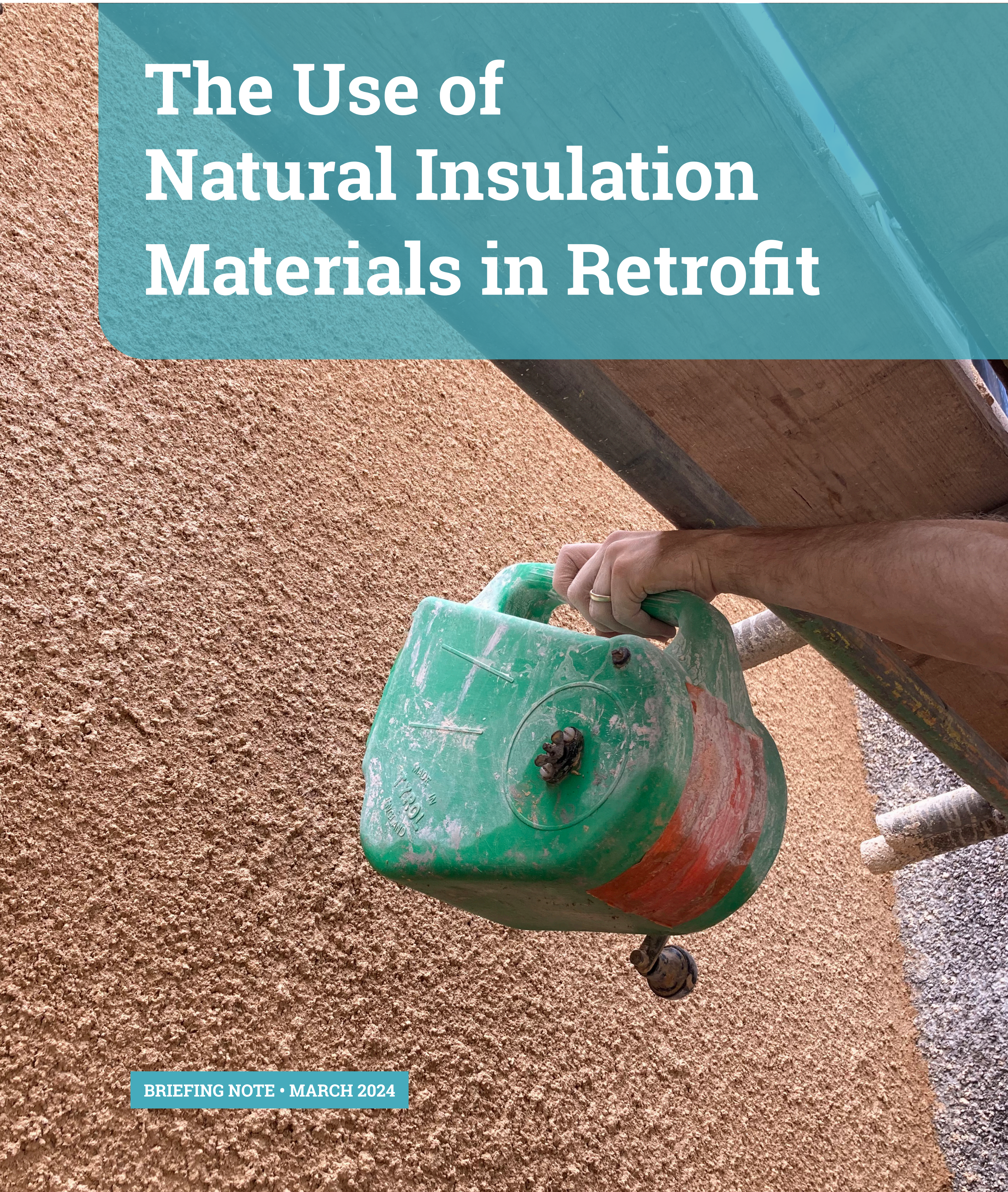
STBA
SUSTAINABLE TRADITIONAL BUILDINGS ALLIANCE

Responsible Retrofit Series

The Use of Natural Insulation Materials in Retrofit



BRIEFING NOTE • MARCH 2024

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Images: cover and above: Peter Draper, STBA. Below, Babatunde Ibrahim, Ecotecture Ltd

1 Introduction

1.1 Purpose

The purpose of this briefing note is to explore the opportunities, limitations, and barriers around the use of natural insulation materials in retrofit. The subject is important because it has been demonstrated that many natural materials can help reduce risks in retrofit, and deliver healthier buildings.

1.2 Definition

To define 'natural materials' is not straightforward, but one common definition is those materials which are used in a form which is as close as possible to their natural state. Effectively this means that they are minimally processed. Taking insulation as an example, wood fibre, and sheep wool would be included in the definition, whereas oil-based plastics are not.

Where materials need to be combined with binders in order to be used, the situation is more complex. Hemp and cork come from plants and trees respectively, though in some uses they need to be combined with a binder (such as lime) which itself requires substantial processing. However, hemp and cork-based materials are generally considered to be natural, along with wood fibre, straw, cellulose, and sheep wool – though sheep wool contains up to 25% of polyester as a binder.

The scarcity of resources also needs to be considered. Anything which can be grown can be considered both natural and renewable, while common foam-based insulants such as phenolic, polyurethane (PIR/PUR) and polystyrene all come from a diminishing non-renewable resource – i.e. oil. By contrast, mineral wool is produced from a plentiful resource (rock, mostly), but one which requires substantial processing (e.g. water, energy) in order to be converted to insulation material, so mineral wool is not included here within the scope of natural materials. Recycled materials vary, and some will be relevant to this briefing, as are some waste materials.

1.3 The aims of retrofit

The aim of retrofit should be to deliver a building stock which is fit for the future. This broad aim (i.e. not just the common target of reduction of carbon emissions in use) needs to be achieved with minimal environmental impact. Natural materials have a significant role to play in this transformation – by protecting health and social well-being, quality of life and sustaining the economy – and for buildings of traditional construction[1] (c.25% in the UK) they have particular applications.

1 Predominantly solid stone or brick laid in lime mortar, also includes timber frame, cob, and other types; generally built pre-1919.

2 Energy and carbon characteristics of natural materials

2.1 Embodied energy and carbon

The embodied energy of retrofit arises from the materials used, and their installation, plus the disposal of any waste. The embodied energy of some retrofit measures may exceed the energy saved by those measures, sometimes exceeding the lifetime of the measure[2]. If the aim of retrofit is (artificially) limited to reducing energy use arising from the occupation and use of our building stock, then it may lead to serious unintended consequences[3].

For example, with an overly narrow focus or the use of certain materials there is a risk that retrofit could actually increase carbon emissions over the medium term, thereby achieving the opposite of one of the main policy drivers. (In addition, there are risks to human health, heritage and the economy etc.) How retrofit is undertaken is therefore just as important in the medium term as achieving arbitrary metrics or standards – which may or may not be optimal for any particular building.

Natural materials tend to have low embodied energy, due to the minimal amount of energy needed to transform them into insulation that can be used in retrofitting buildings.

Table 1: Comparison of non-Natural and Natural Insulation Materials[4]

Insulation Material	Thickness required to deliver U = 0.15W/m^2K (mm)	Embodied emissions A1-A3 (kg CO_2e/m^2)	Embodied Emissions A1-A3 + Sequestered (kg CO_2e/m^2)
Expanded polystyrene	220	20.7	20.7
Phenolic foam	140	10.8	10.8
Mineral wool	227	15.8	15.8
Wood wool boards	253	14.4	-42.6
Sheep wool slab	233	9.1	-8.9
Cellulose (blown)	260	0.9	0.9
Straw-bale (similar results likely for loosefill)	347	4.5	-40.2

This table demonstrates that natural materials generally have lower embodied carbon than processed materials derived from oil. The embodied emissions column takes into account the extra thickness required to deliver the same u-value.

2 https://www.alltenvironmental.com/blog.php?n=231119%20carbon%20payback , https://www.alltenvironmental.com/blog.php?n=220601%20embodied%20vs%20operational

3 *100 unintended consequences of policies to improve the energy efficiency of the UK housing stock*. Shrubsole etc al, UCL 2014

4 Data abridged from https://www.alltenvironmental.com/insulation/insulations.jpg. See website for full product details.

Image: Babatunde Ibrahim, Ecotecture Ltd

Where a waste resource is used to create the insulation material, it should be noted that the starting embodied energy is effectively zero, as the emissions have already been accounted for in the production activity which gives rise to the waste. For example, while it may not be deemed an entirely 'natural' material, insulation produced from recycled denim is making effective use of a waste resource – which might otherwise go to landfill – which has a carbon impact of its own.

Taking the whole-life impacts of materials into account may point to the use of relatively modest amounts of insulation in some cases, which is increasingly recommended for some traditional building elements in any case to reduce technical risks – and may even lead to retrofit designs which would not meet the limiting u-values set out in the Guidance Documents. Perhaps more importantly, the use of materials with low embodied energy keeps down the carbon emissions now (as opposed to uncertain savings in future), which would be prudent if the need to reduce carbon emissions is urgent.

2.2 Sequestered Carbon

Often natural insulation may be considered to sequester carbon for the life of the material. This is to say, CO_2 removed from the atmosphere as the plant grows is effectively locked up in the fabric of a retrofitted building. In addition to being low in embodied energy, natural materials are thus also high in recently sequestered carbon when compared to petrochemical products, whose carbon was sequestered thousands of years ago.

Once the sequestered carbon of natural insulation materials is taken into account, the comparison with non-natural materials becomes more marked.

(For a fuller explanation of the benefits of natural insulation materials, see the work of the Natural Fibre Insulation Group[5] – part of the Alliance for Sustainable Building Products. For a comparison of the varying properties of different insulation materials see Greenspec[6].)

5 https://asbp.org.uk/group/natural-fibre-insulation
6 https://www.greenspec.co.uk/building-design/insulation-materials-thermal-properties/

3 Moisture handling characteristics of natural materials

3.1 Moisture transfer capacity

Perhaps the most significant advantage to using natural insulation materials in retrofit is their moisture-open characteristics (the term moisture-open incorporates three main considerations: vapour permeability, capillarity, and hygroscopicity). These characteristics can facilitate moisture transfer through the insulation material and building fabric, which is in contrast to 'moisture-closed' insulation products such as PUR, PIR and EPS (Expanded Polystyrene) which are generally highly resistant to moisture movement. The application of moisture-closed products to building fabric will inhibit drying from occurring on the side of the fabric where the insulation is applied. By contrast, if moisture-open insulation is used, the drying process should therefore not be adversely affected and can even be aided depending on the characteristics of the material in question[7].

Traditional building fabric is often moisture-open, meaning that moisture can both enter and dissipate from the fabric in various forms (i.e. as a liquid and a gas). Moisture loads may be both external (e.g. rainwater) and internal (e.g. occupant-generated vapour), and are exacerbated by leaks and other building defects which are almost inevitable at some point. As such, it is critical that buildings are able to dry to avoid fabric damage and other issues. In addition to damaging building fabric, moisture affects the thermal performance of insulation materials by increasing the thermal conductivity. In other words, a dry wall is more thermally efficient than a wet wall.

The application of insulation changes the hygrothermal characteristics of the building fabric to which it is applied. This is particularly important in buildings of traditional construction – the majority of which are constructed from stone or brick laid in lime mortar[8]. Lime mortar, lime render, and many bricks and stone types are permeable to water, so walls which become wet (e.g. due to driven rain) are able to later dry out through evaporation (from both sides of the wall) if they are not compromised, which is a natural process.

Natural insulation materials, which are moisture-open (albeit to varying degrees), are thus particularly applicable to traditional buildings (25% of the UK stock). Those which are capillary active[9] can even help with drying of a wet wall, wicking moisture away from the building fabric to the surface where it can dissipate as vapour.

7 Considerations can be different for special situations, e.g. flood zones, where waterproof insulation might be favoured
8 A minority are of other construction materials, such as timber-framed or earthen
9 *SPAB Building Performance Survey 2019*, Final Report May 2020

3.2 Moisture bearing capacity

The indoor environment is subject to rapid changes in humidity levels due to sudden variations in moisture generation as a result of occupation and use, for example cooking and bathing. Many natural insulation materials have the capacity to absorb moisture due to their hygroscopic characteristics. This means that they can help to even out natural fluctuations in the moisture level within a building, if correctly installed.

The binding and later release of moisture vapour minimises the harm that excessive internal moisture loads can cause, protecting not only the inhabitants[10] but also the building fabric. By contrast, where timber members are embedded in masonry walls, the addition of impermeable insulation assemblies can in some cases lead to moisture becoming trapped and continuing to accumulate, potentially leading to fabric decay and even structural failure in the worst cases.

Although moisture-open insulating materials are beneficial in most areas of an average building, there are some circumstances where a natural insulation material may not be appropriate – such as below ground level or in a highly humid environment – and where a moisture-closed material may be the only realistic choice. In other circumstances, especially in situations where there is any heightened fire risk, a moisture-open non-natural product such as mineral wool might be the optimal choice, even though it has little moisture-bearing capacity[11]. A fire risk assessment is an essential part of the process when the addition of insulation to improve energy efficiency in buildings is being considered, to avoid any potential for compromising the safety of occupants and users. A fire-engineered solution will sometimes be applicable.

The use of natural insulation materials may also be inadvisable in a situation where a wall (for example) is permanently wet – either from leaks or raised external ground levels – due to the risk of mould and fabric decay. Building defects should always be repaired before or during retrofit works, to ensure the building is dry, sound and 'retrofit ready'; this should include allowing wet fabric to dry out prior to insulation being added. Once the building fabric and services have been restored to their designed state, natural materials can help with the drying out process and provide some capacity in future to deal with occasional high moisture levels[12].

Many natural insulation materials have the capacity to absorb moisture due to their hygroscopic characteristics

Images: Peter Draper, STBA

10 *Every breath we take* – Royal College of Physicians 2016
11 For example in a high-rise building
12 *SPAB Building Performance Survey 2019*, Final Report May 2020

4 Regulatory context and standards

It is worth noting that, for some building elements, a little insulation can go a long way. U-values are only one metric for assessing thermal performance, and a modest amount of internal wall insulation (for example) can greatly improve the radiant heat performance of a wall as well as reducing heat loss. This can help occupants feel warmer, even if the u-value is not drastically improved. Technical risks can also be reduced and value-for-money increased by adding a moderate rather than very thick layer of internal wall insulation, as reflected in increasing guidance and research. In terms of value for money, the initial layer of insulation has the greatest impact, with ever-thicker layers (and associated costs) required to achieve significantly improved thermal performance.

It thus becomes important to look at actual energy savings achieved. For walls of traditional construction where EWI (External Wall Insulation) is not possible, a relatively modest amount of a moisture-open natural insulation product internally (such as a woodfibre board) can often deliver substantial savings with minimal loss of internal floor area. This is not currently reflected in Building Regulations in England; even though there are special considerations for traditional buildings, other buildings have to meet limiting u-values set out in Part L. In addition, even good u-values can be significantly undermined by poor design and installation, e.g. by thermal bridging and/or poor airtightness. As observed in multiple research papers, a moderate depth of internal wall insulation accompanied by a thorough, coherent approach is more likely to realise meaningful benefits and reduce risks than a thick layer of insulation poorly applied: do a bit, but do it properly. This is covered in more detail below.

In terms of value for money, the initial layer of insulation has the greatest impact

Image: Jenny Knowles

4.1 Trustmark and the 25-year guarantee

Trustmark is the Government Endorsed Quality Scheme for work carried out in or around homes. The publicly-available specification for **domestic** retrofit PAS2035 , introduced in 2019, requires all retrofits to be lodged with Trustmark. To meet with Trustmark approval for solid wall insulation (and several other insulation measures), a 25-year guarantee must be provided.

The origin of the requirement for this guarantee is understood to be the ECO (Energy Company Obligation) scheme regulations, which were taken over by Trustmark. In practice, a solid wall insulation guarantee offers little protection against retrofit failure, and is rarely invoked, though it does add significantly to costs. However, by virtue of it being a Trustmark lodgement requirement, **the need for the guarantee has effectively been extended into all other publicly-funded retrofit schemes** – as these are obliged to use PAS 2035 – plus any other scheme which chooses to use the new Specification. The guarantee requirement thus continues to have an impact on the selection of materials for the retrofit of buildings under LADS, HUG and SHDF Waves 1, 2 and 3.

The insulation materials which presently carry this 25-year guarantee fall into two main categories:

- moisture-closed insulation such as polystyrene or polyisocyanurate
- mineral wool.

Natural materials often have shorter duration guarantees available (e.g. 10 years), but at present none carry a 25-year guarantee.

This means that the national quality scheme currently encourages the use of insulation materials which in some circumstances could increase the risk of moisture problems, while effectively prohibiting the use of materials which could actively help to manage moisture loads and protect the health of the building and its occupants – i.e. natural materials.

Insurers may well view the provision of a 25-year guarantee as a way to control risks. However, insurers are unlikely to be technical experts in traditional building retrofit. The current regime actually increases risk in retrofit, so it will be necessary to work with insurers and guarantee providers to share understanding of the beneficial properties of natural insulation materials, and of the risks (in some instances) of using more widespread moisture-closed materials.

A 25-year guarantee is difficult and expensive to obtain and may be beyond the reach of manufacturers of natural insulation materials – who at present tend to be relatively smaller companies. However, mass retrofit is gathering pace, so there is now a significant risk that we will apply potentially inappropriate insulation to a substantial number of domestic buildings. No such regulatory-driven risk is currently identified for non-domestic buildings, as these are not currently the focus of public subsidy/investment programmes and there is less need for consumer protection.

4.2 Government guidance on Internal Wall Insulation (IWI)

As set out in Section 3, IWI is one of the most complex and potentially risky retrofit measures, especially on buildings of traditional construction. Some of the key risk factors include:

- colder wall fabric
- challenges addressing thermal bridging
- any joist ends or other timber elements embedded in external walls
- condition of the external wall face
- the need to maintain a moisture-open structure
- the need to ensure robust internal ventilation.

In September 2021, BEIS (whose responsibilities in this area now lie with DESNZ) published *Retrofit Internal Wall Insulation – Guide to Best Practice*[13]. The justification for the guidance was set out as follows:

> " ...when internal insulation is applied, the hygrothermal characteristics of the building may change and moisture management is therefore a major consideration for the installation of internal wall insulation and systems, for which further guidance and work towards a systemised approach is necessary."

Changes in hygrothermal characteristics in traditional buildings may reduce the ability of the wall structure to dry out effectively. The Guidance goes on to say:

> "The lowest risk designs for internal wall insulation are consistent with the existing moisture strategy of the building. **For solid walled (traditional) buildings, this is likely to be moisture open, so capillary active insulations (such as woodfibre) and vapour open adhesives and finishes shall be chosen**. This does not involve the use of vapour barriers, but will include an air barrier. This allows drying to both sides of the internal wall insulation and therefore maintaining the moisture balance within the wall. *A Bristolian's Guide to Solid Wall Insulation*[14] contains more information about this approach and illustrates a series of vapour open designs for internal wall insulation."

(N.B. *A Bristolian's guide to solid wall insulation* was written by the STBA for Bristol City Council, and is signposted not only in the above BEIS IWI guide but also in the British Standards Institute's *BS 5250:2021 Management of moisture in buildings* publication, as a resource for detailed guidance in this area.)

Image: Peter Draper, STBA

The clear implication is that moisture-open and capillary-active insulation is the safest and most appropriate type of IWI for traditional buildings (c.25% of the UK stock). This indicates that natural insulation materials – most of which are both moisture open and capillary open – are the optimal products to use for IWI in such buildings.

13 *Retrofit Internal Wall Insulation – Guide to Best Practice*, Department of Business, Energy & Industrial Strategy, 2021
14 *A Bristolian's Guide to Solid Wall Insulation*, Bristol City Council, 2015

As noted previously, the thickness of IWI is important. Too much IWI will have two potential negative unintended technical consequences:

- The ability of the external masonry to dry out will be reduced as less heat is flowing into and through the wall.
- The presence of unavoidable thermal bridges leads to relatively cold spots which may cause condensation where previous this did not occur.

The government guidance also addresses the question of IWI thickness:

> "The thickness of internal wall insulation is an important factor in vapour permeability. The greater the thickness of insulation, the lower the vapour permeability of the final build-up. Vapour permeable and capillary active thin internal wall insulation (TIWI) will help to reduce moisture risks. TIWI is also a benefit when considering insulated plaster as the installation process is simpler and drying times are reduced."

Recent Government-funded research also shows similar findings: "Measures that could reduce the risk of unintended consequences…include…removing minimum target u-values for IWI retrofits in [Part L]"[15].

This guidance and research implicitly points towards the use of natural materials, principally due to their vapour permeability.

4.3 Building Regulations in England[16]

The need to balance energy efficiency and heritage, and the special characteristics of moisture-open traditional construction have been recognised in UK Building Regulations since the introduction of Part L in 2002. Clear principles, and the basis for finding balances are set out in Part L Volume 1 (Dwellings) and Volume 2 (Buildings other than Dwellings) for England.

Building Regulations in England include special considerations for buildings of traditional construction (25% in the UK). While there is no 'exemption' from energy performance standards ("work to a [historic] building must comply with the energy efficiency requirements where this would not inacceptably alter the building's character or appearance … The work should comply with standards…to the extent that is reasonably practicable"), it is recognised that a careful, appropriate approach is required:

> "The energy efficiency of historic and traditional dwellings should only be improved if doing so will not cause long term deterioration of the building's fabric or fittings. In particular this applies to historic and traditional buildings with a vapour permeable construction that both absorbs moisture and readily allows moisture to evaporate. This special consideration means that traditional buildings should be improved where possible, but not necessarily to meet highly demanding u-values if this would involve damage to the fabric or character of the building. There are some instances where the risk of damage to building fabric from retrofit can be reduced by the use of moisture-open insulation materials, especially for internal wall insulation."

15 Thin internal wall insulation (Leeds Sustainability Institute, 2021)
16 Similar provisions apply in Scotland and Paras 0,10-0.15 of Part L for Wales.

Building Regulations in England do not prescribe what materials should be used in what situations, which sometimes results in insulation materials being installed which are acceptable under the Regulations but which experts might consider inappropriate in some instances.

There has been a suggestion from various sectors of the industry that an added 'Part Z' of the Building Regulations could be introduced to address embodied energy. Embodied energy of materials and labour is a complex topic and notoriously difficult to calculate. (Also note that building products have many types of impacts – for example water use and pollution – i.e. not just embodied energy). Nonetheless, it is likely that if regulations on embodied energy were to be introduced, this would in many instances encourage the use of natural materials.

Image: Babatunde Ibrahim, Ecotecture Ltd

Building Regulations in England include special considerations for buildings of traditional construction

5 Key conclusions and recommendations

Conclusions

a Natural materials are generally low in embodied energy/carbon, and low in other forms of pollution. Their production sequesters carbon and in many cases can be used to stimulate the local economy, and encourage the circular economy.

b Natural materials have properties which can help manage effective moisture movement in buildings and can therefore help protect both fabric and occupants, especially when used in the retrofit of traditional buildings.

c At present it is difficult or impossible to use natural materials in mass retrofit, due to guarantee requirements at Trustmark.

Recommendations

a Eliminate the requirement for a 25-year guarantee on solid wall insulation from current Trustmark lodgment rules. Consider introducing a requirement for a 10-year guarantee, or use public funds to expedite longer-term guarantees for natural materials.

b Work with the insurance industry to help them understand the ways in which natural materials can help de-risk retrofit.

c Ensure that the Government's own guidance on internal wall insulation across all typologies is well understood by all relevant policy officers.

d Establish a broad range of metrics for retrofit materials, to encompass: resource scarcity, sequestered carbon, embodied energy, water use and embodied pollution. EPD's (Environmental Performance Declarations) or Materials Passports could be considered as a starting point.

e Establish a broad range of metrics for retrofit, including benefits to health, welfare, net energy savings, water efficiency and sustainable drainage, and include wider community benefits such as employment, green spaces, and social cohesion.