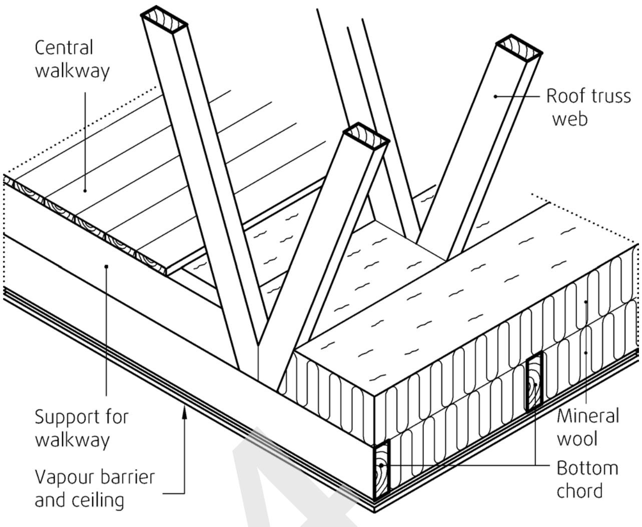


Fig. 32
Insulation of roof with W-shaped roof trusses and cold loft with walkways

34 Walkways

In order to prevent the thermal insulation from being trodden down, it should always be protected by a raised floor in the middle and below any storage areas, see Fig. 32.

4 Inner air and vapour barriers

41 General

The vapour barrier below the thermal insulation is intended to prevent air leaks and the diffusion of water vapour up through the roof. A 0.15 mm thick polyethylene Guide is recommended as a vapour barrier. The Guide should be as wide as is practicable. Design Guide 573.121 provides further details on requirements relat-ing to vapour barriers.

42 Installing a vapour barrier

The vapour barrier should be installed before any non load-bearing partition walls. This reduces the number of joints and terminations.

The vapour barrier should be placed continuously across the whole width of the house, directly below the thermal insulation, see Fig. 42. All overlap joints and terminations must be clamped between firm and level materials. Clamping joints with panelling or boards using concealed nails in the flange does not produce a satisfactory air seal, and the joints in the Guideing should be clamped with separate nailing strips or battens.

In order to achieve extra tight joints or where it is difficult to press the joints together well, you can use a semi-elastic sealing compound in the joint. Use a compound that is documented as producing a durable bond to the vapour barrier. Using a sealing compound in the joints is particularly suitable above premises that produce a lot of moisture.

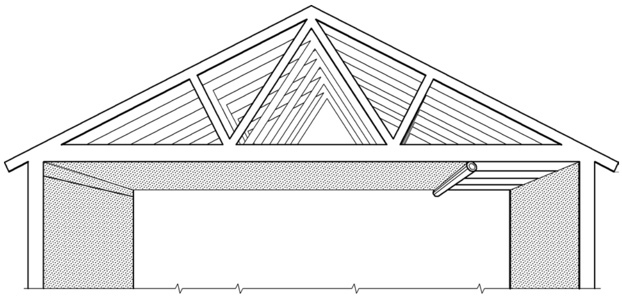


Fig. 42
The vapour barrier should go right across with width of the house, without any lateral joints. Lengthwise joints should be clamped against the beams. The polyethylene Guideing should be as large as possible in order to minimise the number of joints.

43 Electrical installations

Penetrations for electrical installations must not perforate the vapour barrier, thereby causing air leaks. The safest principle is to have non-concealed electrical installations. Concealed electrical installations in the ceiling must always be installed in a conduit in a false ceiling below the vapour barrier using battens that are at least 30 mm thick; see Fig. 43. We advise against downlights as they often create large air leaks and extra heat loss up to the loft. In order to avoid air leaks you must use airtight covers with airtight joints to the vapour barrier. See Design Guide 543.615 *Fitting downlights in ceilings*.

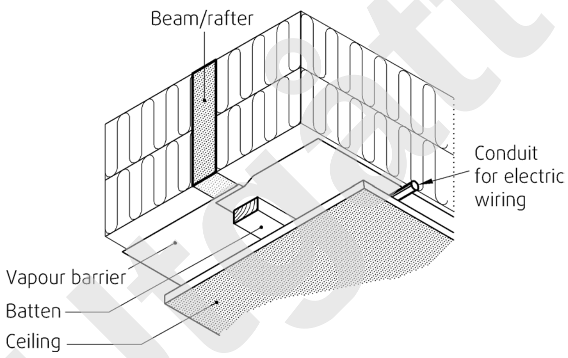


Fig. 43
Concealed electrical fittings should be installed in a false ceiling.

5 Cold, unventilated lofts

51 Roof underlay

For cold, unventilated loft spaces the roof underlay must be vapour permeable and wind proof. Vapour resistance can be expressed as an s_d-value; see Design Guide 573.121. SINTEF Building and Infrastructure recommend that a vapour permeable roof underlay has as low as possible an s_d-value, and a maximum of 0.5 m. A Vapour permeable roof underlay ensures that vapour in the structure and the loft space can escape by diffusing out through the underlay and then with the air flow in the ventilation gap. Over lofts that require a particularly low risk of fire spreading, the roof underlay must provide at least 10 minutes of fire resis-tance. One way of creating a sufficiently vapour permeable and fire resistant roof underlay is to use 15 mm roof boards combined with a roof underlay product with an s_d-value of less than approx. 0.25 m. As an alternative to 15 mm roof boards you can use plasterboard designed for external use, moisture permeable plywood boards or OSB boards with vapour resistance equivalent to wooden boards.

52 Ventilation

Ventilation principles are described in Section 131. The size of the ventilation gap and ventilation openings are the same as for roofs with a combined roof underlay and wind barrier, see Design Guide 525.102. The ventilation gap should be cross-ventilated and have openings under the eaves both on the side walls and gable ends. When using battened roofing, it is easy to achieve adequate ventilation by increasing the height of the counter battens.

53 Ridge details

The joint at the ridge must be airtight between the roof underlay and the two roof surfaces, and the joint should be clamped with lengthwise battens. At the same time, there should be an opening beneath the ridge board so that the roof receives a through draft along the ridge, thus improving the ventilation of the roofing, see fig. 53.

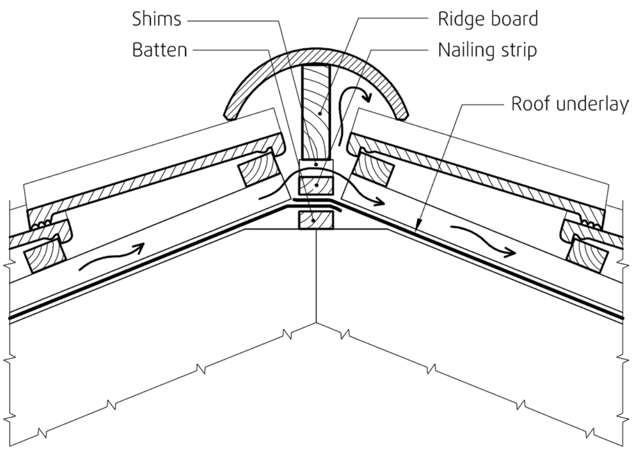


Fig. 53
Ridge design for cold, unventilated lofts with sealed roof underlay and an opening below the ridge board to improve ventilation

54 Sealing the roof base (eaves)

Figure 54 shows how to seal the roof base (eaves). In order to reduce the risk of fire spreading, the cladding on the underside of the eaves must be airtight and fireresistant. Furthermore, the joints against the outer wall and the outside edge of the roof base (eaves) must also be sealed, to prevent fire gases from entering the loft.

The underside of the eaves can be sealed using cladding made of 15 mm fire-resistant plasterboard jointed on studs. The boards should be supported by open-jointed cladding to prevent them from sagging over time. The boards should be painted before you panel the walls. The insulation should extend as far as the rafter-felt carton in order to increase fire resistance, see Figs 54 a and b.

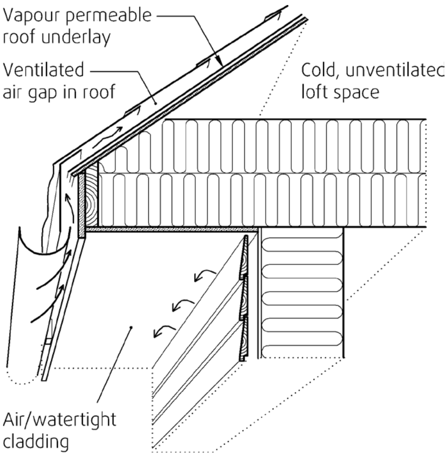


Fig. 54 a
Cold, unventilated loft. Diagram showing design principles
Over lofts that require a particularly low risk of fire spreading, the roof underlay must provide at least 10 minutes of fire resistance, and have an airtight underfelt consisting of a fire resistant board.

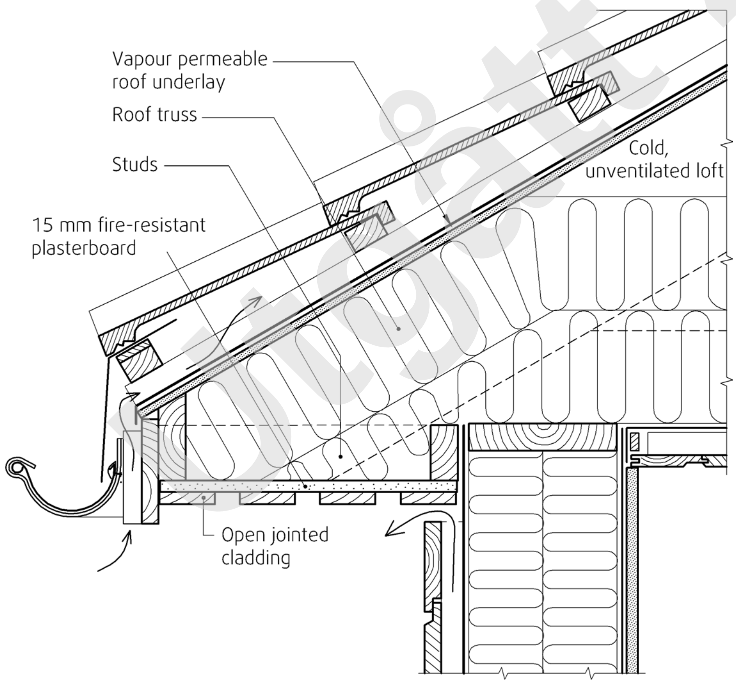


Fig. 54 b
Vertical section through Fig. 54 a
Execution of sealed eaves

55 Wind tightening

When using a combined roof underlay and wind barrier, the joints must be air and water tight. It is normal to clamp overlap joints between firm, even materials, but there are also products that can be glued, meaning that they don't have to be jointed on the rafters. When using a vapour permeable roof underlay product on roof boards, the joints must be clamped between two flat materials. Raising the joints reduces the risk of water leaks, see Fig. 55.

The roof base (eaves) must be executed in such a way that there is a continuous wind barrier between the roof underlay and the wind barrier in the outer wall, see also Section 54. The gable walls of cold, ventilated loft spaces must also have a wind barrier with properly sealed joints to the roof underlay and to the wind barrier in the wall below them.

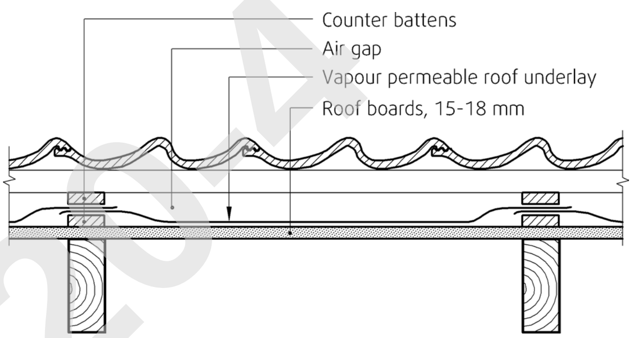


Fig. 55
Moisture permeable roof underlay on roof boards
When sealing overlap joints on roof boards, the joints between two flat materials should be clamped as shown in the diagram. Raising the joint reduces the risk of water leaks.

6 Cold, ventilated loft spaces

61 Roof underlay

Over cold, ventilated lofts you can use either vapour permeable or impermeable roof underlays. Bitumen felt on timber Guide decking is a more expensive solu-tion than reinforced roofing felt, but provides a more solid and secure roof over ventilated lofts. Building Details 525.861 and 525.866 deal with roof underlays in greater detail. In order to delay the spread of fire to the loft from outside through the roof, the roof underlay must provide at least 10 minutes of fire resistance in the same way as for roofs with cold, unventilated loft spaces, e.g. under roof with bitumen felt covering or foil, see also Section 51.

62 Ventilation

Ventilation principles are discussed in Section 141. In order to achieve adequate ventilation on calm (windless) days, there must be openings both at the roof base and at the ridge of the roof, or vents as far up as possible on the gables, see Sections 63 and 64. In addition to ventilating the loft space, cross-ventilation under battened roofing will also help to keep the surface of the roof cold, as described in Section 52.

Limited ventilation in order to reduce the risk of fire spreading is described in Section 65.

63 Ventilation gaps at the ridge and gable

Ventilation gaps at the ridge of a roof are particularly vulnerable to precipitation ingress in exposed areas, but are also designed to minimise this risk. In practice the opening at the ridge exerts great air-flow resistance and provides only limited ventilation on calm (windless) days.

Ventilation at the ridge of the roof can be executed in three different ways:

- On small roofs that receive little snow it may be enough to insert vents into the gables instead of ventilating the ridge of the roof. The vents should have a net opening of approx. 200 mm x 200 mm in each gable and be positioned as high up as possible at the ridge to ensure that they provide sufficient ventilation even in calm weather, see Fig. 63 a.
- By providing ventilation under ridge tiles, see Figs 63 b and 53
- In areas exposed to much snow, and where the distance between the roof base and the ridge is more than 7 m, it may be necessary to fit a louvre in the ridge to prevent the opening being blocked by snow.

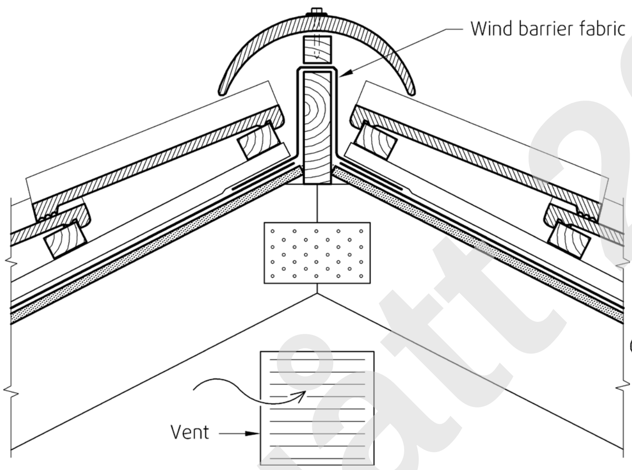


Fig. 63 a
Ridge design for cold, ventilated lofts with sealed ridge and vents in the gables

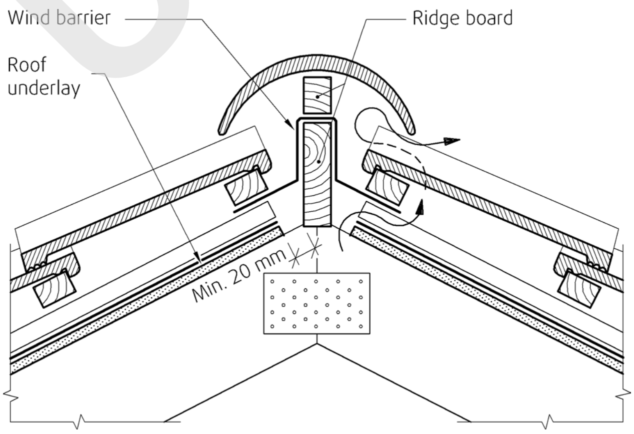


Fig. 63 b
Ridge design for cold, ventilated lofts with ventilation gap under the ridge tiles

In areas with high winds, that are exposed to little snow and rarely experience long cold periods, having openings under both eaves may be sufficient.

64 Ventilation at the roof base

We recommend that you have ventilation gaps to the loft at both roof bases along the full length of the building. In cold, high-snowfall areas and where there is a risk of snowmelt, the gap should correspond to a continuous opening of approx. 50 mm, see Fig. 64. In order to reduce the risk of snow driving into the loft, you should use a rafter-felt carton with a single gap as far away from the outer wall as possible. Where there is a risk of driving snow and snowmelt, the gap in the rafter-felt carton should be significantly narrower than the opening into the loft in order to reduce the risk of snow ingress.

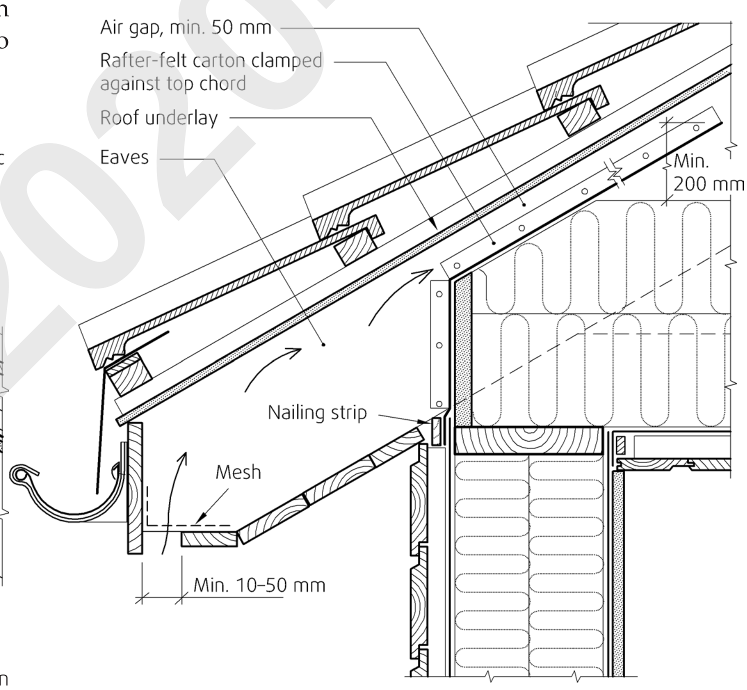


Fig. 64
Transition between outer wall and a roof with roof trusses and a cold, ventilated loft space
In order to prevent cold air penetrating into the insulation, the rafter-felt cartons (see Section 66) should go far enough into the loft for the distance from the end of the wind barrier down to the insulation to be at least 200 mm.

65 Preventing the spread of fire, ventilation gaps

The risk of fire spreading to cold, ventilated loft spaces can be reduced by positioning ventilation gaps in the roof base at least 1.8 m from fire compartment walls and a similar horizontal distance from windows beneath them (top two storeys), see Figs 65 a and b. The roof base (eaves) can be designed and clad as shown in Fig. 54 b, apart from the sections with ventilation gaps, which should correspond to Fig. 65 b. If the fire compartments are offset by at least 2 m, it is not necessary to seal the roof base completely.

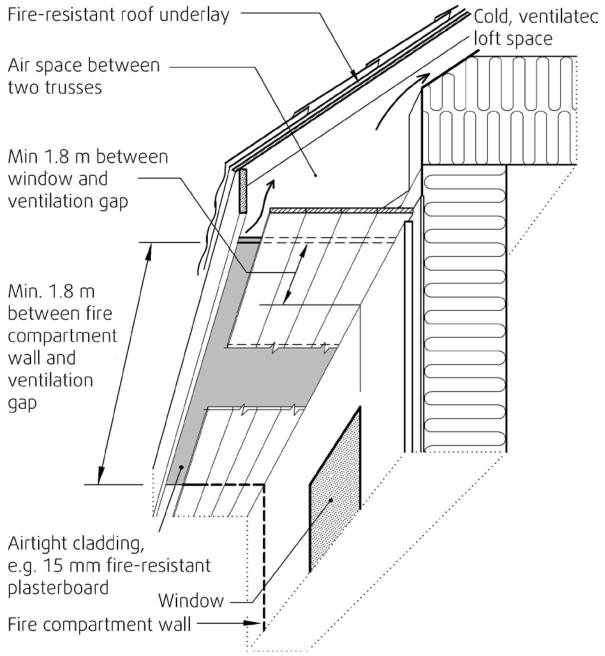


Fig. 65 a
Cold, ventilated loft space with partially clad roof base (eaves). Illustration showing design principles

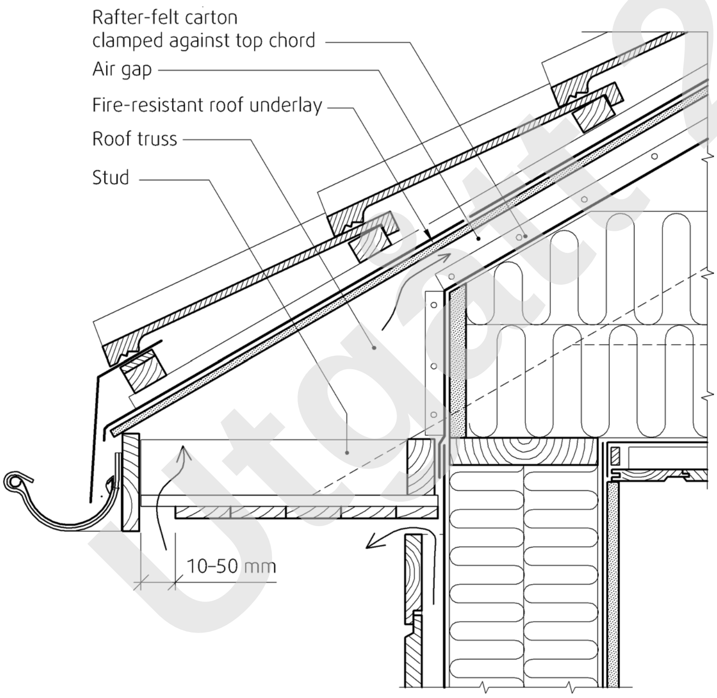


Fig. 65 b
Detail of ventilated, partially clad roof base (eaves). The diagram shows a vertical section of Fig. 64 a with ventilation gaps below the roof base (eaves).

66 Wind tightening

Wind tightening is intended to prevent cold air streaming into and under the mineral wool. Without wind tightening, insulation capacity will be reduced resulting in condensation/stains on the underside of the ceiling. It is important to ensure efficient wind tightening at the roof base as this is where the air-speed and pressure gradient is highest. You can use prefabricated rafter-felt cartons with flanges that are pressed against the sides of the roof trusses. Alternatively you can use wind-barrier material cut to size and clamped with battens against the sides of the roof truss.

The wind barrier must divert the air well above the insulation, and should continue far enough into the loft for the distance down from the end of the wind barrier to the insulation to be at least 200 mm; see Fig. 64. From that point and inwards, the speed of the air-flow in the loft will be so reduced as to make a wind barrier unnecessary in preventing cold air blowing into the insulation.

The overlap between the rafter-felt cartons and the wall's wind barrier should be clamped with a moulding, see Fig. 64. Accuracy is required to prevent air leaks in the corners by the bottom chords.

67 Ventilation grilles that close in the event of fire

Fire tests show that special ventilation grilles that automatically close in the event of fire can be used if it is undesirable or impossible to completely or partially seal the roof base (eaves). Such products must have a fire rating based on standardised testing.

68 Joints with high walls

Figure 68 shows the transition between a roof with a cold, ventilated loft space and a higher framework wall. Cold, unventilated loft spaces should not have a vent in the wall.

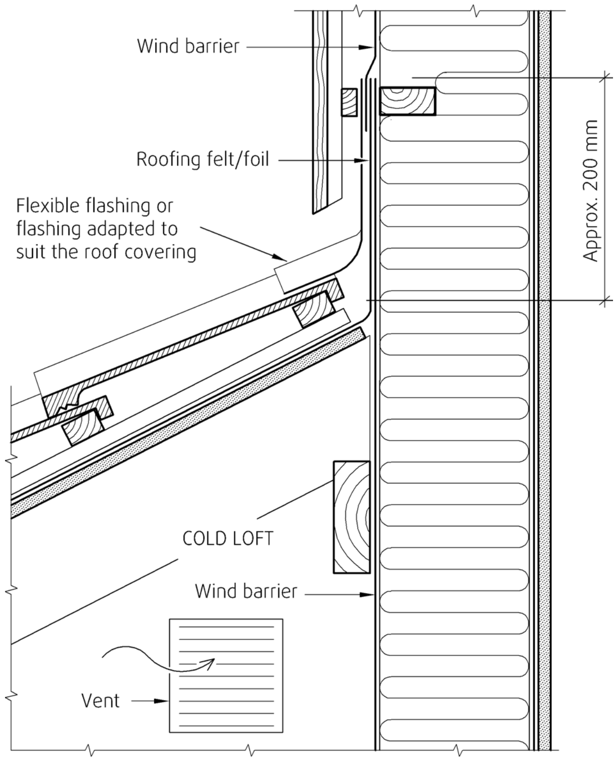


Fig. 68
Joint between cold loft and tall framework wall. For cold, ventilated lofts you will need wall vents as shown on the illustration.

7 Penetrations, hatches and technical installations

71 Penetrations

Figures 71 a–c show seals around penetrations such as chimneys and ductwork. It is important that chimneys made of uncoated lightweight aggregate (LWA) building blocks also be rendered at the level of the floor of the loft, to prevent air leaks. Design Guide 525.866 describes how to seal penetrations through the roof underlay.

72 Access hatches

Loft access hatches must have sealing strips around the edges, as well as strong hinges and closing points that exert sufficient force against the sealing strips all around the hatch; see Fig. 72.

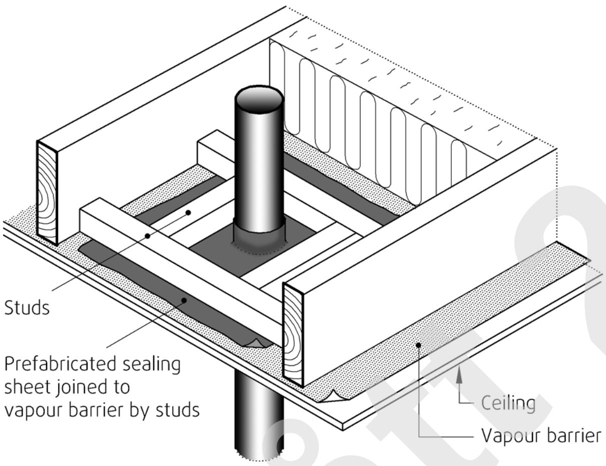


Fig. 71 a
Sealing a vapour barrier around a pipe with the help of foil

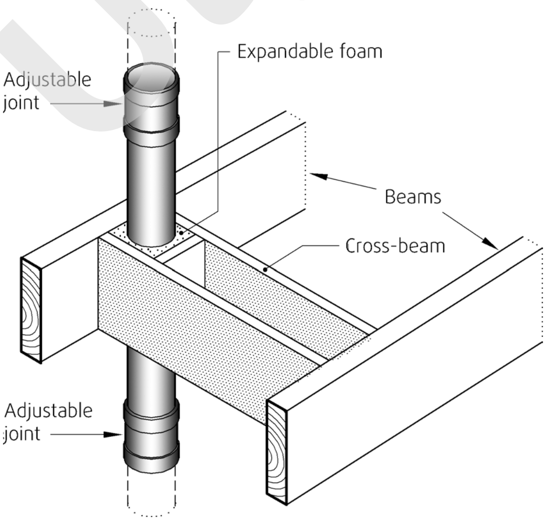


Fig. 71 b
Foam seal around pipe/duct

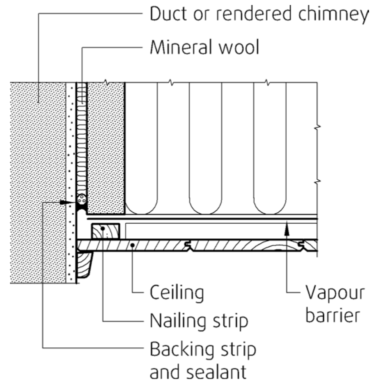


Fig. 71 c
Mineral wool and sealing compound seal around chimney/duct.

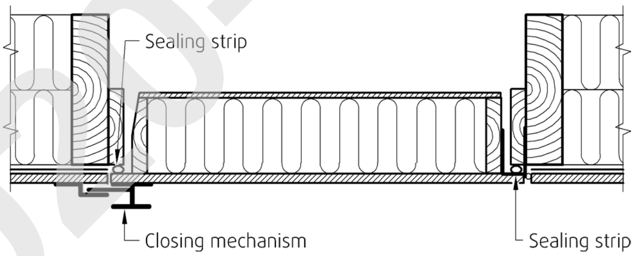


Fig. 72
Hatches to cold lofts must have strong closing mechanisms that exert sufficient force against the sealing strips.

73 Ventilation systems

Ventilation systems and ventilation ducts should not be located in cold lofts. These release heat into the loft. This increases the risk of snowmelt and icing, and might also result in condensation forming in the ducts and cooling of the supply air.

8 References

81 Authors

This guide has been revised by Sivert Uvsløkk. It replaces the Design Guide of the same number published in 1997 and parts of Design Guide 525.108, published in 2002. The technical editor was Morten Lian. Technical editing was completed in November 2005.

82 Literature

821 Gustavsen, A., Uvsløkk, S., Oustad, M., Hofseth, V., Thiis, T., Barfoed, P., Delpech, P. and Dufresne de Virel, M. Climate 2000. Snow ingress into cold, ventilated roofs – wind tunnel experiments. Project Report 382, SINTEF Building and Infrastructure. Oslo, 2005

83 Translation

This design guide has been translated from Norwegian into English. The solutions in this guide are therefore based on Norwegian regulations and practice.