ENGLISH HERITAGE

# ENERGY EFFICIENCY IN HISTORIC BUILDINGS

# Insulating solid walls

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 solid masonry walls. The insulation of early forms of cavity construction (mid19th century onwards) is covered by a separate guidance note.

Traditional solid wall construction is probably the most difficult, and in many cases the least cost effective building element to insulate. Whether applied externally or internally, work of this nature will have a significant impact on the appearance of the building. For listed buildings any form of wall insulation is likely to require listed building consent and for the majority of buildings external insulation will usually require planning permission. External insulation can be particularly difficult to incorporate into existing buildings as costly ancillary adaptations such as changes to the eaves and verges of roofs, rainwater goods, and window and door reveals are often required.

Wall insulation will alter the performance of the solid wall and can in some cases either exacerbate existing moisture-related problems or create new ones. Particular caution needs to be taken with adding insulation to walls with high moisture content. Adding vapour barriers and materials that are highly resistant to the passage of water vapour are not normally appropriate for older buildings as they will tend to trap moisture and can increase the risk of decay to the fabric.

In many cases the technical risks of adding insulation to solid walls will be too great and alternative ways of providing a more cost effective long-term solution to improving energy efficiency may be more appropriate.

# Issues to consider before adding insulation

Traditional solid walls have very different physical characteristics to modern cavity walls. The construction and performance of the walls need to be fully understood before adding insulation or there will be a significant risk of creating long term problems.

## CONSTRUCTION

The first step should be to identify the external wall materials and their form of construction. Many older buildings may have three or four different types of wall construction, reflecting different stages of their development over many years. Construction can vary from single skin brick and stone walls of as narrow as 100 mm thick up to rubble-filled walls of a metre thickness or more. Wall materials can include brick of varying hardness and permeability, rammed earth, dressed stone blocks of varying types, rubble stone, flint and many more. Mortars can also be earth and/or lime based, also with wide variations in permeability and durability.

A single wall will often contain more than one material with quite different performance characteristics. For example, soft porous chalk and hard impervious flint have very different properties but are commonly found in the same wall.

The presence of voids, irregular bonding patterns and concealed timbers also add to the complexity of solid wall construction and performance.

Theoretical calculations are frequently used to understand and assess the movement of energy and moisture through solid walls often using quite sophisticated computer programmes. However data giving the thermal transmittance and moisture permeability of many traditional materials is simply not available and calculations at present are based upon idealised, homogenous walls. The actual variations within the wall and the influence of other variables such as the presence of salts that occur in reality can make such calculations very misleading when applied to many solid walled buildings. If 'theoretical modelling' is used as a basis for the design of thermal upgrading then performance should be closely monitored after installation in case any problems occur.

## BREATHING PERFORMANCE

Traditional solid walled buildings are colloquially referred to as 'breathing' structures, meaning that they exchange moisture readily with the indoor and outdoor environment. Where insulation is introduced it is important that this breathing performance is taken fully into consideration.

It is important to recognise that moisture in solid walls comes from several possible sources:

- Water from rainfall. This obviously affects solid walls but not all internal damp is a result of penetrating rain. With the exception of extremely demanding locations such as on exposed coast or high ground, it is unusual for driving rain to pass through most solid walls in good condition. Normally it will only saturate the outer part of the wall, which will then dry out when the rain stops.
- Rising ground moisture can be present in any solid wall which does not have a physical damp proof course. In such situations the moisture level is generally controlled by the 'breathability' of the material, which limits total moisture by allowing the excess to evaporate harmlessly away.
- It is often underestimated how much moisture can be generated by people using a building internally, simply through breathing but also from cooking and washing. The 'breathability' of external solid walls also significantly helps to control excess moisture and condensation from these sources.

**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 other impermeable 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, if essential, needs to be based upon an informed analysis of the full implications of their inclusion in order to minimise the risk of problems arising.

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.

Materials used in repair and maintenance must be selected with care to preserve this breathing performance. Modern impermeable materials – not just vapour control layers but cement renders, plasters and pointing and many modern paints and coating will significantly impair the breathable performance and will therefore trap moisture. More often than not this will increase problems of damp and associated decay of the building fabric, and possibly also create health risks for the occupants.

## THERMAL MASS

Solid walled buildings, particularly those with thicker walls have comparatively high thermal capacities, which means they can absorb heat over time and release it relatively slowly as the surroundings cool down. This is the same principle as a storage heater, although on a larger scale and can have a significant stabilising effect on the internal environment. External insulation means little of this heat will be lost to the exterior. This allows a building to maintain a level of warmth over day-night heating and cooling cycles, improving human comfort and potentially reducing overall energy use. Internal insulation, whilst reducing short-term heat losses to the exterior will isolate the internal environment from the benefits of much of this thermal mass.

In summer, when strong sun can cause overheating, the thermal mass of the walls cools the interior by absorbing excess heat during the day and releasing it slowly during the night. This helps reduce the need for air conditioning or mechanical cooling.

### ENVIRONMENTAL INFLUENCES

Location, aspect, and the differing exposure of individual elevations to direct sunlight and wind driven rain have important influences on a building's condition and performance which need to be taken into account when making alterations.

Different parts of a building are affected by very different micro-climates. For example, north facing elevations can be subject to prolonged damp, as they do not receive the benefit of a drying sun and are usually sheltered from drying winds. However, they receive little driving rain from the prevailing south-westerly winds, so conditions are more stable over time. This often means that north-facing walls deteriorate less than south and south-west facing walls which tend to suffer from accelerated rates of decay caused by fluctuations in temperature and regular wetting and drying cycles.

Each building's exposure to the elements is as much influenced by the proximity and position of surrounding buildings and its own projections and extensions as by the exposure of the site. For example, an apparently homogeneous terrace of houses can be affected by quite widely varying local levels of exposure and shelter. Such complex variations in microclimate would ideally need to be taken into account in the design of any insulation.

## DAMP

If a wall suffers from prolonged damp then a number of problems can occur such as:

- decay in timbers in contact with the masonry
- deterioration of the external fabric of the wall due to freezing and thawing
- movement and crystallisation of salts

- movement of tars and other chemicals through the walls, causing staining at the surface
- growth of mould on the inside surfaces of walls
- corrosion of metallic compounds in contact with, or buried within, the wall

Before making any improvements, it is therefore important to understand how solid walled buildings 'manage' the movement of water, in both vapour and liquid form. This is not only complex in itself, but may also be affected by the presence of soluble salts (see below).

Most insulation systems are designed and developed solely to limit heat loss and to avoid interstitial condensation from water vapour generated internally. They do not take account of how they affect the movement of water and salts already in a traditional wall. So they can easily:

- exacerbate existing problems;
- create new problems, such as the displacement of damp and salts and the decay of timbers in contact with the walls;
- create health risks for the occupants, e.g. from mould growth;
- be affected by the moisture, reducing their performance and sometimes failing entirely.

Where walls have been damp for a long period of time it can take years for them to dry out. The selection and design of insulation must take account of the drying-out process, both before and after installation, and the presence of residual damp and salts.

## SALTS

Buildings without a damp-proof course can be prone to damp and salt contamination, particularly at low level, where ground salts are carried in solution. Salts are also commonly found around fireplaces and chimney breasts where they originated as by-products of combustion. They can also originate from a previous use of a building, e.g. from animal excrement and storage of fertilisers in agricultural buildings. Salts may also have been present in the original building materials (e.g. stone or aggregate extracted from marine environments) or from the use of chemicals such as caustic soda to remove paint.

Many of these salts are 'hygroscopic', that is they have an affinity for water and so exacerbate the problems of damp by attracting moisture out of the air leading to the phenomenon of surfaces feeling 'clammy' to the touch. They may also re-crystallise at drying faces with changing moisture levels, and the related expansion within the pores can very effectively turn sound masonry into powder. The interface between existing walls and added insulation can be susceptible to cycles of evaporation, condensation and salt crystallisation. As such locations are hidden from view, major deterioration may have taken place before anybody becomes aware that there is a problem. Unfortunately salts are notoriously difficult to effectively remove from porous building materials such as brickwork, masonry and plasters.

# Wall insulation generally-relevant issues

## LOCATION OF INSULATION

Insulation may be added to existing solid walls either externally or internally, but the physical effects on both the building fabric and the internal environment can be very different. This is explored in more detail below.

## COST-EFFECTIVENESS

The necessity to achieve good building detailing to perimeters and openings can significantly add to the initial base cost of both external and internal insulation and may significantly reduce its overall cost-effectiveness.

## IMPERVIOUS MATERIALS

Practical experience of the repair and conservation of historic buildings shows that the introduction of materials and systems that do not maintain the traditional ‘breathing’ performance can seriously exacerbate existing problems and or create new ones. Examples of incompatible materials and systems which should be avoided include:

- closed cell and extruded plastic insulation
- plastic vapour barriers
- cement or acrylic based renders
- cement pointing
- plastic based external wall paints
- vinyl wallpaper and emulsion paint

Any of these used on the outside of the wall will trap moisture within the wall and lead to damp and decay, as well as making the walls feel cold and ‘clammy’. Installed on the inside, they may do less damage to the building fabric itself, but will negate its ability to buffer moisture levels in the internal air. Both of these can significantly reduce comfort for people using the building, who tend to try to compensate by turning the heating up, thus wasting energy.

Clearly, if the walls are already damp before installing insulation these effects will be exacerbated. Under these circumstances it is particularly important to allow walls to ‘breathe’ in order to dry to the outside as effectively as possible. Drying to the inside is significantly less effective, and may be extremely unpleasant for users of the building.

## THERMAL BRIDGES

Whenever insulation is added to an existing building there is a danger of creating thermal bridges at critical details where full coverage may be interrupted. When insulation is added externally these weak points are typically at window and door reveals, but with internal insulation they may also be formed at the points where floors meet external walls.

Areas left with reduced or no insulation coverage will not only be colder because of the lack of protection from the outside environment, but will also attract relatively more condensation because the majority of other surfaces are warmer and can no longer share the load. The result can be severe local decay, particularly to timber and finishes. For example, the ends of floor joists embedded in the external walls are at increased risk of decay from condensation.

Great care needs to be taken to ensure adequate detailing around window and door openings to avoid potential thermal bridges, and this can significantly increase the overall cost of both design and installation. The necessary level of detailing can even be impossible to incorporate in certain circumstances, in which case, depending on the potential severity of the consequences, it may even be better not to install insulation at all.

## FINANCIAL COST AND PAYBACK

As noted, the addition of external or internal insulation to solid walled buildings tends to be expensive, and financial payback times are potentially correspondingly long. It is important not to underestimate the costs associated with the necessary levels of care in detailing to avoid cold bridges. Full payback periods are typically 30 years or more, but they will inevitably vary greatly between individual instances.

This suggests that in the majority of cases it would not be worth considering the insulation of external walls until the full range of easier and more immediately rewarding upgrades to traditionally-constructed buildings have been carried out. These would include actions such as repairing and draught-stripping windows and doors; insulating roofs and suspended ground floors, and possibly even installing condensing boilers. Significantly, most of these upgrades will also have considerably fewer detrimental effects on the character and cultural significance of historic buildings.

# External insulation – relevant issues

Most external insulation systems comprise an insulation layer fixed to the existing wall and a protective render or cladding installed on top to protect the insulation from the weather and mechanical damage (impact or abrasion).

## PHYSICAL ADAPTATION OF THE BUILDING

The increased depth of an external render or insulation system will require adaptation to the roof and wall junctions, around window and door openings and the repositioning of rainwater down-pipes. These alterations will require scaffolding access and possibly a temporary roof to reduce the risk of water penetration during the work.

## CHANGES IN THE APPEARANCE AND CHARACTER OF A BUILDING

External insulation will radically alter a building's appearance, even if it is already rendered. Even then, decorative architectural features such as cornicing, string courses and window surrounds will be affected. Even where the elevations are quite plain, simple alterations such as the deepening of window and door reveals and the alteration of eaves lines can markedly alter a building's appearance.

In many cases it will be necessary to actually relocate windows and doors further forward in the overall wall thickness in order to minimise the danger of creating cold bridges at the reveals. This can reduce some of the visual impact, but will inevitably impact on the building's character.

Planning permission will be required for external insulation in the majority of instances, whether or not the building is listed; the local planning authority should be consulted before work commences. For listed buildings, consent will be needed, and will normally only be likely to be granted in very special circumstances.

## CHANGES IN MOISTURE MOVEMENT WITHIN THE WALL

It is vital that insulation installed externally should be moisture permeable in order to retain the necessary 'breathability', and allow moisture to evaporate away harmlessly. A useful rule of thumb is that all layers of an insulated solid wall should become progressively more permeable from the interior to the exterior. Whilst it is important to protect external insulation from rain, this should not be done in any way that will trap moisture from within the fabric or from the ground within the solid wall material.

## MATERIALS

The need to prevent impermeable layers within the external insulation precludes the use of modern closed-cell foam and other plastic-based insulations, as well as the use of protective finishes which bar moisture vapour movement. As most suitable external insulations will also need to be protected from external rain and from mechanical damage, external insulation should normally be considered as a two-component system where all layers need to work together.

Useful materials for the external insulation itself include:

- Hemp-lime composites
- Sheep's wool
- Mineral wool

Cellulose fibre, although having excellent properties in itself, is too susceptible to damp to be used externally.

All these insulation materials need to be protected from both the weather and mechanical damage, although to differing degrees. Suitable moisture-permeable finishes include:

- Lime renders
- Rain-screen cladding (tile hanging etc.) with lapped joints

Materials which can be used as a single coat are possible, such as insulating lime renders containing expanded vermiculite, but these tend to give significantly lower insulating values. They can, however, sometimes be applied in circumstances where other types of external insulation would be unacceptably detrimental to the character of a historic building.

# Internal insulation – relevant issues

Internal insulation is usually applied directly to the inner face of the relevant external wall, and then a finish is installed to the room side.

Rigid board insulations can often be fixed directly to the wall face itself, and then the finish applied to conceal them without any additional structure. In its most convenient form, plasterboard can be obtained with a factory-applied foam insulation backing which can be fixed to the inner face of the wall very easily, although such systems typically do not offer very great insulating performance overall.

For significant insulation thicknesses a non-rigid insulating material will often be installed between timber studs or battens erected internally to the wall, with the new internal finish applied to the timber structure. Occasionally, the structure and insulation may be erected as a separate inner leaf, with a cavity between the insulation and the original wall.

In all cases it is necessary to very carefully consider the control of vapour from the warm internal air entering and condensing within the insulation, or within vulnerable parts of the original solid wall.

## PHYSICAL ADAPTATION OF THE BUILDING

As with external insulation, care needs to be taken with the design and installation of internal insulation at critical details in order to avoid cold bridging, particularly at the reveals of windows and doors. It is also often necessary to relocate services (radiators and associated pipe runs, electric power points and light switches) as well as making adjustments to skirting boards and door architraves, fitted furniture etc.

The construction of a separate insulated inner leaf will normally include ventilation to the cavity, in which case the vents to allow air movement through the outer wall will need to be specifically designed in order to allow full flow though the cavity without dead spots, but without unacceptably harming the character or appearance of the building. There is no point in ventilating such a cavity to the inside of the building, as the air movement will simply by-pass the insulation, rendering it ineffective.

Thick, high-performing internal insulation installations will often significantly alter the sizes of internal rooms, corridors etc, sometimes to the extent that they cannot be used as before.

## CHANGES IN THE APPEARANCE AND CHARACTER OF A BUILDING:

Internal insulation will reduce the floor area of the internal rooms/spaces, and thus their overall proportions. Valuable internal details such as plaster cornices and important joinery fittings such as picture rails, skirting boards and door architraves may all be significantly affected. They will inevitably be either concealed or disturbed to accommodate the insulation. Although it is normally possible to replicate such details on the inner face of the new insulation, the effect of revised room proportions on the design of adjacent wall finishes needs to be carefully considered at the design stage, as the side walls of an insulated room will become shorter.

The disturbance to the internal appearance can be compounded by the need to extend insulation back from the external wall onto party walls, other internal walls, floors and ceilings to reduce the risk of thermal bridging.

In listed buildings, consent will be required for any internal alterations that affect the appearance and character, including any materials, details and finishes of historic or architectural interest. In many cases this may simply make the installation of insulation unacceptable.

## CHANGES IN MOISTURE MOVEMENT WITHIN THE WALL

As noted above, it is a useful rule of thumb that all layers of an insulated solid wall should become progressively more permeable from the interior to the exterior. In order to protect internal insulation from condensation occurring within its thickness it is generally necessary to separate it effectively from the warm, moisture-bearing air of the building's interior. This will require either the use of impermeable closed-cell foam insulation or an effective vapour control layer.

This means that it is impossible to allow internally-installed insulation to 'breathe', or transpire moisture in the manner that traditionally-constructed historic buildings always have done. This introduction of performance and qualities more appropriate to modern buildings removes any possibility of the external wall playing its normal part in the moderation of the internal environment by buffering moisture levels within the internal environment. Whether this trade-off is appropriate needs to be considered on its merits for each individual case.

In addition, vapour control, whilst theoretically entirely desirable, is in reality notoriously difficult to achieve. Vapour barriers, or more accurately 'checks' or 'control layers' are usually formed using a sheet of polythene internally to the insulation but behind the new finish. These sheets are normally very fragile, and can easily be broken by building users nailing through walls or modifying electrical fitting etc. They can also be broken during the construction process itself. All penetrations will allow moisture vapour through, which will condense either within or adjacent to the insulation, causing rot and decay in a hidden location. Closed-cell foams are inherently vapour-impermeable, but can be vulnerable at the joints.

Both forms of vapour control are vulnerable at the perimeter, particularly in a traditional permeable structure, where moisture can by-pass the physical vapour barrier through adjoining walls and floors.

However, many of these problems can be usefully overcome by creating a separate insulated inner stud wall with a ventilated cavity between it and the original external wall, as the ventilation will carry away much of the moisture which tends to by-pass the vapour check. This will, however, be at the expense of the loss of internal space, and the need to introduce the external ventilators.

## MATERIALS

Almost any insulation material available can be used internally, subject to proper control of vapour and careful isolation from sources of dampness. The full range of possible internal finishes can also be applied, either to copy the original or to introduce a new design.

In all cases, however, it is vital to understand the likely effects of proposals at the design stage in order to avoid damage to both new and valuable historic building fabric.

# Further information

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# English Heritage National Offices

**North East**
English Heritage
Bessie Surtees House
41 - 44 Sandhill
Newcastle upon Tyne
NE1 3JF
Tel: 0191 269 1200
E-mail: northeast@english-heritage.org.uk

**North West**
English Heritage
3rd floor Canada House
3 Chepstow Street
Manchester
M1 5FW
Tel: 0161 242 1400
E-mail: northwest@english-heritage.org.uk

**Yorkshire and the Humber**
English Heritage
37 Tanner Row
York
YO1 6WP
Tel: 01904 601901
E-mail: yorkshire@english-heritage.org.uk

**West Midlands**
English Heritage
The Axis
10 Holliday Street
Birmingham
B1 1TG
Tel: 0121 625 6820
E-mail: westmidlands@english-heritage.org.uk

**East Midlands**
English Heritage
44 Derngate
Northampton
NN1 1UH
Tel: 01604 735400
E-mail: eastmidlands@english-heritage.org.uk

**East of England**
English Heritage
Brooklands
24 Brooklands Avenue
Cambridge
CB2 8BU
Tel: 01223 582700
E-mail: eastofengland@english-heritage.org.uk

**London**
English Heritage
1 Waterhouse Square
138 - 142 Holborn
London
EC1N 2ST
Tel: 020 7973 3000
E-mail: london@english-heritage.org.uk

**South West**
English Heritage
29 Queen Square
Bristol
BS1 4ND
Tel: 0117 975 0700
E-mail: southwest@english-heritage.org.uk

**South East**
English Heritage
Eastgate Court
195-205 High Street
Guildford
GU1 3EH
Tel: 01483 252000
E-Mail: southeast@english-heritage.org.uk

**The Conservation Department**
English Heritage
Room 2/20, NMRC
Kemble Drive
Swindon
SN2 2GZ
Tel: 01793 414963
E-mail: conservation@english-heritage.org.uk

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Telephone: 0870 333 1181
Fax: 01793 414926
Minicom: 0800 015 0516

E-mail: customers@english-heritage.org.uk