



ENGLISH HERITAGE

ENERGY EFFICIENCY IN HISTORIC BUILDINGS

Insulating pitched roofs at ceiling level-cold roofs

This guidance note is one of a series which explain ways of improving the energy efficiency of roofs, walls and floors in historic buildings. The full range of guidance is available from the English Heritage website:

www.climatechangeandyourhome.org.uk

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Introduction

This guidance note provides advice on the principles, risks, materials and methods for insulating pitched roofs at ceiling level. When insulation is placed at this position the roof is often referred to as a 'cold roof'.

Insulating the top floor ceiling is one of the easiest and cheapest means of improving the energy efficiency of buildings. Such work can be carried out successfully in older buildings if approached with care. Even very thick layers of insulation will not cause problems if installed carefully with materials that are compatible with the existing construction. However, the installation can be made much more difficult if part of the ceiling is sloping, for instance if the room is partly within a roof space.

WARM ROOFS AND COLD ROOFS

In this guidance the term 'cold roof space' or 'cold roof' is used to describe a pitched roof with insulation at the level of the horizontal ceiling of the uppermost floor, leaving an unheated roof space (attic or loft) above the insulation. In contrast a 'warm roof space' or 'warm roof' has insulation between or just under or over the sloping rafters, so that the whole of the volume under the roof can be heated and used. Some buildings have combinations of these two arrangements.

The installation of insulation at ceiling level allows high levels of ventilation to be achieved within the roof-space above, either through eaves ventilators or through the gaps between tiles. This ventilation is extremely beneficial in reducing the danger of rot within roof timbers and also allowing any interstitial condensation occurring within the insulation to evaporate harmlessly away. Its principal disadvantage is in restricting the potential use of the roof-space.

Installing insulation at ceiling level is usually possible without modification to significant parts of the building. However, it is important that the character and significance of a building is not compromised by alterations to install insulation, such as changing roof levels, removing plaster ceilings, altering gutters and rainwater outlets. Such changes may require consent if the building is listed. Any change to the roofing material of a building in a conservation area may also require consent. In each case all proposed changes should be discussed in advance with the local authority's conservation officer.

Ceiling construction

The earliest buildings generally had no ceilings being fully open to the underside of the roof. Heating was provided by an open fire with smoke escaping through a hole in the roof. Often the smoke also seeped through the roof covering which kept the roof timbers dry and minimised the likelihood of any rot or insect attack. As a result, smoke blackening is frequently found on roof timbers in very early buildings.

It was only after the introduction of masonry fireplaces and chimneys that upper floors began to acquire ceilings. These were often constructed from timber boards or a more fire resistant, insulating and decorative lime plaster. Original boarded ceilings are now relatively rare so surviving examples should be treated with the utmost care.

THE IMPORTANCE OF TRADITIONAL 'BREATHING' PERFORMANCE

Most traditional buildings are made of permeable materials and do not incorporate the barriers to external moisture such as cavities, rain-screens, damp-proof courses, vapour barriers and membranes which are standard in modern construction. As a result, the permeable fabric in historic structures tends to absorb more moisture, which is then released by internal and external evaporation. When traditional buildings are working as they were designed to, the evaporation will keep dampness levels in the building fabric below the levels at which decay can start to develop. This is often referred to as a 'breathing' building.

If properly maintained a 'breathing' building has definite advantages over a modern impermeable building. Permeable materials such as lime and/or earth based mortars, renders, plasters and limewash act as a buffer for environmental moisture, absorbing it from the air when humidity is high, and releasing it when the air is dry. Modern construction relies on mechanical extraction to remove water vapour formed by the activities of occupants.

As traditional buildings need to 'breathe' the use of vapour barriers and many materials commonly found in modern buildings must be avoided when making improvements to energy efficiency, as these materials can trap and hold moisture and create problems for the building. The use of modern materials needs to be based upon an informed analysis where the implications of their inclusion and the risk of problems are fully understood.

It is also important that buildings are well maintained, otherwise improvements made in energy efficiency will be cancelled out by the problems associated with water ingress and/or excessive draughts.

Lime plaster ceilings became the norm in the 18th and 19th centuries even on quite low status buildings. The lime plaster was applied to timber laths attached to the ceiling joists.

Lath and plaster ceilings are not very strong, and will not bear much weight. Care should be taken when installing insulation not to disturb the plaster 'nibs' that protrude between the laths – otherwise there is a chance the

plaster could become detached. If repairs are required then compatible materials should be used. Timber laths and lime plaster mixes are now readily available, though as with any plastering, skill is required to achieve a good finish.

Timber laths and lime plaster are natural, 'breathing' materials. Any materials laid against them should have compatible properties. In particular the fitting of a vapour check layer, such as foil or plastic sheet, could create a barrier to the movement of water vapour that may change the performance of the existing materials. If water vapour is not allowed to pass through the ceilings and insulation layers there is a risk of condensation occurring, which can lead to mould and timber decay.

Insulation Materials

During the last ten years 'ecological' or 'natural' insulation materials have been developed and introduced into traditional buildings in the course of repairs and improvements. Before this time the insulation materials available were designed for use in modern buildings and so were to an extent incompatible with the performance of traditional buildings.

Because of their porous nature the presence of dampness cannot be ruled out from any parts of most buildings of traditional construction. Condensation can occur at the surface or even within the pores of vapour permeable materials. Insulation materials added to traditional buildings therefore need to be able to absorb and release moisture and perform well as an insulator within a range of moisture contents.

There are several types of materials suitable for insulating above ceilings. The most appropriate materials for traditional construction are natural fibre based insulation such as sheep's wool and hemp fibre insulation as they have the following performance characteristics:

- They are hygroscopic, i.e. they can absorb but also release excess moisture.
- They retain their insulation qualities even when damp.
- They are non-hazardous fibres.

The use of flexible insulation batts and rolls between the rafters improves the ability to achieve a tight-fitting insulation. In contrast, rigid insulation boards can be difficult to cut and scribe tightly between rafters, which in many cases are highly irregular. This will allow gaps and cold bridges in the insulation layer which will be particularly susceptible to the formation of condensation on surfaces and the resulting damage, as well as allowing heat to escape.

Cellulose insulation (fibres derived from newsprint) is another useful material, but its performance can be compromised if it comes into contact with moisture. Loose fill cellulose insulation is unsuitable for use between pitched rafters because of its tendency to settle. Such settlement would leave a gap near the ridge where a cold bridge can develop.

When selecting an insulation material consideration needs to be given to how it will perform over many years. If the material is likely to settle then allowance should be made for that and care should be taken so that the material cannot 'flow' out through the eaves or be blown about in the loft space if there is strong air movement. If the insulation is likely to suffer physical degradation a more robust material would be appropriate. Similarly, insulation which tolerates vapour movement will be required if high moisture levels are anticipated nearby.

CONDENSATION IN ROOFS

All air contains some water vapour, but warm air can hold more water vapour than cold air. When warm, damp air is cooled it will reach a temperature at which it cannot hold all the vapour within it and the water will condense out. This temperature is called the dew point.

Warm damp air passing over a cold surface will be cooled locally below the dew point and condensation will take place. This effect causes the familiar condensation on the inside of cold windows.

Sections where insulation is missing or ineffective are called 'thermal bridges'. Common thermal bridges in roofs insulated at the rafters include:

- around the rafters, particularly to the top face where there is no sarking insulation above
- joints and gaps between individual sarking insulation boards
- joints and gaps between the sarking insulation and abutting walls, chimneys etc
- around pipes, cables and light fittings that penetrate the roof.

In winter thermal bridges will be cold. Warm, moist air passing over a thermal bridge will cause condensation to occur at the bridge. Often this causes spots of mould growth, which are both unsightly and potentially hazardous to health. Condensation forming near structural timbers can be absorbed into the timbers increasing the risk of active timber decay.

The risks to any particular building will be dependant on a number of influencing factors, with perhaps the most significant being the amount of water vapour being produced. The greater the intensity of use the greater the risk of problems will be. The more people there are in the building producing water vapour from breathing, cooking and bathing – particularly the use of showers – the more likely that poor detailing will be exposed and problems suffered, such as thermal bridging and condensation.

Without extensive stripping and re-covering of roofs and the provision of vapour permeable roofing felts there will be a continued risk of condensation damp and associated defects. Older impervious felts should be replaced when roofing works are being carried out.

Installation checklist

Roofs of historic buildings can be complex and awkward, often compounded by a series of additions and alterations. It makes good sense to plan the installation of insulation carefully.

Consider the following questions and if possible sketch out a roof plan which will help identify the difficult areas:

- Has the roof been checked for the presence of bats or nesting birds? It is important that roofs are checked before works are programmed as the presence of protected species can cause delays.
- Has the roof been checked for the presence of asbestos? Discovering asbestos insulation or pipe lagging during works could lead to health risks, delays and increased costs.
- How will every corner and awkward area be insulated?
- Will building paper be needed to separate insulation from damp walls?
- Will the roof space be well ventilated? Will eaves ventilators be required to prevent the insulation from blocking the ventilation?
- Are there areas of sloping ceilings? If so those will need special attention
- How will people be able to move around the roof space when the insulation is in place? Which areas will need to be accessed, and where will items be stored? Design and prepare for walkways. Don't forget about access for maintenance even to awkward parts of large roof spaces and for inspection and maintenance of small roof spaces that will not be used for storage.
- Are the services in the roof space near the end of their lives, no longer used, or likely to need adding to in the near future? This is a good time to remove redundant pipe and cable runs, TV aerials, etc.
- Consider the plumbing in the roof space: How will it be insulated? Is this an opportunity to renew an old cold water tank?
- Look at the wiring in the roof space. Will it need renewal in the next few years? Will it be accessible once the roof is insulated?
- Has air pressure testing being considered to assess the effectiveness and performance of the improvements?
- It is rarely possible to install an airtight membrane above an existing ceiling. The barrier preventing cold air from the roof void entering the living accommodation below is therefore only the plaster ceiling.

REMOVE EXISTING INSULATION

Many buildings have had insulation installed sometime in the past twenty or thirty years which is most likely to be either fibreglass or mineral wool. If the insulation is in poor condition, badly installed or if there are any signs of dampness in the roof timbers (e.g. staining, fungal growth) near the insulation, it should be replaced.

Great care needs to be taken when handling existing insulation. Do not disturb any insulation until you are sure what the material is. Certain insulation materials, such as asbestos, fibrous vermiculite and fibreglass are

hazardous to health and require special precautions to be taken when disturbing it.

Protective clothing, including dust masks, should be worn at all times whatever the material. Any type of insulation may be impregnated with rodent droppings. Where existing insulation is removed it provides the opportunity for dust, debris and rubbish to be removed from the roof space prior to new insulation being laid.

AVOID CREATING COLD SPOTS

Where practicable, provide a consistent depth of insulation over the whole ceiling area, Areas left un-insulated, or with significantly differing depths of insulation, could be at increased risk of providing a thermal bridge.

COVER THE INSULATION WITH BUILDING PAPER

Protecting the insulation with a vapour permeable building paper or a vapour permeable membrane in a well-ventilated roof space can keep the insulation 'warm', protect against water ingress and keep the insulation free of dust and debris. It will also assist in preventing draughts through gaps in the insulation from service runs – pipes and wiring.

MAKE THE INSULATION TIGHT FITTING

Gaps in the insulation can allow draughts that reduce the thermal benefits of the insulation, and also cause cold spots (thermal bridges) which are prone to damp and mould growth. It is therefore important that gaps are kept to an absolute minimum.

It is thermally beneficial to lay the insulation in two layers; the first layer between the ceiling joists and the second layer over (perpendicular to) the ceiling joists – this assists in reducing the risks of thermal bridging from the ceiling joists. For example a 250 mm thickness of insulation can be installed in two layers, 100 mm between the joists (assuming 4 inch deep joists) and 150 mm over the joists.

In many older buildings the ceiling joists to the upper storeys are roughly cut and may be particularly slender and not of sufficient depth (less than 100 mm) to allow insulation to be firmly positioned between the joists. In these circumstances it is important that a gap is not created between the two layers of insulation, as they will be prone to draughts that can create cold spots within the insulation build-up, reducing its effectiveness. It is important that such gaps are filled to remove a potential problem and improve the effectiveness of the insulation. Soft fleece type insulation (e.g. sheep's wool) can be 'teased out' to fill slight gaps; larger gaps can be filled with a small quantity of loose-fill cellulose fibre insulation.

MAINTAIN EAVES VENTILATION

Ventilation is provided to the roof void in cold roofs by open eaves or by vents in gable walls, ridges or through the roof coverings. Reducing the ventilation can cause problems of condensation, particularly where the roof

is provided with an impervious roofing/sarking felt. It is important that the insulation is kept free at the eaves to allow for ventilation and the junction between the rafters and ceiling joists is not obstructed with insulation. Some roofs have ventilators at the eaves, which help keep ventilation pathways clear.

INSULATE PLUMBING AND WATER TANKS

All plumbing and water tanks should be insulated in a cold roof, as the insulation at ceiling level will make the roof space colder thus increasing the risk of freezing. The cold surfaces of pipes and tanks are also common areas for condensation to occur with any run off leading to potential decay in the adjacent timbers.

The area below water tanks should be kept free of insulation, unless the water tank is raised well above the joists. The insulation to the sides and top of the water tanks needs to be lapped with that over the ceiling joists to be effective. Tight fitting lids to water tanks will assist in removing a potential source of water vapour in the roof space, which is particularly important where impervious felt is present.

SEPARATE INSULATION FROM DAMP CHIMNEYS AND WALLS

Great care needs to be taken when placing insulation against damp chimney breasts and gable, party and parapet walls. The thermal performance of insulation that is damp will be significantly reduced, and timbers could also be at risk of being subjected to prolonged dampness and associated decay. Physically separating the insulation from damp chimneys and walls by using a vapour permeable building paper will help to keep the insulation dry.

AVOID THERMAL BRIDGES AT JUNCTIONS WITH WALLS

It is also important to avoid thermal bridging against external walls and chimney-breasts within the roof space. This can be achieved by insulating the gap between the last ceiling joist and the external gable or parapet wall or chimney-breast. Measures such as turning loft insulation up against the walls, to a height of 225 mm or so, will assist in reducing the effect of the inevitable thermal bridge at the junction of the ceiling and a solid external wall or chimney-breast.

Sometimes there are steps in ceiling levels where buildings have been extended and altered over the years. It is important that the vertical faces of these steps (often masonry walls) are also insulated to avoid thermal bridging.

PLAN FOR ACCESS AND MAINTENANCE

Crawl-boards or walkways should be provided where access is required to a roof-space to store items or for routine maintenance of tanks, wiring, aerials

etc. Even lightweight goods can compress insulation causing it to lose some of its effectiveness. Walkways will reduce the risk of damage to ceilings and of injury caused by people stepping between joists. They are essential if the positions of the joists have been concealed by a second layer of quilt insulation laid over the joists. A small ventilated space, ideally 50mm or so, should be allowed between the crawl-boards and the top of the insulation to reduce the likelihood of condensation.

INSULATE AND SEAL THE LOFT ACCESS

The access hatch to the roof-space in many buildings is often poorly sealed and completely un-insulated which undermines many of the benefits made in insulating the remainder of the roof space. Gaps at the perimeter will allow heat loss to simply by-pass any amount of insulation. Simple measures such as insulating and draught-sealing the loft hatch to prevent air infiltration can reduce loss of heat from the living accommodation, remove a potential thermal bridge and improve comfort levels. The effectiveness of the draught-seal is usually greatly improved if the loft hatch is secured and held firmly in position with bolts or catches.

SEAL ALL CRACKS

All cracks and holes, particularly around pipes and cables where they pass through the ceilings, should be sealed to prevent moist air from the habitable accommodation entering the roof space adding to the risks of condensation, especially from areas of high humidity such as bath and shower rooms. The sealing of all cracks and joints will also reduce the levels of cold air infiltration from the roof space into the habitable accommodation.

ROUTE ELECTRIC CABLES ABOVE INSULATION

Electric cables give off heat when in use and may overheat where they are covered by thermal insulation, increasing the risk of short circuit and fire. This risk is further increased if combustible loose fill or plastic insulation is present.

Before installing insulation consider whether some re-wiring in the roof space should be undertaken. Routing electric runs above insulation will avoid any risks of overheating, make future maintenance and modification of the electrical system simpler and reduce the likelihood of the insulation having to be disturbed to access cabling.

If running electrical cabling within the insulation layer is unavoidable, it should be encased in a conduit and consideration should be given to upgrading its specification to a greater cross-sectional area to reduce its electrical resistance. A qualified electrician should be consulted on the degree of upgrading necessary.

AMOUNTS OF INSULATION

Building Regulations Approved Document L1B calls for roof insulation at ceiling level to have a U-value of 0.16 W/m²K. Such levels of insulation are quite high, but they are not intrinsically harmful to traditional buildings.

U-VALUES

U-values measure how quickly energy will pass through one square metre of a barrier when the air temperatures on either side differ by one degree.

U-values are expressed in units of Watts per square metre per degree of temperature difference (W/m²K).

To reach a level of 0.16 W/m²K above a typical lath and plaster ceiling requires 250mm thickness of sheep's wool, 250mm thickness of hemp or 217mm settled thickness of cellulose fibre insulation.

Insulating short sloping ceilings

The short sloping ceilings near the eaves of a pitched roof are extremely difficult to insulate successfully. They can often create a thermal bridge, an effect which is exaggerated when the horizontal ceiling in the roof space is well insulated. A second challenge is to maintain cross ventilation of the remaining cold roof space when it is separated from the eaves.

In a warm roof the most effective insulation option is to strip the roof and install insulation above the rafters. This is often simply not a cost effective option for small areas of sloping ceilings on buildings which have predominantly 'cold roofs' as it would require raising the entire roof to insulate a relatively small area. Raising the roof level is also often inappropriate for many historic buildings because of the damage to their character. Thus the options available in such circumstances are to either insulate between or below the rafters as well as can be achieved.

The extent and type of insulation placed between the rafters will be dictated by the size of the rafters, which can vary considerably in older buildings from slender rafters as little as 100 mm deep to those that are 225 mm deep or more. The maximum insulation thickness is typically 50mm less than the depth of rafters, allowing space for ventilation channels between the top of the insulation and the underside of the roof covering to allow fresh air ventilation to flow through to cold roof space above.

The four options for insulating the space between the rafters above the sloping ceiling are discussed in turn below.

METHODS FOR INSTALLING INSULATION

METHOD 1: INSTALLATION FROM ABOVE

Temporarily remove the roof coverings and sarking felt if present above the sloping ceiling area.

Install insulation between the rafters maintaining an air gap between the insulation and the sarking felt or roof coverings. The insulation can be the same as that used in the roof space.

Advantages:

- Full access provides opportunity to achieve maximum standard of installation and detailing.
- Tight fitting insulation that is compatible and consistent with that in the main roof space above the horizontal ceilings can be fitted.
- Provides an opportunity to install a vapour permeable sarking felt above the sloping ceiling.
- Lath and plaster ceilings can be retained and repaired from above if necessary
- This option provides effective and compatible insulation.

Disadvantages:

- Disturbance of the roof covering, which if in satisfactory condition would be better left alone.
- The need for scaffolding and protection together with the lifting and replacing of the roof coverings and sarking felt make this an expensive option.
- For a listed building consent may be required. Advance consultation with the local authority conservation officer is strongly recommended.

METHOD 2: PUSH INSULATION DOWN FROM ROOF SPACE

Install the insulation by pushing it down from the roof-space above without lifting the roof coverings and sarking felt or removing the sloping ceiling.

Maintain an air gap between the insulation and the sarking felt.

Rigid boards are the easiest to install, although achieving a tight and effective fit will still be difficult. However, rigid foam insulation boards, usually with foil facings for vapour control, do not have the same performance characteristics as the building and may well be incompatible.

Advantages:

- Reduced cost and minimal disturbance.

Disadvantages:

- Difficult to get the insulation fully in place or tight fitting. Also risks forcing any debris into the bottom of the gap and blocking the ventilation path.
- Care should be taken above lath and plaster ceilings that the rigid boards do not snap off the plaster nibs.

METHOD 3: REMOVE THE CEILING

Remove the sloping ceilings and replace them with new insulated ceilings. Maintain a ventilation air gap between the insulation and the sarking felt.

Advantages:

- Reduced cost and relative minimal disturbance

Disadvantages:

- Listed building consent may be required where the building is listed.
- Difficult to work from the underside and achieve a tight fitting insulation detail.
- Causes disturbance, and where lath and plaster survives will result in the loss of historic fabric

METHOD 4: INSULATE BENEATH EXISTING CEILING

Apply an insulation board to the underside of the existing sloping ceiling.

Advantages:

- Less expensive than removing the ceiling or the roof coverings.
- The existing air gaps and ventilation arrangements are preserved.
- The work area is readily accessible.

Disadvantages:

- Not readily reversible, future removal may result in extensive damage or the loss of the existing ceilings.
- The thickness of insulation that will often be limited by ceiling to floor heights and the presence of windows and doors
- It may be difficult to achieve a good detail with the horizontal ceiling and walls.
- May change the appearance and proportions of the areas affected.
- Listed buildings will require consent.

IMPORTANT POINTS TO NOTE

VENTILATION

It is always important to maintain a gap between the underside of the roof covering or sarking felt and the insulation. Not only does this permit through ventilation to the roof void above, but it also separates the insulation from the underside of the roofing material. In most cases the roofing material will either be impervious slates or tiles, or an impervious felt. Physical contact between the roof and the insulation would increase the risk of condensation, wetting of the insulation and possibly the transfer of dampness into vulnerable parts of the building fabric. Even where the felt is vapour permeable, good practice still calls for separation of insulation from the felt. Firm physical contact also risks pushing the felt onto the slates or tiles, increasing the wind uplift load on them and the risk of the tiles being blown off.

The 50 mm gap required by the Building Regulations for new buildings can be used as a benchmark for existing buildings. Sometimes a compromise may have to be reached, where separation is maintained but it is not the full 50 mm. In this situation, it is important to monitor conditions in the roof-space. Ideally this should include both regular visual inspections for condensation and continuous data logging of humidity. To facilitate such monitoring it is important to design and install hatches to access even small roof voids.

If condensation or humidity levels in the roof void are a cause for concern, or if regular monitoring is not possible, additional through ventilation of the roof space should be considered. This could be provided by vents in gable walls, ventilated tiles or slates, or ventilated ridges. Each of these additional ventilation methods have both visual and conservation impacts, and the suitability, positioning and effectiveness of these measures will have to be assessed on a case by case basis. Where the effectiveness of the ventilation of the roof space is in doubt it would also be sensible to minimise sources of moisture entering the roof-space in the first place, for example by moving water tanks, and by paying particular attention to the sealing of any gaps in bathroom ceilings.

AIR-TIGHTNESS

None of the measures outlined include the provision of an air-tightness barrier between the ventilation path for the roof void above and the living space below. The effectiveness of such a barrier will usually be compromised, to a greater or lesser extent by the impossibility in an existing building of making it continuous. When insulation is added from above, it is possible to install an air-tightness barrier using counter-battens above the rafters and directing the ventilation path to the cold roof void above rather than below the vapour permeable sarking. This would, however, require the

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removal of tiles from and the counter-battening of the whole of the roof with all the consequent effects on the building's character which would result.

However, if a new ceiling is to be placed either beneath or in place of the existing ceiling, that ceiling can be designed with an air-tightness barrier within the construction in the normal position with all joints lapped and taped.

Further Information

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English Heritage is the Government's statutory adviser on the historic environment. English Heritage provides expert advice to the Government about all matters relating to the historic environment and its conservation.

The Conservation Department promotes standards, provides specialist technical services and strategic leadership on all aspects of the repair, maintenance and management of the historic environment and its landscape.

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