ENGLISH HERITAGE

ENERGY EFFICIENCY IN HISTORIC BUILDINGS

Insulating timber-framed walls

This guidance 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

Content

Introduction

This guidance note provides advice on the methods, materials and risks involved with insulating the walls of timber framed buildings. The benefits of making improvements will include improved comfort for occupants as well as lower fuel bills and carbon emissions. However, such improvements can have conservation and planning implications.

Timber-framed houses are a striking feature of many of England's towns, villages and farmsteads. Examples can date back to the 12th century but most have 16th century origins. They continued to be built up to the 19th century in rural parts of the country. Many timber-framed buildings still retain important fabric and finishes, such as wall paintings and historic wattle and daub. Any repair or improvement needs to minimise the risk of damage to the historic fabric.

Often the timber frame can be concealed by historic renders or claddings, such as tile-hangings and weatherboarding. Alternatively the timber frame can be fully exposed with infill panels of render, wattle and daub or brickwork. Some timber frames are completely concealed behind masonry, either brick or stonework which may also conceal other historic construction or detailing. Where the timber frame is fully concealed by masonry or is partly of masonry construction it may sometimes be more appropriate to consider this part of the building as a solid walled building. Internally the timber frame can be concealed behind lath and plaster or exposed with plastered infill panels. The variations found within this building type add considerably to their charm and character.

Wall insulation alters the performance of traditional buildings, and can exacerbate existing moisture-related problems or create new ones. Any installation requires great caution and it is strongly recommended that insulation is not added to damp walls. Modern methods of upgrading thermal performance which include 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 – including the structural timber frame.

Timber-framed wall construction

THE STRUCTURAL FRAME

The timber frame is usually the primary structural component of the building which is made weather-tight with timber or tile cladding or with infill panels of wattle and daub, plaster or brick. The structural performance of a timber-framed building is dependent on the strength and condition of the joints that make up the frame. The failure of a single timber or joint as a result of decay and/or alteration can impose unpredictable additional stresses and loads upon other timbers within the framework. This can lead to the distortion of the frame and, in a worst-case scenario, to the actual failure of parts of the building.

In many buildings the process of repair and adaptation will result in a ‘composite construction’; that is the buildings comprise both masonry and timber framing, providing varying degrees of structural support. The particular circumstances, construction and performance of each timber-framed building and in many cases each part of the building will need to be individually assessed before making any changes. If the structural importance of the frame is not properly understood, the structural stability of the building can be threatened by well-intentioned but inadvertently damaging repairs or improvements.

TYPES OF CONSTRUCTION

Timber framed houses are constructed from a series of prefabricated timber frames (cross frames, wall frames, floor and roof frames) joined one to another dividing the building into bays. The two main types of timber-framed building are cruck and box frames and variations on both themes can be highly characteristic of both date and locality. The longevity of timber-framed buildings means that the timber frames will very often have been adapted over the centuries, creating hybrid and non-standard forms.

The timbers most commonly used to construct medieval timber frames were oak and elm but from the 18th century onwards imported softwood became more commonly used. The same fundamental principles apply to the timber frame irrespective of the species of timber used; that is the timbers need to be kept free of prolonged damp. Where this can be achieved all types have been proven to last for centuries.

There are many different types of cladding and infill panels used with timber framed buildings. The traditional presentation of the building is important as it can reflect regional styles and the materials locally available as well as the social status of the building. The local traditions and styles should, wherever possible, be recognised in any repairs or improvements.

In many buildings the cladding and infill panels will have been replaced over time. It is not unusual to find several types of infill panel in the same building,

from original wattle and daub or early brick infill through to modern materials. These illustrate the history of the building and changes in available materials and skills over the lifetime of the building. Unless the infill panels are causing a problem they should normally be retained as a record of the building's history.

BREATHING PERFORMANCE

Traditional timber-framed walls have very different characteristics to modern walls. They are typically of a lightweight 'breathing' construction that both absorbs and emits moisture externally and internally and they do not incorporate damp-proof courses.

THE IMPORTANCE OF '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 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.

Where insulation is introduced it is important that this breathing performance is taken into consideration, or it may create problems for the building and its occupants.

Materials used in the repair, maintenance and improvement of traditional buildings must be selected with care. Modern impermeable materials – not just vapour control layers but cement based renders, plasters and pointing and most modern plastic-based paints will impair the breathable performance and will tend to trap moisture against the fabric.

Where moisture is trapped against the timber frame, as a result of using impermeable materials in past programmes of repair and decoration and/or other causes such as defective roofs and rainwater gutters, it can lead to serious problems of decay to the structural timber frame. Before making any improvements it is therefore important to examine the condition of the timber frame in detail.

THERMAL PERFORMANCE CHARACTERISTICS

The walls of a timber frame building are usually very thin, especially when compared with stone and earth walled structures. Where the timber frame is rendered externally and the internal panels between the timber frame are plastered, the 'wall' can be as little as 40mm thick. Where the panels have brick in-fills the walls are often only 100mm thick.

Thin walls are poor insulators, and can allow a great deal of heat to escape through the building fabric. Timber framed walls are usually also lightweight structures that have little thermal mass and these buildings can therefore be prone to large fluctuations in internal temperature from a cycle of thermal gain through solar heating (sunlight) followed by rapid cooling at night.

Different parts of a timber framed wall will typically have different insulating abilities. Until recent upgrading of thermal performance standards for new buildings, timber was generally regarded as an insulant in itself and still provides very useful resistance to heat loss. Most materials used traditionally for infill panels, however have considerably poorer thermal performance.

The poor overall thermal performance of the walls is often made considerably worse by the presence of cracks and gaps between the timber frame and infill panels and within the fabric of the infill panels and/or cladding itself. In thin walls these cracks can easily pass right through the walls, allowing large amounts of uncontrolled air infiltration (draughts) and consequent additional heat loss. These cracks tend to occur as a result of shrinkage of renders and mortars used in the construction or subsequent repairs or from the different degrees of flexibility and thermal expansion between timber frames and the infill panels.

The lightweight nature of timber frame construction can however offer opportunities to upgrade the insulation of walls without introducing all of the same technical risks associated with upgrading solid walls.

PLINTH AND SOLID WALLS

Timber framed buildings were normally constructed with the lowest horizontal timber (the sill beam or sole plate) sitting on a solid plinth wall. One of the functions of this wall was to isolate the timber frame from the damp ground. This was possible without a damp–proof course by allowing the maximum of evaporation from the surface of the permeable plinth material.

Where timber-framed buildings incorporate masonry either as plinth walls or where the timber frame has been under-built or provided with a façade, they

need to be treated carefully particularly carefully in order that the masonry does not become a reservoir of moisture in contact with the timber frame. However, as with all 'breathable' buildings, periods of occasional dampness are not usually a problem if the construction is allowed to dry out freely and rapidly afterwards.

DAMP

If the timber framed building is well maintained and there is a good projection of the roof eaves and verges then a timber-framed wall should not suffer from prolonged damp. The thin nature of the walls, and the high surface area to volume ratio, will allow moisture to readily evaporate where the wall is constructed and finished with permeable materials.

For a timber-framed building in good condition the principal source of damp problems will be driven rain causing damp to penetrate through thin walls or through gaps between the timber frame and infill panels. Even for thin walls the permeable qualities of traditional materials will, in all but the most extreme of conditions, help reduce the risk of serious problems of water penetration to the internal face of the wall.

Where a wall regularly suffers from penetrating damp because it is exposed to prevailing winds there may be a case for providing it with a protective coating or cladding, such as lime washes, lime slurries or lime render, or in particularly severe locations tile or slate hanging or weatherboarding. Local precedents should be followed if possible. Such an alteration would however require consent for listed buildings and may require planning permission for other buildings.

The most damaging decay to a timber-framed building is usually found where inappropriate materials have been used to repair the building. The introduction of impermeable materials, such as cement-based renders and modern paints, will significantly increase the risk of water being trapped next to the timbers and prolonged damp will always cause active decay. Decay in the timbers of a historic timber-framed building is not only an aesthetic problem; it can result in the loss of a primary structural joint or component and historic fabric.

The most vulnerable part of the timber frame to damp and associated decay is the lowest horizontal timber (sill beam or sole plate) as this is the timber nearest the damp ground. The sill beam should always be raised above external ground levels and it may be necessary for the ground level to be reduced back to a suitable level. In many cases water spillage onto the plinth (either stone or brick) can lead to the sill beam suffering from prolonged damp and decay. Any repair must treat the cause of the dampness, not just the decay itself.

Where water penetration has occurred or where walls have suffered from prolonged damp the structural timber frame should be carefully inspected for any problems of decay as it is quite possible that the worst areas of damage can be hidden within the construction.

Issues to consider before insulating

Adding insulation to timber framed buildings demands great care to ensure that thermal bridges are not created, and problems of damp and associated timber decay are not triggered particularly to the structural timber frame.

It is important to remember that in-fill panels within the timber frame can have as much historical significance as the frame itself, and improvements should not endanger those panels by trapping dampness against the timbers or the panels.

Wall insulation is most likely to be appropriate in situations where the timber frame is clad externally and internally. Such cladding often leaves voids between the inner and outer faces of the wall that provide the opportunity to add insulation.

THE TIMBER FRAME

In the first instance it is important to understand the construction and condition of the timber frame and the solid wall elements so that the appropriate approach can be applied to these different forms of construction. The condition of the timber frame is often dictated by the condition of the external cladding and infill panels and whether they have been repaired or replaced with inappropriate impermeable materials.

Secondly, the significant historic fabric (the timber frame, infill panels and cladding) needs to be identified so that repairs and improvements can be devised that take into account their special interest.

In most cases the timber frame is the primary structural component of the building, it is therefore important that before any structural alterations are made to a timber-framed building that appropriate professional advice be sought.

THE CLADDING AND INFILL PANELS

Great care is needed when making improvements to historic timber-framed buildings to ensure that highly sensitive and very rare fabric and finishes are not damaged or lost. The historic fabric found can include wattle and daub infill panels, which may be as old as the frame, historic render finishes that illustrate how the building was presented, brick infill panels and internal plasters and finishes such as traditional lath and plaster.

Many historic timber-framed buildings may have remnants of wall paintings and decorations behind existing finishes. For this reason great care needs to be taken to avoid causing the irreparable loss of extremely rare finishes.

Within the repair and reinstatement of cladding and infill panels it is important that traditional materials, such as lime putty and earth based

mortars and renders, are used that are compatible and consistent with the traditional breathing performance. Timber-framed buildings are highly vulnerable to decay when the wrong materials are used. For this reason cement and high strength hydraulic lime based mortars and renders (NHL 3.5 and above) should not be used on historic timber-framed buildings.

FURTHER INVESTIGATION

Where the condition of the timber frame is in doubt or where the presence of impermeable materials is a threat to the timber frame it may be necessary to carry out some further investigation to ascertain the precise constructional detailing and the condition of concealed elements. Physical opening-up work should be kept to a minimum, especially where cement renders may have taken on a structural role, to reduce the risk of damage or disturbing the structural equilibrium of the building.

It some cases it may be appropriate to use non-destructive survey techniques to gain a better understanding of the timber frame condition. The following techniques can be useful, although all will need to be interpreted by an experienced professional:

- Calibrated resistance micro-drills can assist in determining the condition of the inside of timbers with the minimum level of disruption and can also clarify the internal arrangement of complex or unusual joints.
- Thermal imaging can help identify timbers concealed by external render and internal plaster
- An endoscope can enable visual inspection within small voids or behind rigid coverings although it may be necessary to drill a small hole to enable access.

THE THERMAL PERFORMANCE

Time spent identifying areas that needs attention; which elements of the building are not performing well and where performance could be improved, is well worthwhile. This can be achieved by using data loggers to accurately measure temperature and humidity levels. Pressure testing a building with a fan pressurisation test will help determine how much air is leaking and infiltrating into the building and will quantify excessive heat losses. The fan test will also help trace the sources of air leakage. An appropriate plan can then be developed to reduce the scale of the problem and target resources where they are actually needed. For many timber-framed buildings the walls will be a primary source of excessive air infiltration (draughts).

Once suitable repairs to under-performing historic construction have brought it back to its original performance it is then possible to consider whether additional upgrading may be necessary or desirable.

OPPORTUNITIES FOR UPGRADING

The difficulty and cost of upgrading thermal performance will mean that in many cases such works are only really viable if they can be incorporated into planned repair or improvement works. However, if it is necessary to repair the timber frame and cladding, this can provide a suitable opportunity to improve the thermal performance of the building. This will be particularly the case if it involves the removal of impermeable materials, such as cement renders.

The need to provide improved protection against driving rain would also provide the opportunity to improve the thermal performance of the building.

MATERIALS

NATURAL INSULATION MATERIALS

It is important that the materials and methods used to improve the performance of a timber-framed building are compatible with its performance as a 'breathing' building. For this reason the selection of materials and the detailing of proposed solutions need great care.

There are many insulation materials available that have similar performance characteristics to traditional materials and these can be used to improve the thermal performance of these buildings without compromising the 'breathing' behaviour. These materials include:

- wood fibreboard,
- sheep's wool batts,
- hemp fibre insulation boards
- flax fibre batts
- cellulose fibre

In many cases these will be used with vapour-permeable 'breather' membranes.

Insulation systems based on cement-based or acrylic renders, or including impervious membranes should not be used on a historic timber-framed building. There are many cases of cement-render having caused serious problems of decay to the structural timber frame. The use of impermeable plastic-based paints should also be avoided both internally and externally.

Well-intentioned improvements can lead to the introduction of new technical risks; either because of poor detailing at the design stage or inadequate care during installation. Very minor errors can lead to serious problems. For example, where vapour control layers are necessary and could potentially have worked, even small perforations can lead to severe problems of damp, especially in rooms where large amounts of water vapour are produced.

HEMP-LIME COMPOSITES

Hemp lime composite materials have been successful in France and more recently in the UK and Ireland in providing compatible insulation which can infill timber frames. The material has also been successful in meeting very demanding thermal performance targets in new buildings. The material is based on chopped hemp 'shiv' (the remains of the woody stem of the plant) mixed with specially developed lime based binders. It can be mixed conveniently on site to give a lightweight 'concrete' or 'hempcrete' containing a great deal of air. It is then finished externally and internally with lime renders, cladding or clay plasters.

The resulting material is a rigid cast insulation which can accommodate a certain amount of movement in the timber frame and which is highly compatible with the moisture behaviour of the timber itself. It also has inherent thermal mass and can therefore help to dampen out the internal temperature fluctuations which can be such a problem in lightweight construction (typically 10mm or so), or it can be cast to a greater thickness if the opportunity arises. Around 300mm can meet 2006 Building Regulations requirements for external walls in dwellings and 500mm can even obviate the need for heating.

Ways of improving the thermal performance

EXPOSED TIMBER FRAME WALLS

Where the timber frame and the infill panels are both exposed it is more difficult to improve the performance than if the frame has an overall cladding. In many cases the addition of external insulation overall, under a weather-screen cladding, offers best configuration for wall insulation. Such an arrangement allows the insulation to bridge cracks and to protect the frame and the original panel material. If no external cladding is already present however this may well unacceptably compromise the character of a historic building.

Additional insulation may well make the wall thicker, requiring modifications to eaves and window reveals which can add significantly to both the cost and the disruption.

GAP FILLING

One of the characteristics of timber-framed buildings is that there can be a high number of cracks and gaps in the construction, particularly between the timber frame and infill panels. Some of these sources of draughts will be obvious to a visual inspection (chinks of light) or to an occupant on a cold windy day feeling the draughts. However, a more thorough and far more

effective way to identify all the cracks and gaps will be to carry out an air pressure test.

The most effective improvement that can be made is to fill the gaps. As air passing through these simply by–passes even the limited insulation capability of a narrow wall. How to fill gaps and cracks will depend upon their size, location, exposure and on the materials used for the infill panel itself. Traditional lime-putty mortars with hair are often a very suitable filler to minimise cracking and maintain compatibility with lime-based panel materials. Filling the worst cracks with such mortar is a simple cost effective method to create improved internal environment for the occupants and to reduce heating bills. Silicone mastics, car body filler, cement, and many other impermeable sealants are totally incompatible with traditional construction and should be avoided.

REMOVED INFILL PANELS

Where infill panels have to be removed, possibly as they are of unsuitable materials or to facilitate structural repair to the frame, this would provide the opportunity to replace them with insulated panels.

INSULATION WITHIN THE THICKNESS OF TIMBER FRAME WALLS

RENDERED ELEVATIONS

Where historic renders survive they should be retained and not removed to facilitate the insertion of insulation. However, where render is to be removed, for example where it has failed or is an inappropriate later cement render, there is an opportunity to insert insulation within the timber frame before the render is reinstated. Wherever the render is reinstated back to its original/existing profile this option need have no detrimental visual impact on the building.

A lime putty or earth based render will provide an effective barrier against excessive draughts keeping the insulation ‘warm’. As with any render some shrinkage can be expected, this will allow some air infiltration but should not be excessive. Regular maintenance with a traditional limewash finish will assist in filling any shrinkage or movement cracks which might develop. This is a traditional form of maintenance and would have been carried out historically.

CLAD ELEVATIONS

The removal of tile-hanging or weatherboarding for repair will also provide an opportunity to install insulation within the thickness of the timber frame. Cladding can be relatively easily removed and in the case of tile or slate hanging can normally be re-used. The removal of weatherboarding is more difficult without causing damage particularly if any rot has occurred. Reinstatement of the cladding over a vapour permeable ‘breather membrane’ added as a secondary barrier behind the cladding can

significantly improve the performance and effectiveness of the insulation by reducing air infiltration. The breather membrane should be installed with some 'slack' behind the cladding, in particular when used with weatherboarding, so that it is not held tight to its' back face. This will allow any water that penetrates the cladding to run freely away down the face of the membrane without being redirected against the timber cladding.

INSULATION OUTSIDE THE TIMBER FRAME

External insulation is the most effective means of insulating a timber-framed wall. It can be achieved by fitting wood fibre or other similar boards over the external face of the timber frame, taking care to seal any gaps between boards caused by the unevenness of the frame beneath. The disadvantage of such boards is that their fitting will change the position of the cladding, making the wall thicker. This will require consequential changes in window reveals, eaves projections, rainwater goods locations and other façade details that are costly to make and could have a material, possible unacceptable, impact on the appearance of the building. Wood-fibre boards are available that are impregnated with latex. Such boards can act as a secondary barrier to any rain driven through the cladding. Other boards may require the provision of a vapour permeable felt to protect them from driven rain.

Insulation on the outside of the timber frame may be the only possible way of upgrading the thermal performance of a wall if there are historic infill panels that cannot be removed.

INTERNAL LINING

The addition of internal insulation is possible for most timber framed walls, but such work can have major implications on the internal appearance of the walls, and will reduce the floor area of the internal rooms.

If the timber frame is visible on the inside it will be concealed by the insulation. If the main elements of the timber frame are substantial in depth and intermediate elements thinner, it may be possible that the insulation will only cover the intermediate elements, leaving the principal posts exposed. However, this is still a significant alteration and its effect on the character of the building should be carefully considered.

If the timber-frame is already covered by a plaster finish, there may also be valuable decorative cornicing and picture rails, skirting boards and in some cases door architraves that may be concealed or disturbed by the installation of insulation.

If internal insulation is separated from the timber-framed wall by a cavity, careful thought will need to be given to the movement of air and moisture within the cavity. Ideally, such a cavity should be ventilated to the outside, but this will require ventilators to the external wall which may well be unacceptable. If the cavity is not ventilated a void is created where damp air can collect and cause rot in concealed areas.

Added internal insulation can also create new problems, such as thermal bridges that did not exist previously. Areas with little or no insulation will not only be colder for the reasons outlined above, but will attract relatively more moisture because other surfaces are warmer and can no longer share the load. In timber-framed buildings this risk is less than in solid masonry but care still needs to be taken particularly where only partial improvements are being made.

Insulating the walls above and below a suspended timber floor can create a cold bridge where the floor meets the external wall. The ends of floor joists embedded in the external walls are at increased risk of decay from condensation and the damage is also usually concealed from view.

In listed buildings, consent will be require for any internal alterations that affect the appearance and character, including any materials, details and finishes of historic or architectural interest.

Summary

It can be difficult and relatively expensive to insulate the timber-framed walls of historic buildings reliably and to achieve worthwhile gains in thermal efficiency without compromising their appearance, character and performance and possibly creating additional problems in the longer term.

There are instances where wall insulation may be acceptable. However, this should only occur after a thoroughly detailed assessment has been made of the particular building, taking into account the often complex performance characteristics. Any solutions may need to adapt to take account of the location, orientation, exposure and condition of an individual wall.

English Heritage strongly advocates that monitoring is undertaken before, during and after any such insulation to ensure that the work is not only done on an informed basis but that lessons can be learned from any successes and failures.

Further Information

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