Historic England

Energy Efficiency and Historic Buildings

Insulating Flat Roofs

This guidance note has been prepared and edited by David Pickles. It forms one of a series of thirteen guidance notes covering the thermal upgrading of building elements such as roofs, walls and floors.

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Front cover:
Lead roofs are a distinctive feature on many historic buildings.

Summary

This guidance note provides advice on the principles, risks, materials and methods for improving the thermal performance of flat roofs by the addition or upgrading of insulation. Adding insulation to flat roofs can lead to a significant reduction in heat loss but thought and care is needed to make sure this is effective and does not cause problems.

Many older buildings have areas of flat roof, typically over porches, dormers, small extensions, and towers. If insulation work is being carried out to the main areas of pitched roof it is important that flat roofed areas are not forgotten, even if small, otherwise the insulation of the building as a whole will be compromised with risks of cold bridging and condensation. Upgrading a flat roof to a desirable standard can be complicated and is not without risks. Generally solutions will need to be individually designed and professional advice will often be needed.

It is important that the character and significance of a building is not compromised by the removal of flat roof coverings or significant historic ceilings to install insulation, or by changing roof levels, altering gutters and rainwater outlets. Such changes may require consent particularly if the building is listed. Any change to the roofing material of a building in a conservation area may also require permission. In each case, all proposed changes should be discussed in advance with the local planning authority.

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Introduction

Energy Planning

Before contemplating measures to enhance the thermal performance of a historic building it is important to assess the building and the way it is used in order to understand:

- the heritage values (significance) of the building
- the construction and condition of the building fabric and building services
- the existing hygrothermal behaviour of the building
- the likely effectiveness and value for money of measures to improve energy performance
- the impact of the measures on significance
- the technical risks associated with the measures

This will help to identify the measures best suited to an individual building or household, taking behaviour into consideration as well as the building envelope and services.

Technical Risks

Altering the thermal performance of older buildings is not without risks. The most significant risk is that of creating condensation which can be on the surface of a building component or between layers of the building fabric, which is referred to as 'interstitial condensation'. Condensation can give rise to mould forming and potential health problems for occupants. It can also damage the building fabric through decay. Avoiding the risk of condensation can be complex as a wide range of variables come into play.

Where advice is given in this series of guidance notes on adding insulation into existing permeable construction, we generally consider that insulation which has hygroscopic properties is used as this offers a beneficial 'buffering' effect during fluctuations in temperature and vapour pressure, thus reducing the risk of surface and interstitial condensation occurring. However, high levels of humidity can still pose problems even when the insulation is hygroscopic. Insulation materials with low permeability are not entirely incompatible with older construction but careful thought needs to be given to reducing levels of water vapour moving through such construction either by means of effectively ventilated cavities or through vapour control layers.

The movement of water vapour through parts of the construction is a key issue when considering thermal upgrading, but many other factors need to be considered to arrive at an optimum solution such as heating regimes and the orientation and exposure of the particular building.

More research is needed to help us fully understand the passage of moisture through buildings and how certain forms of construction and materials can mitigate these risks. For older buildings there is no 'one size fits all' solution, each building needs to be considered and an optimum solution devised.

Technical Details

The technical drawings included in this guidance document are diagrammatic only and are used to illustrate general principles. They are not intended to be used as drawings for purposes of construction.

Older buildings need to be evaluated individually to assess the most suitable form of construction based on a wide variety of possible variables.

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1 Flat Roof Construction and Materials

Flat roofs typically have a simple structure, with the waterproof covering laid over timber decking on timber joists. Roof coverings that have been replaced since around 1950 will often have an underlay of some kind between the covering and the decking to provide protection and ease thermal movement. Traditionally decking was laid as plain-edged timber boards with small 'penny' gaps between to assist ventilation and accommodate seasonal movement. In many cases these have subsequently been replaced with plywood or other manufactured sheet materials.

A principal design issue for all flat roofs is the effect of thermal expansion and contraction of roof coverings. All roofing materials will expand to some degree in strong sunlight and contract in colder conditions but for some materials this movement can be significant. Roofing materials must accommodate these stresses without cracking, to avoid water penetration.
Metals in particular need joints to accommodate the necessary movement.
These joints can include drips, laps, up-stand seams, welts or batten rolls, all of which need to be carefully designed to avoid water penetration by backflows or capillary action.

Flat roofs should never be completely flat.
A finished incline of at least 1 in 80 (around 1 degree) is required to carry water off roofs, more for some roof coverings. In order to achieve these falls, the design inclines should be steeper (typically 1 in 60) to allow for variations in construction and any subsequent movement or deflection.

1.1 Metal roofs

Metal roofs are generally recognised as the most durable form of flat roof covering, if correctly designed and installed. They will usually be laid in trays with appropriate movement joints in between. Typically joints across falls will be formed over an up-stand in the decking or 'drip', whilst joints along the falls will be made using battens or welts.

1.2 Lead roofs

Lead roofs are a distinctive feature on many historic buildings as lead has been the flat roofing material of choice, largely due to its extreme durability and the way it can be easily worked to complex profiles. Historically lead sheets were made by casting molten metal onto a bed of sand. Such material is still available for specialist repair of historic buildings, and is specified in lbs/square feet, but most modern lead sheets are formed

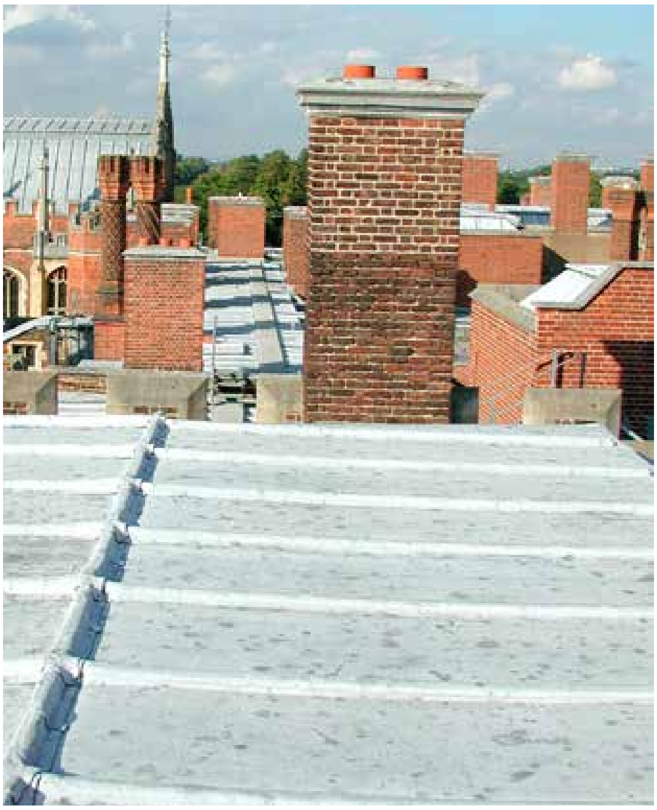


Figure 1 (left)
Lead roofs are a distinctive feature on many historic buildings.

Figure 2 (above)
Condensation on the under-side of lead roofs can cause significant corrosion of the lead.

by milling the material between rollers, and are specified by a numerical code (Code 4, for example).

The weight of a lead roof is a significant load on the supporting structure which, if decayed or modified, may no longer be able to support a new lead roof without repair and strengthening. Lead is resistant to corrosion caused by contact with other metals and both copper and stainless steel are used for fixings.

Lead naturally patinates under the influence of air and rainwater to form a resilient blue-grey surface film of lead carbonate and lead sulphate. This film is stable and insoluble, and protects the lead from further corrosion. However, in contact with pure water a white lead oxide can form instead, exacerbated by the presence of certain acids and this is not protective. Condensation forming on the underside of lead roofs can therefore cause quite rapid corrosion failure of the lead, usually not apparent on the visible side until it has progressed through much of the sheet thickness. This mode of failure is not common, but has become more evident in recent decades, often an indirect result of the addition of insulation at ceiling level below. This cools the lead and allows the increased levels of moisture in centrally-heated internal air to readily condense.

The use of good quality softwood decking is preferred as it helps buffer or absorb moisture below the lead, and does not introduce the acidic glues often found in plywood. New oak decking should not be used under lead as it contains large amounts of tannic acid. However, historic oak decking is likely to be significant, and should normally be retained and conserved, in which case useful protection can be gained by applying chalk emulsion on the underside of lead prior to laying.

Historic England and the Lead Sheet Association have carried out considerable research into the problem of underside lead corrosion, and guidance on the findings has been published in the advisory note *Lead Roofs on Historic Buildings* (1997).

It is preferable for the problem to be designed out as far as possible by careful analysis and design to control vapour levels before the insulation is installed. Where a new roof is being installed, modern practice is to install a ventilated warm roof. Provided it is acceptable to alter and raise the height of the roof then the guidance Lead Sheet Roofing: The Complete Manual produced by the Lead Development Association should be followed. It is essential a new roof constructed to this design is fully ventilated.

1.3 Other metals

Copper has been used in roofing since the Roman period, and is an extremely durable roofing metal. Over time it takes on a distinctive blue-green colour due to oxidisation and conversion to copper sulphate which forms a protective patina inhibiting further attack. Being so resistant to corrosion, copper can be laid directly onto a full range of boards (including insulating boards) without the need for a ventilation path, although this may be desirable for the health of any timber structure below.

Stainless steel is a relatively new roofing material which is increasingly being used for new roofs on historic buildings due to its durability, versatility and availability. It is as durable as copper and can be worked and installed using similar techniques and details. Although naturally bright and shiny it is widely available with a 'terne-coated' finish which dulls down after installation to a matt grey colour, similar to the appearance of weathered lead. Due to its low scrap value, terne-coated stainless steel is sometimes used to replace lead on roofs which have been subjected to recurrent theft, and where security remains a problem, such as churches in isolated locations. It can also be used in long tray lengths, making it useful for replacing lead roofs or gutter linings which may have been constructed to excessively shallow falls.

Zinc began to be used in roofing in the 19th century, and is relatively common on small parts of Victorian and Edwardian buildings. It is less corrosion resistant than lead, copper or stainless steel, and should be laid at falls of no less than 3 degrees (1 in 20). Steeper pitches will ensure a longer service life by encouraging rapid runoff of

Figure 3
Stainless steel is available with a terne-coated finish which dulls down to a finish similar to the appearance of weathered lead.

Figure 4
Zinc began to be used for roofing in the 19th century and is relatively common on small parts of Victorian and Edwardian buildings.

Figure 5
Aluminium roofs can be found from the mid-20th century.

rainfall. As zinc tends to corrode it is advisable to ventilate the underside, although zinc panels are now available with treated, corrosion resistant undersides that can be used above unventilated warm roof constructions. Acidic woods (such as oak) and panels with acidic glues are not suitable for use in decking below zinc roofs.

Aluminium roofs can occasionally be found from the mid-20th century, particularly on Art Deco buildings, although many of these have since been lost due to its poor durability in an untreated form. Aluminium reacts rapidly with oxygen in the air to form a thin, stable layer of aluminium oxide on the surface, and this layer protects the metal from further corrosion by air or water. The metal can, however, be attacked by alkalis such as cement and lime, and by acids such as the dissolved by-products of combustion around chimney flues. It is highly susceptible to bi-metallic corrosion if used in contact with more stable metals such as copper and stainless steel.

When used in new building aluminium is now normally coated in plastic, paint, or anodised by electrolysis to increase its durability.

1.4 Continuous coverings

Continuous coverings of various materials have become relatively common on flat roofs, often as a cheaper and more convenient replacement for previous metal roofs. They are made of materials which can accommodate thermal expansion and contraction, enabling them to be laid un-jointed. They can also be used in direct conjunction with modern insulated boards. Such materials are not susceptible to corrosion, but tend to lose elasticity and become brittle over time. As a result they are less durable than metal roofing and may be unsuitable in an historic context.

1.5 Bituminous coverings

Mastic asphalt is the only continuous material which can be regarded as historical in its own right. Natural rock asphalts became relatively widespread in the second half of the 19th century, superseded by synthetic versions based on crushed limestone and bitumen from oil refining after the First World War. From the late 20th century the elasticity and durability of the material has been enhanced by the addition of a proportion of synthetic polymer to the binder, and it is now possible to anticipate a service life of up to fifty years. The durability of asphalt is considerably enhanced by protecting it from strong temperature fluctuations, and it is now normally covered with light stone chippings or solar reflective paint, although older asphalt roofs may often be found uncoated.

Bituminous felt is generally a short life material made of bitumen-coated fabric, often laid in layers with hot bitumen between. Unless found on a temporary building it is in this form primarily a cheap, quick repair material, the presence of which tends to indicate that a more suitable and durable material has failed. However, as with asphalt, the addition of synthetic polymers in the late 20th century has extended this family of materials to include some with durability approaching that of mastic asphalt itself. As with asphalt, it is ideally protected with solar reflective coatings.

Figure 6
Mastic asphalt here protected from strong temperature fluctuations with stone chippings.

1.6 Modern synthetic membranes

Modern synthetic polymer single-layer roofing membranes are remarkably effective and convenient in certain circumstances, as they can be tailored to the specific shape of any building. They can be mechanically fixed, which enables them to be used over valuable structures with the minimum of physical intervention, but they will often be unsuitable in a historic context particularly where they are visible.

Synthetic chemistry has also made liquid-applied roofing finishes more durable than they used to be. These should still be treated with caution as their actual service life will depend on so many factors that it can be unpredictable, and removing them from valuable fabric after failure can be very difficult indeed. They are best regarded as a quick, cheap and inferior repair to a failed roof, and there are very few situations where another material would not be more suitable.

1.7 Ceilings and internal finishes

It is commonplace in historic buildings for the rooms below flat roofs to have ceilings, which are typically lath and plaster or boarding. These ceilings may have particular significance, in which case they should not be disturbed. Often it will be easier and less damaging to take up roof coverings and boarding to upgrade a roof than to take down and replace ceilings, although the latter may in some cases be preferable. A lath and plaster ceiling can be quite delicate, especially if it has been subjected to water penetration from above at any time in its history, which may have corroded nails, rotted laths and weakened plaster nibs. In such circumstances the necessary repairs should be carried out before any upgrading work. Care should always be taken not to force insulation down onto the ceiling from above.

Low-status and service buildings may not have ceilings to the internal spaces, the joists and decking will then be visible from below. Where this is of significance, the addition of insulation internally may be inappropriate. The installation of insulation above the decking will require the roof to be raised externally, which may also be unacceptable. In such cases installing insulation may not be possible and other ways of improving energy efficiency may need to be considered such as evaluating whether the space below should be heated at all.

2 Placing Insulation

2.1 Insulation and moisture

The main risk associated with the addition of insulation, particularly below an impermeable roof covering, is the increased probability of condensation occurring within the construction (referred to as interstitial condensation). This can be damaging to certain types of metal roof coverings, and may also increase the danger of rot and corrosion in timber and ferrous metal structures supporting the roof.

The problem could be significantly greater if the insulation is not correctly detailed or installed, as gaps and cold bridges will attract condensation. If condensation occurs within the insulation itself, both its performance and durability could be dramatically reduced.

There are two principal methods for dealing with the potential for condensation:

- to prevent the warm, moist air leaving the room below usually by the addition of a vapour check membrane below the insulation
- to provide effective ventilation to the cold zone of the roof, above the insulation, to evaporate moisture away as quickly as it forms. However, some historic flat roofs, with a substantial timber structure have dealt adequately by buffering any condensation, despite having no ventilation. Moisture stored in the timbers evaporates away under summer sun, particularly lead roofs. In these cases adding ventilation can undermine this process

Whichever method is most suitable will depend on the individual circumstances of each roof, and on the type and quantity of insulation added.

Insulation within the roof construction can be installed either:

- below the decking and above the ceiling, called the 'cold deck' system
- above the decking and below the waterproof layer, called the 'warm deck' system

Insulating with the 'cold deck system' is perhaps the most frequently used arrangement in historic buildings, but not necessarily the most appropriate. It is quite possible, and often desirable, to combine both warm and cold deck systems, subject to a careful condensation risk assessment, in order to achieve the best upgrading possible.

A modification of the 'vapour check method' can be used with continuous covering materials where certain types of impermeable insulation can be installed above the main roof waterproofing, this is called an 'inverted roof' system.

In rare cases it may actually be acceptable to insulate below the ceiling layer, or at least below the structure, in which case the insulation design is in principle similar to a cold deck system.

Condensation in roofs

All air contains some water vapour, but warm air can hold more water vapour than cold. When warm, damp air is cooled it will reach a temperature at which it cannot as much vapour in it and excess 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. Similarly, any parts of a construction where insulation is missing or bypassed are called 'thermal bridges'. Common thermal bridges in roofs insulated at rafter level may 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, and will cause condensation to occur locally where in contact with warm, moist air. Often this causes spots of mould growth which are both unsightly and potentially hazardous to health, but the problem can continue to damage the building fabric itself. Condensation forming near structural timbers can be absorbed into the timbers and will increase the risk of active timber decay.

The risks to any particular building depend on a number of influencing factors, but perhaps the most significant is the amount of water vapour being produced from the occupants breathing, cooking and washing, so the greater the intensity of use, the greater the risk of problems that will result from thermal bridging.

2.2 Depth of insulation

Within a building of traditional construction the upgrading proposals should try to achieve the targets set out in the Approved Documents of the Building Regulations. The amount of insulation required to meet the stated U-value in any particular construction can be relatively easily calculated from its thermal conductivity using specialised thermal software. Such calculations are often provided as a free service by material manufacturers and suppliers. However, if other parts of the building are exposed to risks as a result of trying to meet these targets, then the amount of insulation may well have to be reduced.

In churches and other high status buildings there may well be a separate ceiling, with its own structure, set some way below a flat roof covering. Here there will often be ample room for a deep insulation build-up above the ceiling which can achieve or even exceed the requirements of the Approved Document. In this case it is reasonable and normal to expect full upgrading to be carried out, unless there are good technical reasons to install less, such as the danger of accentuating damaging condensation in adjoining un-insulated building components.

It is common for a flat lead roof to be laid over shallow joists with a lath and plaster ceiling below. If the underside of the lead is to be ventilated it is important to provide a consistent unobstructed air path of 50mm depth below the decking. If the overall roof build-up cannot feasibly be deepened, this ventilation path will set the upper limit for the insulation thickness above the ceiling.

If a flat roof behind a parapet is to be entirely replaced due to structural failure, it may well present the opportunity to deepen the overall roof build-up above ceiling level to install a relatively high degree of insulation, meeting Approved Document standards. In this case, the amount of insulation which can be accommodated will be governed by the level to which the roof can be raised, allowing for the necessary falls and the depth of the perimeter flashing. Conversely, if replacement is not essential, and the roof structure, ceiling and covering are all historically significant, only minimal insulation may be possible.

2.3 Calculating condensation risk

It is possible to calculate the degree of condensation risk in any particular roof construction, and certain types of proprietary thermal software can carry out this task as an extension of compound U-value calculations. The actual calculation itself is relatively simple, requiring only data on the vapour permeability of the materials in addition to their thermal conductivity. Unfortunately, vapour permeability data is less easily available than thermal data. Nevertheless, if there is any doubt about the condensation risk in any individual situation, a reasonably approximate calculation can often be carried out from available generic data, and this may be very helpful in identifying particular risks, and enabling appropriate mitigation measures to be added at the design stage.

3 Insulation Materials

All insulation materials work by trapping air within voids. The more air which can be trapped within the insulation material the better the overall performance. In many cases the relative volume of the air is reduced to obtain other qualities, such as resistance to compression, or water resistance.

3.1 Vapour permeable insulation

The majority of insulation materials appropriate for use in historic buildings are vapour permeable. They are generally either fibrous or granular, with air and moisture vapour being able to flow through, although their overall densities, and hence both thermal resistance and permeability, can vary considerably.

The lowest densities and highest insulation values are gained from soft fibre rolls or unformed loose-fill materials. These materials are unable to support their own weight or that of any other materials and must be laid loose on a substrate with nothing over them. Any compression reduces the volume of air trapped but they can be easily installed around complex shapes, minimising gaps and cold bridging.

Semi-rigid insulation batts are often made from similar materials to rolls and loose fill insulation, but compressed to a greater extent so that they can support their own weight. This slightly reduces their insulation performance, but they can be fitted vertically or at an angle, such as between timber studs or rafters, without slumping and leaving exposed areas. They have a certain amount of compressibility, enabling them to be fitted comfortably between irregular timbers. They can be easily cut and pieced in to fit around more complex shapes.

Fibres which are compressed even further are made into rigid boards which can span between joists and resist compressive loads, such as maintenance access. These are often available with tongued and grooved edges to ensure air-tightness and enhance structural rigidity.
Board insulation is now often used to span over or under joists and rafters in conjunction with roll or batt insulation between the structural timbers

Figure 7
Rigid wood-fibre insulation board.

in order to overcome the cold bridging effects of the timbers themselves. This only becomes necessary with high levels of insulation, as timber is a low to medium performance insulant itself. Board insulation often also has a relatively high thermal mass, which helps to dampen out rapid temperature fluctuations, and to limit solar overheating in summer.

Glass-fibre insulation is widely available in roll and batt form. This type of insulation requires high levels of energy to produce, and the fibres can be irritating to both the skin and respiratory system. Natural materials such as sheep's wool or natural hemp-fibre may be preferred although these are more expensive. For board insulation, wood-fibre and compressed hemp-fibre are also useful and versatile materials. These natural materials also have the advantage of being hygroscopic, absorbing moisture at times of high humidity and then releasing it harmlessly later, making them highly compatible with traditional construction and tolerant of intermittent condensation. They are also non-toxic.

Cellulose insulation (fibres derived from newsprint) is an alternative material, but its performance can be compromised if it comes into contact with moisture. Loose-fill cellulose insulation may be suitable for filling above an existing irregular ceiling if the risks of damp and condensation can be minimised.

3.2 Membranes

The performance of vapour permeable insulation materials, particularly of lighter densities, can be usefully enhanced by the addition of vapour permeable or 'breather' membranes. These membranes restrict the airflow into and out of the insulation, but contain numerous microscopic pores which allow levels of moisture vapour to stabilise on either side. When used above an insulation roll, or loose-fill insulation, they can therefore restrict heat loss through air movement into and out of a ventilated cavity, whilst still allowing moisture vapour forming within the insulation to evaporate harmlessly away. When used underneath the insulation they can usefully limit the amount of air and moisture vapour entering from the room below.

The design of these membranes has improved but as yet there has been little independent testing of their performance. Roofing contractors report that these membranes can get blocked by icing in very cold conditions or by build-up of dust and dirt which is very common under tiles and slates. Even though the roof structure can then become very wet this does not seem to have resulted in rotten timbers or battens.

Vapour control membranes, in contrast, are fully impermeable sheets, usually of polythene, installed underneath the insulation of an unventilated roof in order to prevent moisture vapour from entering and condensing within the construction. Whilst vapour control membranes work well in theory, they must be completely airtight to work properly, and remain so throughout their lives. This must include full sealing at the perimeter and all points where pipes or cables pass through, taping of all mechanical fixing points, and no later holes should be made. In reality this is so difficult to achieve that any construction relying fully on a vapour control membrane will in all probability fail relatively soon in its life, with serious consequences for the performance of the insulation and the health of the construction above. In addition, sealing will be at best only partially effective where the vapour control membrane abuts traditional breathing construction of brick, stone or lime plaster, as moisture vapour will be able to simply bypass the sheet. This is probably best regarded as a form of modern construction which is not normally compatible with traditional or historic buildings, and should be used only where no other method is possible.

Where an upgraded flat roof is above a source of unusually high humidity, such as a shower room or kitchen, the addition of a vapour control membrane is highly desirable. Whilst its performance may not be perfect, it will limit the speed at which moisture vapour can enter the construction, and this can be a very effective safeguard when the incidences of high humidity are intermittent, and moisture is allowed to dissipate in between.

3.3 Impermeable insulation

Insulation which is formed of a foamed, impervious material such as certain types of plastic or glass can be entirely vapour-impermeable, as all the pockets of air will be in fully sealed bubbles. This removes the risk of interstitial condensation forming within the insulation itself, although the joints are likely to require careful consideration. These are modern materials which should always be used carefully in accordance with the manufacturer's recommendations.

Plastic-based extruded foams and foamed glass are rigid and resistant to compressive loads, and capable of being installed in a warm deck system above a roof deck but below either a continuous roof covering or a corrosion-resistant metal. Foamed glass is usually bedded in and jointed with hot bitumen, making it a resilient and durable material, but its insulation value is relatively low, and it is expensive. In some situations the insulation has sufficient rigidity to be able to replace the decking as well, spanning directly between the joists.

Extruded foams can also be used above a continuous roof covering material in an inverted roof system, where the insulation protects the covering from light and temperature variations, whilst warming the roof construction and minimising the interstitial condensation risk. The foam itself needs to be held down by paving slabs or similar against wind uplift and to prevent it floating on rainwater. This is a stable, durable and reliable flat roofing system, but if added to a traditional or historic building it needs a roof structure capable of supporting the overall weight, as well as being only suitable behind parapets high enough to accommodate the additional roof thickness.

Whilst it is theoretically possible to install impermeable insulation safely within a roof structure, installation between joists will leave gaps where moisture vapour can penetrate and condense. This construction is therefore dependent on vapour control layers.

4 Insulation Methods

4.1 Insulation within the zone of structure

The most common location to add insulation within an existing flat roof is to install it within the existing structure zone, generally between the existing joists. This has the advantage of causing the least alteration to an existing historic roof by retaining the existing roof structure, its overall thickness, and the upper and lower surface finishes.

With ventilation

The installation of new insulation within the existing structural zone will usually require the temporary removal of the roof covering and decking, and is therefore best carried out whenever the roof covering is due for renewal.

The insulation used should be vapour permeable, and will normally be either in roll or batt form, although loose fill is feasible. It is essential to introduce a ventilation path immediately below the decking when the roof covering is lead or zinc

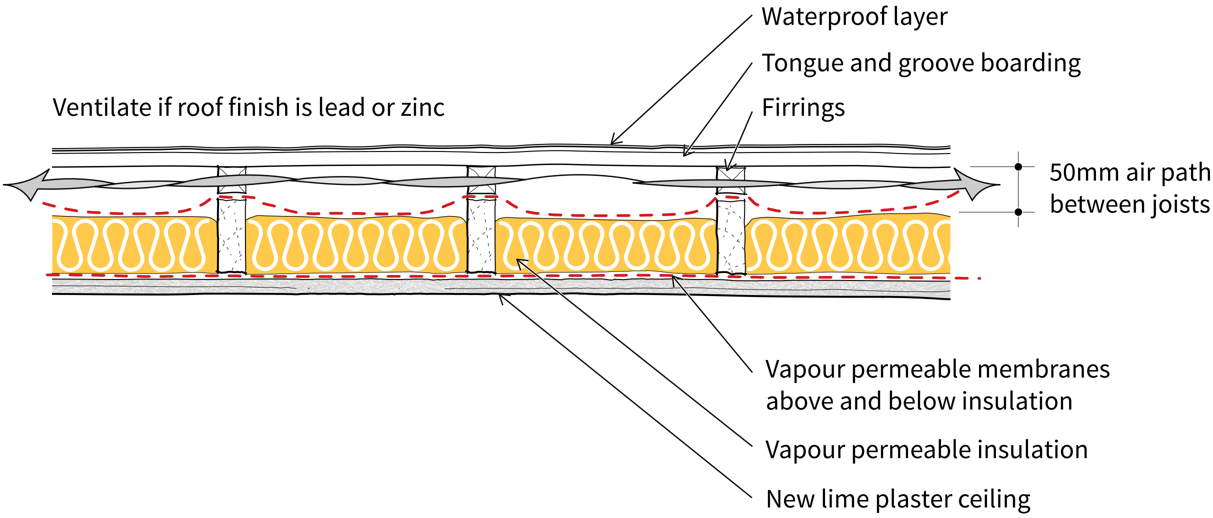


Figure 8: Ventilated cold deck using vapour permeable insulation
The ceiling finish has been removed to allow access to the roof void. Insulation has been added to part of the depth of the roof joists to allow for a 50mm ventilation path which is recommended particularly for metal roof finishes to avoid underside condensation. The insulation is protected by permeable vapour membranes to the top and bottom. If the insulation used was impermeable then a vapour control barrier should be considered at ceiling level.

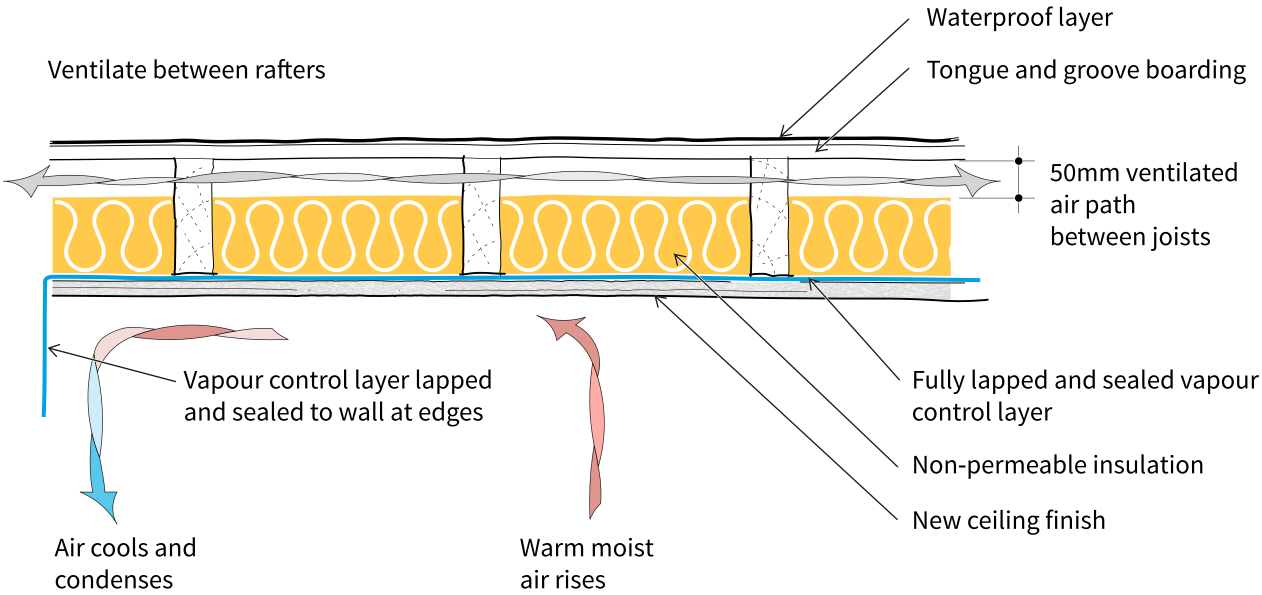


Figure 9: Ventilated cold deck using non permeable insulation
Here the ceiling is removed to access the roof void internally. Insulation is added to part of the depth of the roof joists to maintain an air-path above. For non-metal roof coverings consideration might be given to omitting any ventilation and filling the complete roof void with insulation. A vapour control layer is shown to prevent moist air entering the roof-space and condensing.

in order to control condensation and corrosion. Ventilation here can also help to control potential rot in the decking and structure. If the overall form of the roof is to be unchanged, the introduction of a ventilation path will inevitably limit the amount of insulation which can be added, but it is not unusual for this to be the optimum balance between energy efficiency and retention of historic fabric.

The addition of vapour permeable 'breather' membranes both above and below the insulation can usefully improve its performance, although neither is absolutely essential. If the ceiling is to be replaced, then installing a breather membrane (or, in critical situations, a vapour check) can be easily and neatly installed across the underside of the joists. Installing insulation from below is possible, ensuring continuity of the ventilation path above will require considerable care in installation. In this situation it is recommended that semi-rigid insulation batts are used, and the upper breather membrane omitted.

Introduction of a ventilation path where none exists will require work to the roof covering and decking above.

Under certain circumstances it may be possible to modify this arrangement by reinstalling the decking and waterproofing in a slightly elevated location over firrings. This will increase the amount of insulation which can be added below the ventilation zone, but the feasibility of this technique will depend on the circumstances in each individual situation. Under no circumstances should existing joists be notched to provide cross-ventilation, as this is likely to unacceptably weaken the structure.

Without ventilation

It is possible to install insulation between joists to their full depth without allowing for ventilation. This will allow the maximum possible amount of insulation to be added without altering the appearance or thickness of the roof, but certain risks will inevitably result. Control of condensation build-up in the structure will rely entirely on the efficiency of a vapour check layer below the insulation, with all the consequent drawbacks (see above). This layer is best installed below the joists to ensure both its durability, and to protect the structural timber, although replacement of the ceiling will therefore be necessary. Under no circumstances should unventilated insulation be used below a lead or zinc roof.

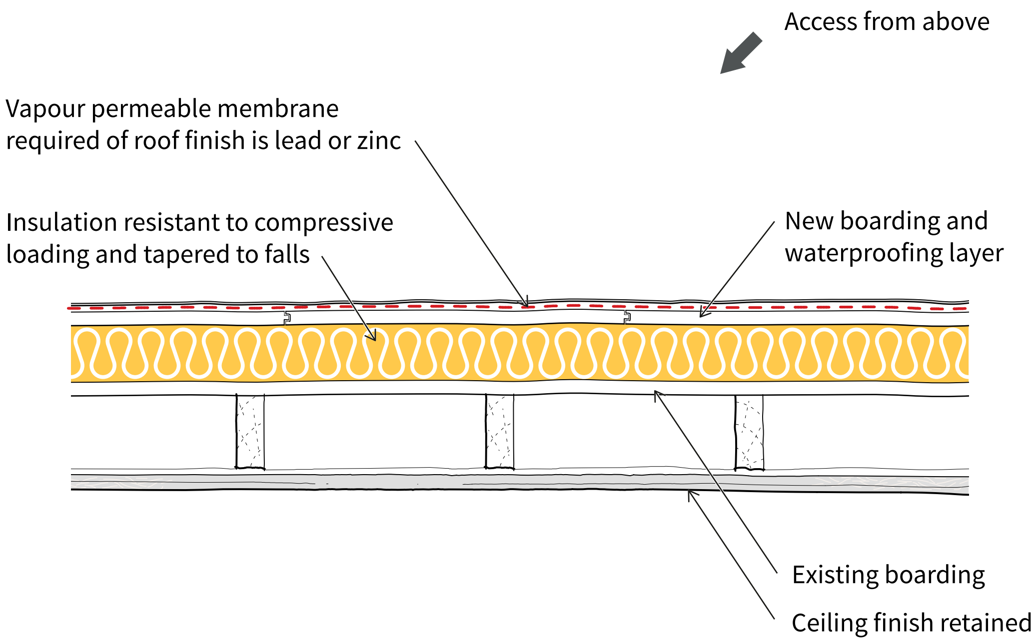


Figure 10: Warm deck system

Where the existing flat roof covering is being replaced or repaired it can provide the opportunity to add insulation above the existing roof deck tapered to provide a fall. The existing roof covering could also be retained providing a partial vapour check. As there is no ventilation between the insulation and the underside of the roof covering then this detail would be most suited to finishes such as asphalt, stainless steel and copper.

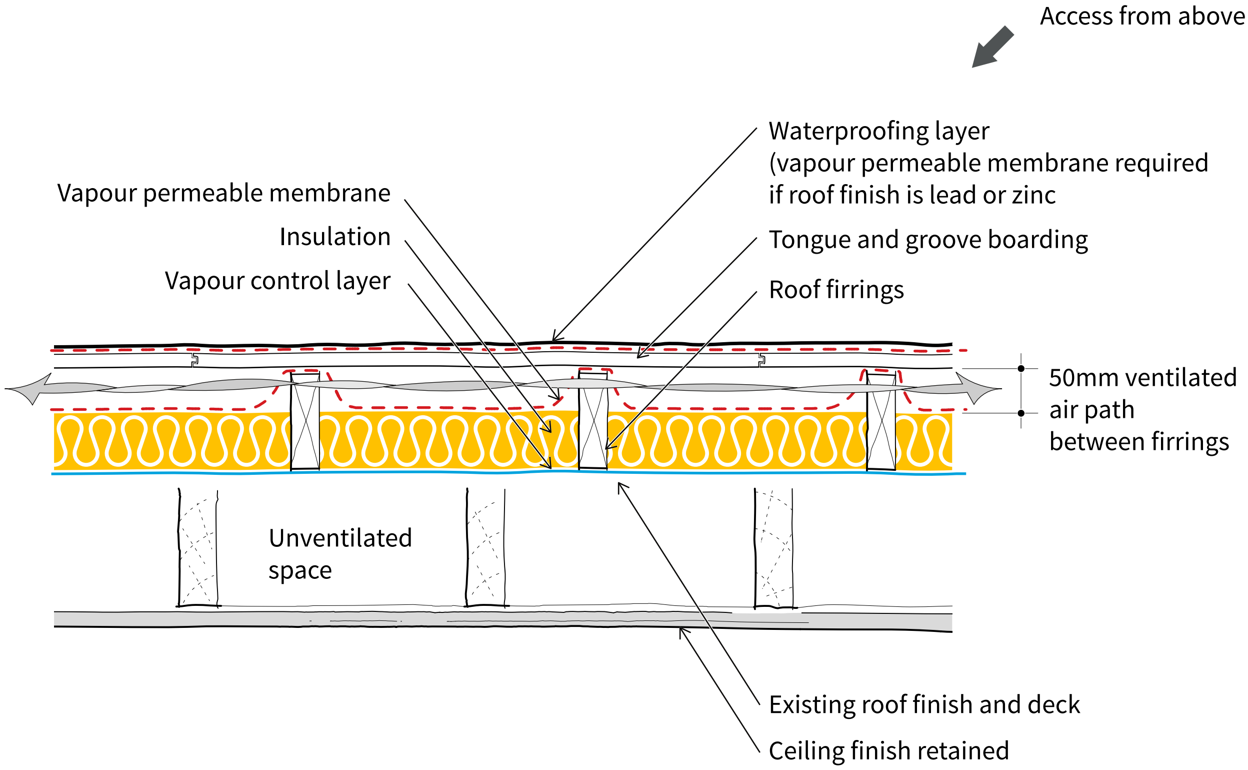


Figure 11: Ventilated warm roof (Insulation above existing roof finish)
This shows a new roof deck added above an existing deck with a ventilated area above the new insulation layer. This adds considerably to the depth of the roof which may pose detailing problems with other parts of the adjoining construction.

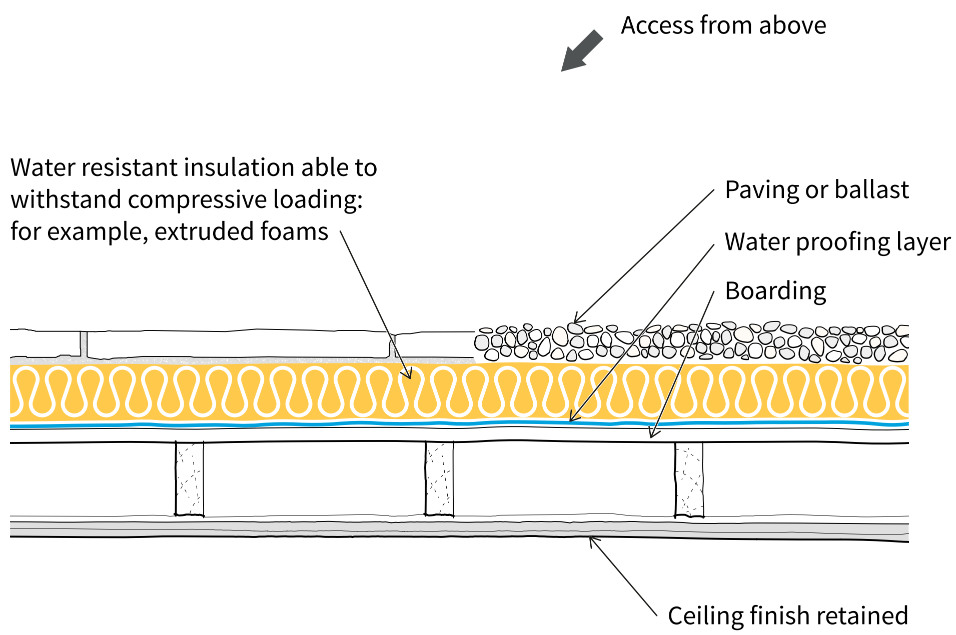
4.2 Insulation above the existing structure

Where it is feasible to raise the level of the roof covering without compromising the character of the building, new insulation can be installed above the decking.

This will require either the use of insulation boards which can resist a compressive load, or the addition of deep firrings or in order to carry a raised deck above the existing one.

If rigid insulation is used, a new roof covering can be directly installed with a corrosion-resistant metal such as stainless steel or copper, or a continuous covering such as asphalt can be used. In each case the recommendations of both insulation and roof-covering manufacturers should be strictly adhered to. The retention of the original waterproof roof covering below the new insulation can assist condensation control by acting as a partial vapour check, although if its service life has expired it should not be relied on as a complete barrier in anyway.

Alternatively, a secondary timber structure can be raised above the existing decking. Here the detailing should be carried out in a similar manner to insulating within the structure zone. If the original roof covering is retained it will only protect insulation above its position, so its complete removal will also allow insulation to be installed within the existing structure as well. This can allow a very high level of insulation to be added overall, but in such cases it is strongly



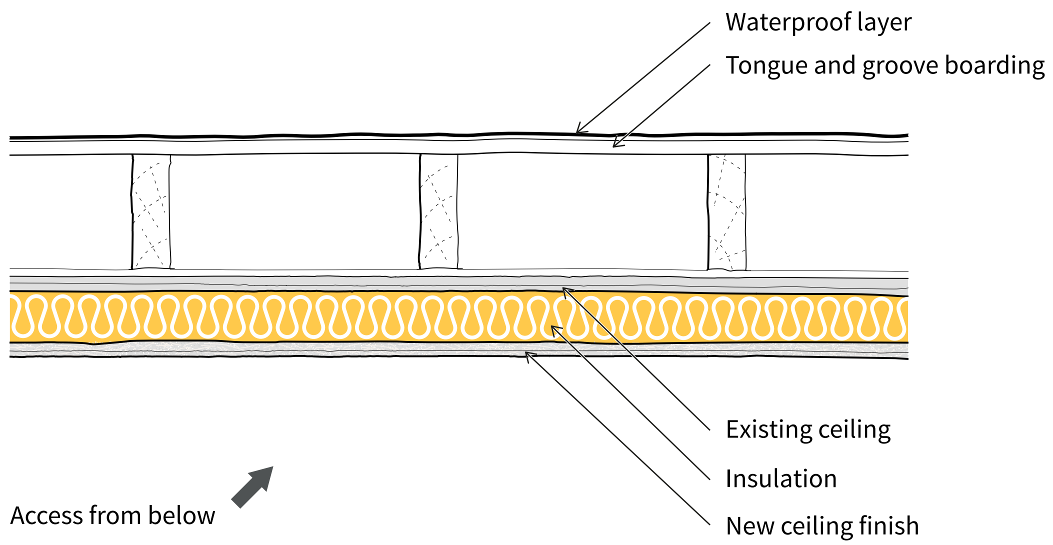


Figure 12 (top): Inverted roof
Here insulation is placed above the waterproof layer and is protected and held down by paving or ballast. The insulation needs to be able to withstand compressive loading. This detail is particularly suited to asphalted roofs. The roof space is unventilated.

Figure 13 (above): insulation added below roof structure
Here the existing lime plaster ceiling is retained and insulation is added below with a new ceiling under.

recommended that a calculation to check for condensation risk should be carried out at the design stage.

If an unventilated insulation layer is required, the same conditions and risks apply as when unventilated insulation in fitted within the structure zone (see above).

Inverted system

An inverted roof is a modified version of a warm deck roof where insulation is applied above a continuous waterproofing layer. Rainwater is allowed to percolate through the joints in the insulation and drain away via the waterproof layer below.

In this case the waterproof covering prevents water vapour from inside the building reaching the insulation to condense within it, whilst the insulation keeps the structure warm, thereby reducing condensation risk within. This system cannot be used below a metal roof as the movement joints between metal trays will be vulnerable to moisture ingress by capillary action. The insulation also increases the durability of the roof covering by protecting it from sun and extremes of temperature.

4.3 Insulating beneath the existing structure

In certain cases where room heights are adequate and the ceilings or internal finishes are not historically significant, it may be more acceptable to add insulation beneath the existing ceiling rather than to raise the roof line. A new ceiling can easily be added below an existing ceiling using shallow joists. In occasional circumstances a damaged but aesthetically important and archaeologically interesting ceiling can be protected by a new ceiling beneath, potentially providing an appropriate solution to both historic building and energy conservation problems, although proper repair is normally preferred.

5 Insulation Detailing

5.1 Key considerations in refurbishment work

Before carrying out insulation works to flat roofs the following issues need to be considered:

- How easily can the insulation be accommodated?
- Will changes be required to the roof detailing -such as the fitting of vapour check membranes and the creation of ventilation pathways?
- Will general detailing (step heights, sheet sizes and junction details) need to be brought up to best practice standards?

Figure 14
A small lead roofed dormer undergoing repair.
© Oxley Conservation

Existing buildings are rarely found to be built to current best practice standards. Lead roofs are often not ventilated, vapour barriers are rare; steps and drips are often undersized. If these roofs have functioned well, there may be no good case for changing the details as part of insulation works. However, if there is evidence of problems then upgrading may be justified. Each case should be carefully assessed on its own merits.

Designers and installers therefore often have to adopt a pragmatic approach to upgrading works. Standards can be relaxed in certain circumstances where:

- The situation is carefully analysed and an informed decision is taken
- The decision, and the reasoning behind it, is documented for future reference
- The work is monitored after construction to check that the assumptions made are correct
- The works are located in a position where the effects of failure would not be highly damaging

If there is any doubt on these matters, it is often better to leave the roof without insulation rather than to take risks.

5.2 Ventilation

Ensuring that outside air can enter and leave the ventilation pathways requires careful design. To be effective, through ventilation must be provided to all areas of the roof without any 'dead' spots. It is also important that water, insects and vermin are kept out of the ventilation path, and that air-tightness barriers are not compromised.

Proprietary ventilators are available for many standard situations, including 'mushroom' type ventilators which can be positioned in the centre of flat roofs. When choosing ventilators thought should be given to what routine maintenance will be required, and whether the ventilators themselves will inhibit access or water flows in storm conditions, particularly in narrow lead gutters.

5.3 Lead valley and parapet gutters in pitched roofs

Many traditional buildings with pitched roofs have lead valley or parapet gutters. If the roof is to be properly insulated it is important the gutters are also insulated, both to ensure the effectiveness of the insulation overall and to prevent local condensation risks from thermal bridging. Lead gutters of this type should be regarded as small flat roofs and insulated in the same way. It may be important that the underside of the lead is ventilated to prevent corrosion but care should be taken when adding ventilation below lead to an historic roof. Improving the energy efficiency of these areas will inevitably require particular attention at the design stage.

6 Where to Get Advice

This guidance forms part of a series of thirteen documents which are listed below, providing advice on the principles, risks, materials and methods for improving the energy efficiency of various building elements such as roofs, walls and floors in older buildings.

This series forms part of a wider comprehensive suite of guidance providing good practice advice on adaptation to reduce energy use and the application and likely impact of carbon legislation on older buildings.

The complete series of guidance is available to download from the Historic England website: HistoricEngland.org.uk/energyefficiency

Roofs

- *Insulating pitched roofs at rafter level*
- *Insulating pitched roofs at ceiling level*
- *Insulating flat roofs*
- *Insulating thatched roofs*
- *Open fires, chimneys and flues*
- *Insulating dormer windows*

Walls

- *Insulating timber-framed walls*
- *Insulating solid walls*
- *Insulating early cavity walls*

Windows and doors

- *Draught-proofing windows and doors*
- *Secondary glazing for windows*

Floors

- *Insulating suspended timber floors*
- *Insulating solid ground floors*

For information on consents and regulations for energy improvement work see historicengland.org.uk/advice/your-home/saving-energy/consent-regulations/

6.1 Useful addresses

Flat Roofing Alliance
Fields House, Gower Road
Haywards Heath
West Sussex RHI6 4PL
Tel: 01444 440027
www.fra.org.uk

The Lead Sheet Association
Hawkwell Business Centre
Maidstone Road
Pembury
Tunbridge Wells
Kent TN2 4AH
Tel: 0I892 822773
www.leadsheetassociation.org.uk

The Copper Development Association
5 Grovelands Business Centre
Boundary Way
Hemel Hempstead
HP2 7TE
www.cda.org.uk

The British Stainless Steel Association
Broomgrove
59 Clarkehouse Road
Sheffield SI0 2LE
Tel: 0114 267 1260
www.bssa.org.uk

The Mastic Asphalt Council
The Mastic Asphalt Council
PO Box 77
Hastings TN35 4WL
Tel: 0I424 8I4400
www.masticasphaltcouncil.co.uk

6.2 Contact Historic England

East Midlands
2nd Floor, Windsor House
Cliftonville
Northampton NN1 5BE
Tel: 01604 735460
Email: eastmidlands@HistoricEngland.org.uk

East of England
Brooklands
24 Brooklands Avenue
Cambridge CB2 8BU
Tel: 01223 582749
Email: eastofengland@HistoricEngland.org.uk

Fort Cumberland
Fort Cumberland Road
Eastney
Portsmouth PO4 9LD
Tel: 023 9285 6704
Email: fort.cumberland@HistoricEngland.org.uk

London
1 Waterhouse Square
138-142 Holborn
London EC1N 2ST
Tel: 020 7973 3700
Email: london@HistoricEngland.org.uk

North East
Bessie Surtees House
41-44 Sandhill
Newcastle Upon Tyne NE1 3JF
Tel: 0191 269 1255
Email: northeast@HistoricEngland.org.uk

North West
3rd Floor, Canada House
3 Chepstow Street
Manchester M1 5FW
Tel: 0161 242 1416
Email: northwest@HistoricEngland.org.uk

South East
Eastgate Court
195-205 High Street
Guildford GU1 3EH
Tel: 01483 252020
Email: southeast@HistoricEngland.org.uk

South West
29 Queen Square
Bristol BS1 4ND
Tel: 0117 975 1308
Email: southwest@HistoricEngland.org.uk

Swindon
The Engine House
Fire Fly Avenue
Swindon SN2 2EH
Tel: 01793 445050
Email: swindon@HistoricEngland.org.uk

West Midlands
The Axis
10 Holliday Street
Birmingham B1 1TG
Tel: 0121 625 6870
Email: westmidlands@HistoricEngland.org.uk

Yorkshire
37 Tanner Row
York YO1 6WP
Tel: 01904 601948
Email: yorkshire@HistoricEngland.org.uk

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