

# Condensation control in dwellings

Condensation in dwellings occurs when warm moist internal air comes into contact with cold inside surfaces, or with cold air or surfaces within the structure.

This Wood Information Sheet (WIS) explains the difference between surface and interstitial condensation and describes design measures to reduce the incidence of condensation.

With improved thermal performance and air tightness in new and existing buildings, the risk of damage from condensation has increased. Most surface condensation is largely caused by the behaviour of occupants, such as breathing, cooking and bathing – all emitting moisture. However, the designer can influence these effects by specifying suitable controls (such as mechanical ventilators) and reducing thermal bridging to enable the occupant to limit the incidence of surface condensation.

While surface condensation should be avoided, interstitial condensation is more serious because it can affect the structure of the building.

This WIS is an overview of the subject with signposts to more detailed sources that are listed at the end.

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- Factors that affect condensation
- Control of condensation
- Design measures to reduce condensation
- Properties, units and definitions related to water vapour in air and in materials

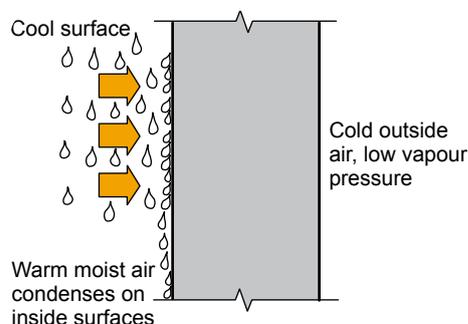


Figure 1: Surface condensation

## Key points

- The dew point is the temperature below which the water vapour in the air will condense into liquid water.
- Surface condensation occurs when warm moist internal air comes into contact with cold inside surfaces that are at or below the dew point and condenses.
- Surface condensation is the most obvious to occupants and, while unacceptable, may not be as serious as interstitial condensation which can result in damage to the structure.
- Interstitial condensation occurs when the vapour reaches colder conditions within the structure and the dew point is reached.
- Sensible design and detailing with good supervision of construction can reduce or eliminate these risks. Factors such as building use, occupancy levels, temperature and the type of heating/ventilation system all need to be considered.
- Ensure that elements have sufficient thermal insulation to enable occupants to heat economically. Reduce thermal bridging to further improve energy efficiency and avoid the risk of surface condensation.
- Ensure that vapour transmission into the structure is controlled and that vapour can escape to the outside.
- Prevent cracks and gaps at joints in order to minimise the infiltration of moist air into the structure.
- Minimise thermal bridges (areas of low thermal resistance compared to the average U-value) to prevent local condensation at these points.

## Surface condensation

Surface condensation (*Figure 1*) occurs when warm moist internal air comes into contact with cold inside surfaces that are at or below the dewpoint of the air in contact with them.

The dew point is the temperature below which the water vapour in the air will condense into liquid water. The dew point is connected to relative humidity. A relative humidity of 100% indicates that the dew point is equal to the current air temperature. That is, if the temperature of the air or a surface decreases below the dew point, moisture vapour in the air will condense.

Surface condensation appears as dampness on internal surfaces and, if persistent, may lead to pattern staining, mould growth and even decay. Surface condensation is the most obvious to occupants and, while unacceptable, may not be as serious as interstitial condensation which can result in damage to the structure.

## Interstitial condensation

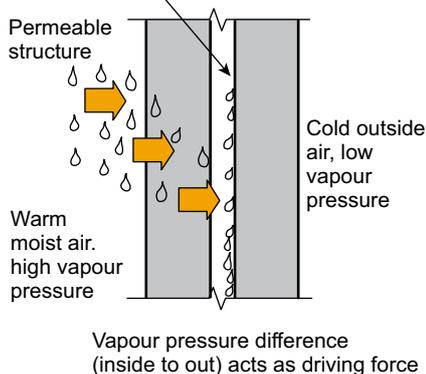
Warm air has a greater capacity for carrying water vapour than cold air and so will readily take up vapour from various household activities such as cooking or washing. This warm moist air then has a high vapour pressure which can drive vapour through most building materials.

Interstitial condensation (*Figure 2*) occurs when the vapour reaches colder conditions within the structure and the dew point is reached.

Persistent deposition of water within the structure can result in:

- spalling of and efflorescence on masonry
- decay in timber (if moisture content is greater than 20% for long periods)
- corrosion of metal elements such as plate connectors or nails
- reduction in the thermal resistance of insulation materials.

Interstitial condensation inside construction



**Figure 2:** Interstitial condensation

## Factors that affect condensation

**Air temperature:** the higher the air temperature within a building, the more moisture the air can hold. As moist air cools, its relative humidity increases to the point where it becomes saturated (i.e. 100% relative humidity).

**Relative humidity:** high relative humidity in a building increases the risk of surface condensation formation on cold surface, such as windows and thermal bridges through external elements (such as discontinuity of insulation at junctions). This is because the dew point temperature is closer to the internal air temperature.

The temperature and relative humidity of internal air depend on how occupants use the dwelling.

**Thermal bridging:** discontinuities in insulation materials (at junctions between walls and ceilings, around external wall penetrations etc) can result in surface temperatures of external elements being considerably lower than the air temperature in the building.

Unless there is a mechanical ventilation system, room ventilation depends on how doors, windows and trickle ventilators are set and, to some extent, air leakage.

The temperature gradient within the structure (decreasing from inside to outside) depends on the position of the insulation material, the effectiveness of the heating system and its frequency of use.

## Control of condensation

There are three primary measures that reduce the risk of condensation arising in dwellings.

- Reduce the relative humidity within the building by limiting the amount of water vapour occupants create and the way in which they ventilate rooms.
- Restrict vapour transmission into the structure and/or ensure that any vapour transmitted can readily escape to the outside. This is affected by the construction details.
- Maintain adequate internal surface temperatures. This is affected by the level of thermal insulation, the type of heating system, and the way in which occupants use the system.

With a high continuous heat input and high room ventilation rates there is very little risk of condensation in dwellings no matter what the design, construction or occupant behaviour due to the high air temperature and low relative humidity. However, such a heating/

ventilation strategy is unacceptable because it wastes energy and is probably uncomfortable.

Instead, consider potential condensation risks at the planning stages. Sensible design and detailing with good supervision of construction can reduce or eliminate these risks. Factors such as building use, occupancy levels, temperature and the type of heating/ventilation system all need to be considered.

## Design measures to reduce condensation

TRADA Technology's *Low-energy timber frame buildings* [1] offers guidance for designers to reduce the likelihood of condensation occurring in the building envelope (Chapter 5) and in ground floors, external walls and roofs (Chapter 6).

TRADA Technology's *Timber frame construction* [2] describes the design of ground floors, external walls and roofs in more detail, with particular attention to the correct positioning of vapour control layers, air barriers and damp proof courses.

### Building planning

Both the shape and grouping of buildings can influence surface condensation as each affects local heat losses and therefore surface temperatures. For example, rooms exposed on three sides can lose more heat than other rooms and therefore have cold surfaces; balconies and access decks can act as cooling fins and detached houses will have more exposed surfaces than terraced houses or flats.

However, given the good insulation values in modern timber frame dwellings, planning is not likely to have a significant effect on condensation risk.

### Heating

In terms of condensation control, the primary function of heating is to maintain reasonable structural temperatures. Timber frame buildings are relatively low thermal capacity structures. This is compatible with intermittent heating because the temperature of the structure as well as the air temperature can rise quickly. Thus continuous background heating is less necessary in timber than in high thermal capacity structures. Since moisture is produced during occupancy and the lightweight fabric warms quickly, there is a low risk of surface condensation in intermittently heated timber frame buildings.

However, heating cannot be relied upon to control interstitial condensation. This is due to the nature of timber frame construction. With the insulation close to the internal surface, heating will not maintain high temperatures much beyond

the immediate room surface. Thus designers must rely on room ventilation and structural detailing to control interstitial condensation.

### Room ventilation

Adequate room ventilation is an essential part of condensation control to reduce internal relative humidity by removing water vapour. National building regulations specify minimum requirements for adequate means of ventilation.

Unplanned ventilation through gaps and joints (infiltration) increases heat losses and can carry water vapour into the structure thereby causing interstitial condensation. An air leakage test during construction will identify defects in detailing and allow action to be taken to improve the construction.

Occupants tend to prefer low ventilation rates because they experience discomfort from draughts and consider the lost heat leads to higher energy bills. Although natural ventilation and internal air movement are difficult to control, the designer can influence occupant behaviour by providing ventilators which minimise draughts and are easily controllable. National building regulations specify minimum ventilation rates for background ventilation. These can be achieved with the use of trickle ventilators over windows, extract fans, passive stack ventilation or continuous mechanical extract systems (with or without heat recovery).

### Natural ventilation of living rooms and bedrooms

Best practice for natural ventilation:

- Position ventilation openings at high level to minimise drafts. For example, specify slot vents to give a minimum of 5,000mm<sup>2</sup>/habitable room in the top of window frames. Opening lights of windows are usually unsatisfactory for winter ventilation as they do not provide sufficient control.
- Position ventilator controls within easy reach of occupants and allow fine control.
- Ventilators should allow some opening without rain or snow penetration.
- Ventilators should provide for security against access so they can be left open when the house is unoccupied.

### Ventilation to kitchens

Natural ventilation will not normally be adequate to remove cooking odours and water vapour from kitchens. Best practice for kitchen ventilation:

- Provide a mechanical fan with an extract rate of 60 litres/second, or a cooker hood fan to give 30 litres/second.
- Locate extract fans above (or nearly above) the cooker, close to

the sink and at high level. Where cookers are not near external walls, use high level ducts to the fan.

- Provide 4,000mm<sup>2</sup>/room slot vents and ensure that the inlet and the extract fan are separated to avoid short circuiting the fan air.
- Ensure that the fan does not adversely affect air supply to heating appliances in the kitchen (seek advice from the relevant fuel utility).

### Ventilation to bathrooms

Best practice for bathroom ventilation:

- Provide a mechanical fan with an extract rate of 15 litres/second.
- Provide 4,000mm<sup>2</sup>/room slot vents and ensure that the inlet and the extract fan are separated to avoid short circuiting the fan air.

An alternative to the recommendations discussed above is the provision of full mechanical ventilation with heat recovery which has the advantage of accurate control at all times.

### Construction details

The designer has most control over construction details. Best practice design for condensation control:

- Ensure that elements have sufficient thermal insulation to enable occupants to heat economically. Reduce thermal bridging to further improve energy efficiency and avoid the risk of surface condensation.
- Ensure that vapour transmission into the structure is controlled and that vapour can escape to the outside. Control of vapour transfer into the structure involves the provision of a vapour control layer on the warm side of the insulation. Common vapour control layers include sheet materials fixed to structure under internal lining, such as 125 micron (500 gauge) polyethylene or proprietary vapour 'check' boards. Cavity ventilation should ensure that vapour can escape to the outside.
- To ensure controlled vapour diffusion, a useful rule of thumb is that the vapour resistance of the layers on the warm side of the insulation (the vapour control layer) should be at least five times greater than that on the cold side; that is, for walls, the sheathing and breather membranes. A condensation risk analysis can provide a more detailed assessment.
- Cavity ventilation requirements for walls, roofs and floors are shown in the relevant sections following.
- Prevent cracks and gaps at joints in order to minimise the infiltration of moist air into the structure.

- Minimise thermal bridges (areas of low thermal resistance compared to the average U-value) to prevent local condensation at these points. Remember that timber framing members can act as thermal bridges.

### Timber frame walls

Figure 3 shows how typical timber frame walls fulfil the general requirements outlined above:

- There is a vapour control layer (such as polyethylene) behind the internal lining. All vapour control layer joints should be lapped and/or taped and all perforations should be taped, such as for wiring.
- The wall accommodates adequate insulation to achieve the specified U-value. 140mm stud voids filled with mineral wool and a 50mm service zone filled with mineral wool provides approximately 0.25 W/m<sup>2</sup>K.
- The external layers are more permeable than the vapour control layer so that the structure can breathe.
- There is a drained and vented cavity between the timber frame and the cladding.

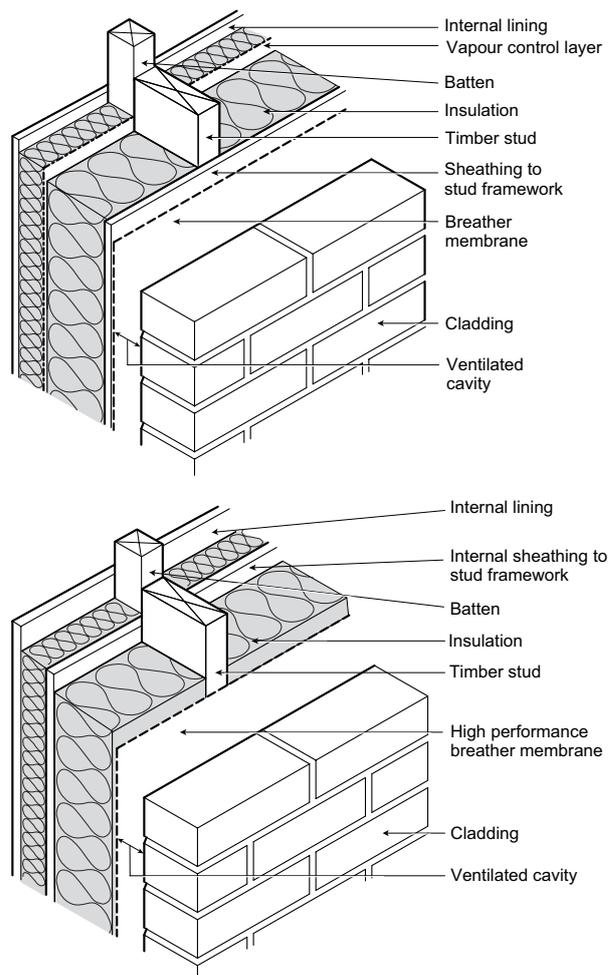
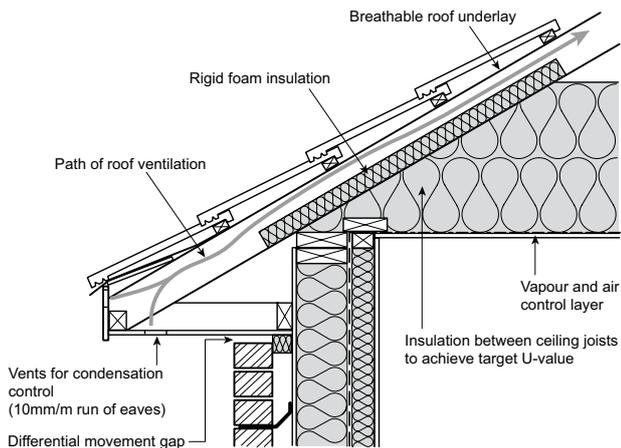


Figure 3: Typical wall construction: Sheathing on external face of frame (top); Sheathing on internal face of frame (bottom)

### Pitched roofs

In pitched roof loft spaces, adequate ventilation will normally disperse excessive water vapour. The popular uptake of modern breathable roof underlays has simplified detailing for ventilation. *BS 5250 Code of practice for control of condensation in buildings* [3] provides detailed information on the requirements for ventilation in various types of pitched roofs with both breathable and non breathable roof membranes.



**Figure 4:** Eaves ventilation of pitched roof

The requirements for roof ventilation depend on the area of the roof, the pitch of the roof, the type of roof underlay used and the configuration of the roof (such as hips).

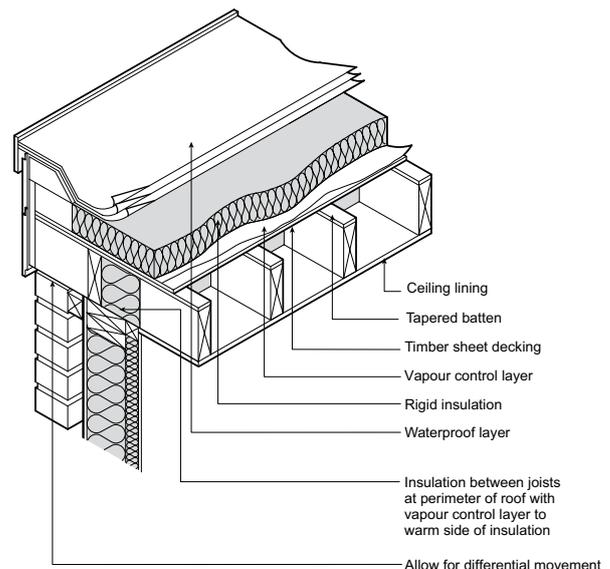
Make provision at all ventilation openings to prevent the entry of birds, rodents and insects.

In all pitched roofs seal air paths from the room to the loft. For example, seal around electric wires and pipe holes, latch and seal access hatches against draught and consider incorporating a vapour control layer into the ceiling construction.

Take care when positioning insulation in loft spaces. Insulation that is pushed too far into the eaves can block the air flow, which may result in loft space condensation. Insulation that does not continue right to the wall plate will leave a thermal bridge which can result in condensation and possible mould growth at the edge of the ceiling. Proprietary insulation-stop vents will normally overcome these problems.

### Warm flat roofs

In a warm roof (*Figure 5*) the structural timber is on the warm side of the insulation and so the structural temperature should always be above dew point (the temperature at which condensation can occur). Thus roof space ventilation is not required. An alternative form of warm roof is the inverted roof where the waterproof membrane is located below the (water resistant) insulation. This membrane also forms the vapour control layer and is protected from UV light and potential damage from foot traffic.



**Figure 5:** Warm flat roof

### Cold flat roofs

Due to the difficulties of ventilation, restrict the use of cold flat roof to spans up to 5m. The Scottish Building Standards Technical Handbooks recommend that, in the climatic conditions of Scotland, ventilated cold flat roofs should not be used and that warm deck and inverted roofs are the only acceptable types.

In a cold flat roof (*Figure 6*) the structural timber is on the cold side of the insulation. Therefore, provide ventilation above the insulation to disperse water vapour to the outside. Because the air spaces in flat roofs are smaller than for pitched roofs there is a greater resistance to air flow through the void. Provide unobstructed ventilation from side to side with openings equivalent to at least a continuous opening of 25mm along opposite sides of the roof (again mesh to prevent the entry to birds and insects is required). Make the airspace between the insulation and the underside of the deck at least 50mm deep.

Install a vapour control layer and take care to ensure that this is complete by careful lapping and taping at joints and taping around perforations for pipes and light points.

It is important to avoid cables and the like penetrating the vapour control layer. One solution is to fix ceiling battens below the vapour control layer, thus creating a void to run building services.

Due to the uncertainty of adequate condensation control in cold flat roofs, specify preservative treatment for structural timbers.

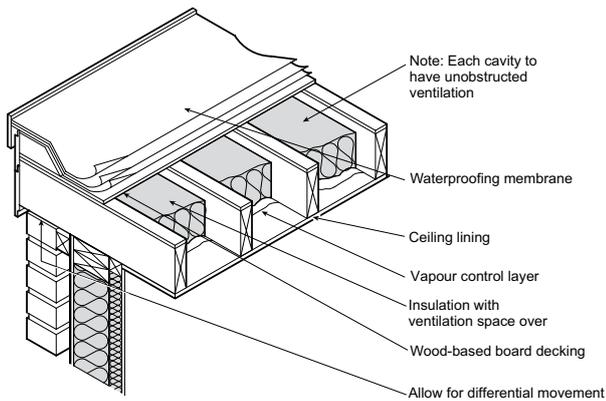


Figure 6: Cold flat roof

### Ground floors

Chapter 3 of *Timber frame construction* describes types of ground floors including suspended timber floors and various types involving floating concrete slabs, together with details for reducing condensation.

Vapour can diffuse through suspended timber floors in the same way as it can through walls and ceilings. As the underside of such floors is ventilated for durability, allow this action to occur; that is, the floor should breathe and the ventilation can disperse the vapour. Consequently the floor need not have a specific vapour control layer.

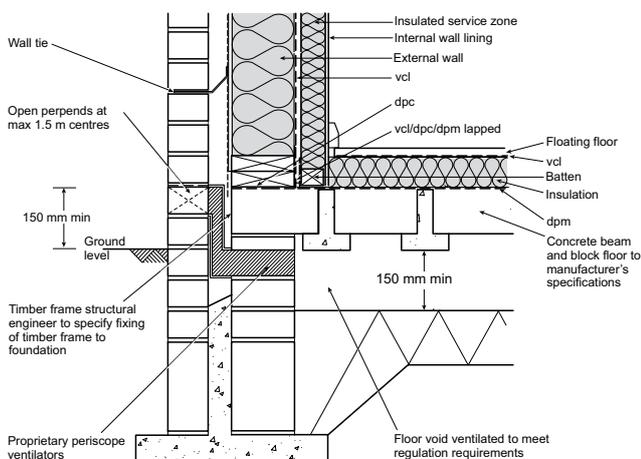


Figure 7: Floating floor on concrete

For floating insulated floors on either concrete slabs or concrete suspended floors, a vapour control layer is required for condensation control (Figure 7). Where water resistant insulation is located beneath a concrete slab a vapour control layer is not required. The insulation should be turned up at the slab edge to avoid cold bridging.

For a floating concrete slab floor (Figure 8), a damp proof membrane separates the floor from the ground. Consequently the floor need not have a vapour control layer.

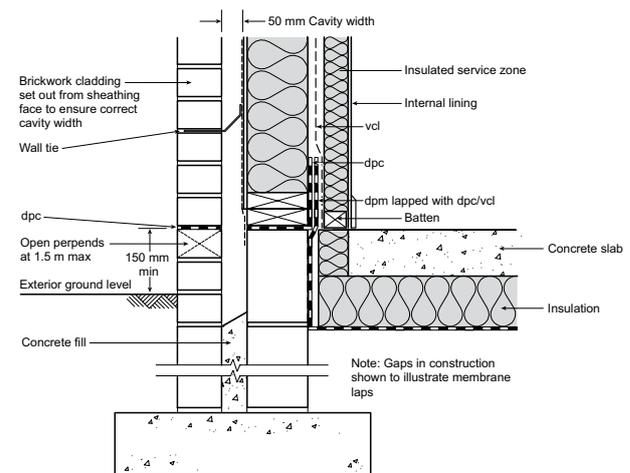


Figure 8: Floating concrete slab on ground

### Windows and rooflights

Window frames can act as thermal bridges and so, dependant on their design and materials used, condensation on these surfaces is possible. However, intermittent condensation on traditional single glazing is inevitable. To reduce this condensation risk and also to improve energy efficiency, double glazing is now the minimum specification for windows and rooflights. Triple glazing is becoming more available in the UK as building regulations drive U-values down further.

## Properties, units and definitions related to water vapour in air and in materials

**Table 1:** The main properties, units and definitions related to water vapour in air and in materials, where

g = grams                      k = kilo ( $10^3$ )                      kg = kilograms                      M = mega ( $10^6$ )                      m = metre  
 m<sup>2</sup> = square metre                      N = Newton                      °C = degrees Celsius                      Pa = Pascal (1 Pa = 1 N/m<sup>2</sup>)                      s = second

| Property                  | Unit        | Definition  |
|---------------------------|-------------|---|
| Moisture content of air   | g/kg        | The ratio of the mass of water vapour in the air to the unit mass of dry air  |
| Relative humidity         | % at °C     | The ratio, expressed as a percentage of the actual vapour pressure to the saturated vapour pressure at a specified temperature  |
| Vapour pressure           | Pascal (Pa) | That part of the atmospheric pressure which is developed by the water vapour present in air. It is directly proportional to the moisture content and absolute temperature of air  |
| Saturated vapour pressure | Pa          | The water vapour pressure in air at 100% relative humidity (or saturation moisture content) for a given temperature   |
| Dew point temperature     | °C          | The temperature at which air containing a specified amount of water vapour becomes saturated and at which condensation begins   |
| Vapour permeability       | gm/MNs      | A measure of the rate (g/s) at which water vapour flows through a material of unit thickness (m) and unit area (m <sup>2</sup> ) when unit difference of vapour pressure (N/m <sup>2</sup> ) exists on opposite sides (mega (M) introduced for convenience) |
| Vapour permeance          | g/MNs       | A measure of the overall rate of vapour flow of a material or combination of materials taking thickness (m) of materials into account. This is derived from diffusivity divided by thickness  |
| Vapour resistivity        | MNs/gm      | The reciprocal of vapour diffusivity  |
| Vapour resistance         | MNs/g       | The reciprocal of vapour diffusance. This is derived from vapour resistivity multiplied by thickness  |

## References

1. Pitts, G. and Lancashire R., Low energy timber frame buildings: designing for high performance, 2nd edition, ISBN 978-1900510806, TRADA Technology Ltd, 2011
2. Lancashire, R. and Taylor, L., Timber frame construction, 5th edition, ISBN 978-1900510820, TRADA Technology, 2011
3. BS 5250:2011. Code of practice for control of condensation in buildings, BSI

## Further reading

BRE 262: Thermal insulation: avoiding risks, ISBN 1860815154, BRE, 2002

### About TRADA

The Timber Research and Development Association (TRADA) is an internationally recognised centre of excellence on the specification and use of timber and wood products.

TRADA is a company limited by guarantee and not-for-profit membership-based organisation. TRADA's origins go back over 75 years and its name is synonymous with independence and authority. Its position in the industry is unique with a diverse membership encompassing companies and individuals from around the world and across the entire wood supply chain, from producers, merchants and manufacturers, to architects, engineers and end users.

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To provide members with the highest quality information on timber and wood products to enable them to maximise the benefits that timber can provide.

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