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Condensation in roofs

Although most roofs perform well, problems of condensation are increasing. The risk is greatest in roofs that have impermeable sheet coverings, and flat roofs in particular have frequently given rise to problems. With newer forms of construction, lower roof pitches, and changes in standards and forms of heating, similar problems are now being met in pitched roofs.

This digest discusses design principles for minimising the risk of condensation and consequential damage to decorations or structure.

Design principles

The simplest roof is no more than a rain shield but many designs include a lining or a ceiling, separated from the rain shield or cladding by an air space and insulation. If warm moist air from the building can enter the air space, it will condense on any surface whose temperature is below its dewpoint. This is most likely to be the underside of the cladding, from which moisture can drip on to the ceiling or damage the roof structure. The design should therefore aim to balance temperatures and humidities so that the surface temperatures of critical component parts of the roof remain above the dewpoint of the surrounding air for most of the time. Practical measures that can be taken are:

(a) provide a vapour barrier at the warm side of the roof structure to prevent the entry of moisture from the building.

(b) provide a rain shield that is permeable to water vapour, to allow for the transfer of moisture to the outside.

(c) ventilate the roof space to the outside air.

(d) blow 'dry' air into the roof space under pressure and thus prevent moist air from entering it.

The practical difficulties of achieving these measures vary from one type of roof to another, and methods appropriate to different roof types are discussed later. For instance, it is very much easier to achieve a permeable rain shield on a pitched roof than on a flat one; it is also easier to form an impermeable membrane above a flat roof deck than below it.

Digest 110 *Condensation* sets out procedures for steady-state calculation of internal temperatures and dewpoints in roofs which do not incorporate ventilated air spaces, and these procedures enable the risk of steady deposition to be assessed for lightweight (low thermal capacity) roofs. An estimate has to be made of the most adverse external and internal temperatures and humidities that will occur at any time.

Such calculations cannot be made for heavyweight (high thermal capacity) roofs such as concrete roofs, which take some time to warm up and cool down, but it is possible to assess whether a steady deposition in concrete roofs is likely by making steady-state calculations based on the most adverse *daily mean* temperatures and humidities.

It is not generally possible to calculate with certainty the risk of condensation in roofs with ventilated air spaces.

Even if there is no steady deposition of water, intermittent condensation can occur. If the roof incorporates absorbent materials that are unaffected by moisture, small amounts of moisture may be deposited for short periods and can later evaporate without causing trouble. Care must be taken to avoid situations where water might drain to where it can cause damage and the ventilation must be good enough to encourage drying during favourable atmospheric conditions.

Condensation is not necessarily troublesome; on the upper side of undertiling felt it is usually harmless as it can normally drain away, but on the underside it is likely to cause trouble either by dripping on to the ceiling below or by draining to a point where it can wet the structure.

Particular attention has to be paid to the possibility of condensation on cellulosic materials such as flax-board, strawboard, fibre insulating board or chipboard, which permanently lose mechanical strength or rot when they become wet. Untreated timber is susceptible to fungal attack when its moisture content exceeds 20 per cent by weight. Where there is any risk that it might reach this condition, it should be pressure impregnated with preservative, but timber that has been treated with preservation salts may, when it gets wet, cause corrosion of metal fastenings.

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Types of roof

Various forms of roof are now discussed to bring out the factors affecting condensation. The order of presentation is not related to the frequency of occurrence of the roofs, but is chosen to illustrate the principles in a convenient manner.

Sheeted roofs (Fig 1)

Sheeted roofs, which are commonly used in factories, consist of an outer cladding of, say, corrugated metal and an inner lining, often fibre insulating board or plasterboard, with thermal insulation between cladding and lining and an air space between the insulation and the underside of the ridges of the roof sheets. In adverse conditions, moisture can enter the air space from the building through gaps between the lining boards or by diffusion through the lining itself, condense on the underside of the cladding and drip on to the insulation or the lining. Ventilation of the airspace through protected openings at the top and bottom of the slope can help in evaporating condensate in favorable conditions. It will not prevent overnight condensation when the skies are clear.

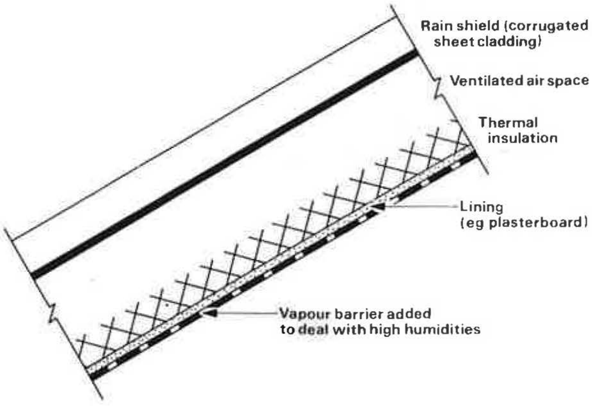


Fig 1 Sheeted roofs

Though sheeted roofs with ventilated air spaces are suitable for most factories, there can be problems in factories where high humidities occur, eg breweries, dye-houses, etc. These can sometimes be overcome by providing a vapour barrier at the inside of the structure. The only successful method of forming a vapour barrier at ceiling level is to spray the underside of the lining with a suitable plastics coating. This treatment is, however, expensive and the film might be ruptured by roof movements.

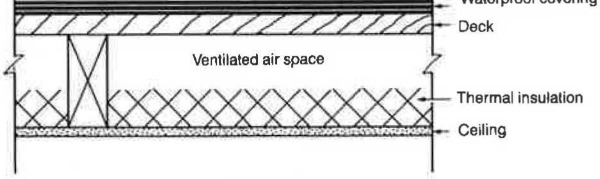
Lightweight flat roofs (Fig 2)

Lighweight flat roofs comprise a waterproof membrane covering a structural deck, an air space and a lining or ceiling; they must also incorporate insulation. The air space cannot be ventilated through gaps in the cladding, neither can water vapour diffuse through the waterproof covering which is usually bitumen felt, asphalt or sheet metal. Moist air which finds its way into the air space therefore condenses on a metal deck, or diffuses through a timber roof deck, wetting the deck and condensing on the underside of the waterproof covering. The condensation risk depends on the roof design and because of this all timber used in flat roofs should be pressure impregnated with preservative.

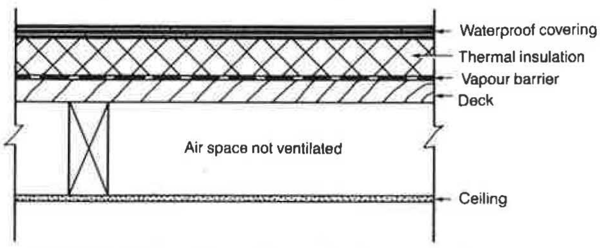
Cold deck roof In the roof illustrated in Fig 2a, the insulation is placed on top of the plasterboard; this will prevent surface condensation on the ceiling but there is a risk of condensation on the underside of the waterproof covering. This type of construction is commonly referred to as a 'cold deck roof' because the deck is external to the insulation and is remote from the warmth of the building when it is heated. The amount of water vapour entering the roof structure can be restricted by a vapour check, eg. sheet polyethythene at ceiling level.

Every void in a flat, cold deck roof must be ventilated. The apertures between connected voids must be at least as large as those between the voids and the outside air. The only way in which the air spaces in a lightweight flat roof can be ventilated is through gaps or grilles at each end of every air space but there is a fairly high resistance to the flow of air in these long narrow air spaces, particularly if they are partially obstructed by stiffeners. If the roof overhangs the external walls, ventilation openings can be provided in the soffit but if the roof finishes flush with the external walls, grilles have to be built into the walls. Neither the air flow through the roof spaces nor the moisture flow into the roof can be estimated with any accuracy. Furthermore, if water is trapped between the timber deck and the waterproof covering, one cannot rely on this being removed by evaporation. Experience has shown that there is a relatively high risk of condensation in this type of deck.

Warm deck roof (Fig 2b) The behaviour of a lightweight flat roof in respect of condensation is improved if the insulation is placed above the deck and a vapour barrier added between the deck and the insulation. Since, in this type of construction,



(a) Cold deck roof (insulation below air space))



(b) Warm deck roof (insulation above air space)

Fig 2 Lightweight flat roofs

the deck is internal to the insulation and is kept warm by the heat of the building, it is commonly referred to as a 'warm deck roof'. In this form of construction with overdeck insulation, no attempt is made to ventilate the roof spaces. If the temperature of the vapour barrier is kept above the dewpoint of the air, condensation will not occur within the roof structure. When it is possible to specify the most adverse temperatures and humidities both inside and outside, the amount of insulation required above the vapour barrier can be calculated.

In housing, the internal conditions are not known but experience has shown that if the roof insulation meets the requirements of the Building Regulations, with most of it located above the vapour barrier, the risk of condensation within the structure is small.

The vapour barrier normally consists of bitumen felt (not less than 13 kg/10m^2) well lapped at joints and nailed or spot bonded to the structural deck in compliance with BS CP 144. An all-over coat of hot bitumen mopped on to the top of the bitumen felt completes the vapour barrier and also provides a means of sticking down the thermal insulation. With this form of construction it is essential that the insulation is kept dry. The insulation boards must also be closely butted since there is a high risk that coverings like bitumen felt or asphalt will fail over gaps. At the perimeter of the roof the vapour barrier must be turned up and sealed to the rain shield to prevent ingress of moisture at the edges of the insulation boards. Similar measures are needed at any breaks in the roof such as at roof lights, around pipes, etc. On large roofs it is also advisable to divide the insulation into sealed compartments.

Lightweight pitched roofs (Fig 3)

Lightweight pitched roofs can be constructed in a similar way to lightweight flat roofs, with a sloping waterproofed deck, a ventilated roof space and a ceiling. Fig 3 illustrates a typical construction with a timber deck and insulation between joists. The roof space can be ventilated by suitable openings at eaves or gables.

The roof illustrated in Fig 3 is a cold roof; the insulation is at ceiling level and the roof space is cold. As with the similar flat roof there is a high risk of condensation on the underside of the waterproof covering. It would be more satisfactory to place the insulation above the deck as in the flat, warm deck roof construction. A vapour barrier of bitumen felt is then necessary between the insulation and the deck.

Tiled or slated roofs (Fig 4)

The tiles or slates of traditional pitched roofs were often laid only on battens on rafters, or fixed direct to timber sarking, so that the roof space was freely ventilated through gaps between the tiles or slates. It is now usual to provide an underlay to the tiles or slates, usually of bitumen felt. If the underlay is permeable, either because it is not saturated with bitumen or because of gaps at the lapped joints, there is little risk of trouble from condensation. Moist air which enters the roof space can escape through the permeable covering, and any intermittent condensation in the roof is absorbed by the timber or felt and later re evaporated. If timber sarking is used above the rafters it provides further absorbent material.

However, impermeable materials such as saturated bitumen felt, PVC and polyethythene are now extensively used for underlays. These reduce the rate at which moist air can escape from the roof space so that condensation problems are becoming more common. Water condensing on the underside of an impermeable underlay may drip on to the ceiling or drain down the roof slope, wetting timbers at the eaves and causing damage to the structure. If timber, chipboard or other organic material used as sarking has an impermeable underlay

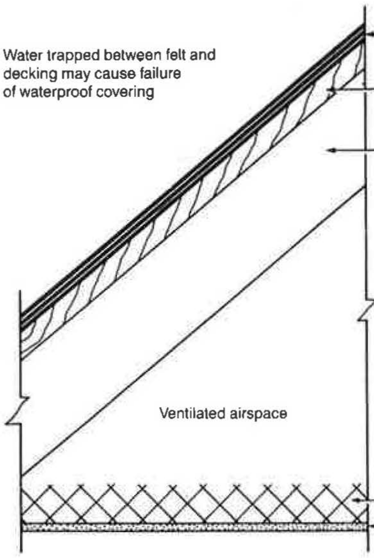


Fig 3 Lightweight pitched roof

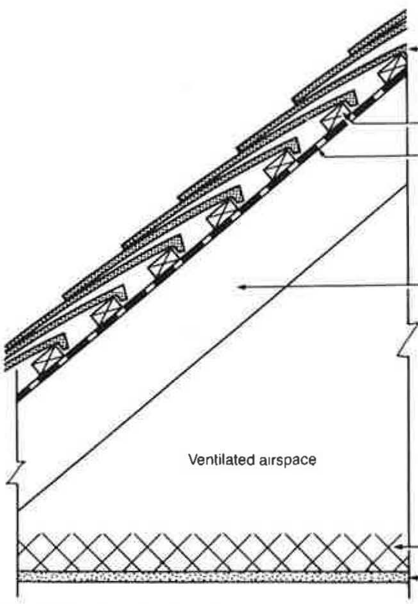


Fig 4 Tiled or slated roof

above it, the sarking material may be damaged by condensation; this might be avoided by increasing the ventilation of the roof space.

If the roof is to have a ceiling line following the line of the roof or where the rafters are to be exposed, it is possible to construct a pitched warm deck roof by placing over the rafters a decking to which can be applied a bitumen felt vapour barrier. Over this is placed the insulation between counter battens of the same thickness as the insulation before placing the sarking, battens and tiles in position.

Concrete roofs

Concrete, either cast in situ or precast, can be used as a structural deck. A lightweight screed is sometimes used to provide falls (though these are better formed in the structural deck) and additional insulation. The deck is usually covered with an impermeable waterproof covering, such as bitumen felt or asphalt.

In wet districts it is not easy to dry out the construction water or to prevent further wetting before the waterproof covering is laid. Rainwater and construction water which is entrapped within the roof construction when the waterproof membrane is laid can move about by diffusion and condensation within the screed as the external temperature changes. In particular, when the sun is strong, entrapped water can be driven downward through the screed and any joints, cracks or holes in the slab to appear inside the building. The water may also saturate any insulating screed, thus greatly reducing its value as insulation.

Although most blisters in flat roofs are not caused by water beneath the membrane, in a few cases the waterproof covering may be damaged by blisters caused by vaporisation of water entrapped below it. Properly designed breather vents, in conjunction with a pressure-releasing layer beneath the rain shield, can overcome this problem but they are not very effective in preventing trouble from condensation.

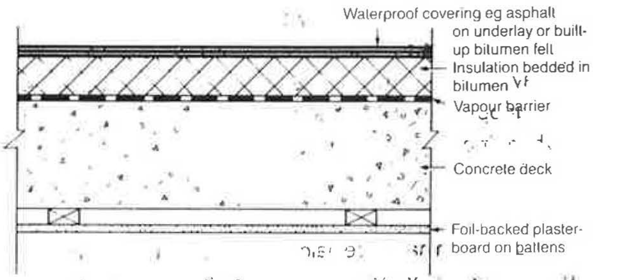


Fig 5 Conventional concrete roof

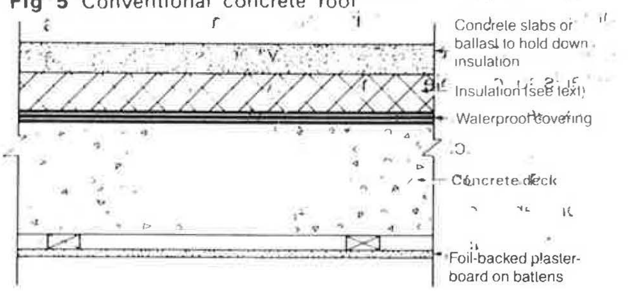


Fig 6 'Inverted' roof (waterproof covering *below* insulation)

An effective method of avoiding condensation, at least in continuously heated buildings, is to provide overdeck insulation as shown in Fig 5. There may be some temporary condensation on the underside of such concrete roofs in intermittently heated buildings, but this can usually be avoided by using a lightweight battened-out ceiling, preferably using foil-backed plasterboard, to avoid staining during the drying-out period.

The 'inverted roof' (Fig 6) operates on the same principle as overdeck insulation but uses materials that are unaffected by moisture, such as foamed glass or extruded polystyrene, above the waterproof covering. The insulation is not covered with a waterproof layer as with overdeck insulation, but simply weighted down by gravel of a suitable size or concrete paving slabs. Insulation is available with a loading layer bonded to it.

Pressurised roof space

A suspended ceiling may be used to provide a roof space to accommodate machinery, or for appearance, or for acoustic absorption (Fig 7). This introduces an air space which must be taken into account in assessing the condensation risk. For instance, the thermal insulation of an acoustic ceiling may be high enough to reduce temperatures within the structure below the dewpoint of the air within the building.

In such cases, external air can be blown into the roof space to ensure that the dewpoint of the air within it is kept below the temperature of any part of the structure. The air pressure in the roof space has to be high enough to prevent the entry of water vapour from the building, and to ensure a downward flow of air through gaps. A vapour check should be incorporated at ceiling level to reduce the diffusion of water vapour into the roof space and to reduce the gaps through which air is lost. The excess pressure can then be kept to a minimum, to save on the cost of fans and energy.

This technique is normally justifiable only for buildings with abnormally high internal humidities, such as swimming pools.

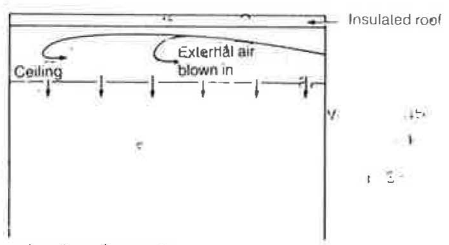


Fig 7 Pressurised roof space

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