Department for
Business, Energy
& Industrial Strategy

Retrofit Internal Wall Insulation

Guide to Best Practice

Technical authors from Enhabit:

Dr Sarah Price (lead), Elena Andreou, Tim Wilcockson, Konstantinos Megagiannis, Nuria Lopez

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Contents

Glossary

Air barrier – A building material with properties that aim to prevent the passage of air through it. An air barrier may also be a VCL or a vapour barrier, but it may be specified to have a very low resistance to the passage of vapour.

Capillary active – Used to describe the mechanism by which a material can exhibit hygrothermal buffering. It is often used in place of the term hygrothermal buffering.

CWI – Cavity wall insulation. Insulation that is installed in a cavity within an external wall. Usually between two masonry structures that are tied together.

EWI – External wall insulation. Insulation that is installed on the cold side of a wall

Hygrothermal – Refers to the movement of moisture and heat through buildings and building materials.

Hygrothermal buffering – A material, such as wood fibre or wood that has the ability to absorb moisture from the air when relative humidity is high, and release moisture back into the air when relative humidity is low

Interstitial Condensation – Is a type of condensation that may occur within an enclosed wall, roof or floor cavity structure, which can create moisture issues.

IWI – Internal wall insulation. Insulation that is installed on the warm side of a wall.

Moisture balanced – A term used to describe a moisture open building construction that does not get wet for prolonged periods and does not have any moisture related issues such as mould or fungus growth, spalling or otherwise.

Moisture closed – A building construction that prevents moisture (vapour & liquid) from moving in an out of it.

Moisture open – A building construction that allows moisture (vapour & liquid) to freely move in an out of it.

PIV – Positive Input Ventilation. A type of continuous ventilation system that pulls fresh air into a property in a central location.

Spalling – Where the cold facing side of brick, stone or concrete walls has flaked, cracked or ‘blown’ off usually as a result of freezing water within the construction.

Thermal bridge – Area of the building envelope where the insulation is:

a) discontinuous or thinner than the adjacent insulation;

b) has higher thermal conductivity than the adjacent insulation; or

c) has reduced effectiveness due to the building geometry;

leading to locally increased heat loss and therefore locally reduced internal surface temperature

Thermal bypass – Unintended penetration or circulation of external air on the warm side of the insulation layer in a construction, rendering the insulation ineffective.

Vapour barrier – A building material (usually a membrane) with properties that aim to prevent the passage of moisture through it.

Vapour impermeable – Prevents the passage of water vapour by diffusion

Vapour permeable – Allows the passage of water vapour by diffusion

VCL – Vapour Control Layer. A building material (usually a membrane) with properties that control the passage of vapour through it.

1. Introduction

The built environment is one of the biggest emitters of carbon dioxide, with space heating being a large proportion of this. To meet UK´s 2050 carbon emissions targets, it is necessary to tackle carbon emissions of the existing building stock. Retrofit not only reduces operational emissions, but also avoids the embodied carbon of demolition[1]. By installing insulation, the thermal performance and comfort levels are improved, with the corresponding reduction on carbon dioxide emissions and bills cost for the householder.

Both, improving the building energy efficiency with insulation measures and using efficient systems and renewable energy are necessary. However, a fabric first approach is a priority as it reduces the size of heating system which comprises up to 60% of the total energy demand of a dwelling, as well as reducing the size of renewable energy system(s) to offset the remaining carbon emissions. Walls are often the biggest exposed area in a building. Hence, the improvement of their insulation level can have a significant impact in the retrofit of a building. Whilst external wall insulation is preferable for protection of the building fabric and reduced moisture risks, internal wall insulation (IWI) is another option available to improve wall insulation levels in existing buildings. IWI offers flexibility and reduced constraints around installation, but it can present technical risks that should be managed, and if recommendations are not considered, a high risk of interstitial condensation and mould growth might be present.

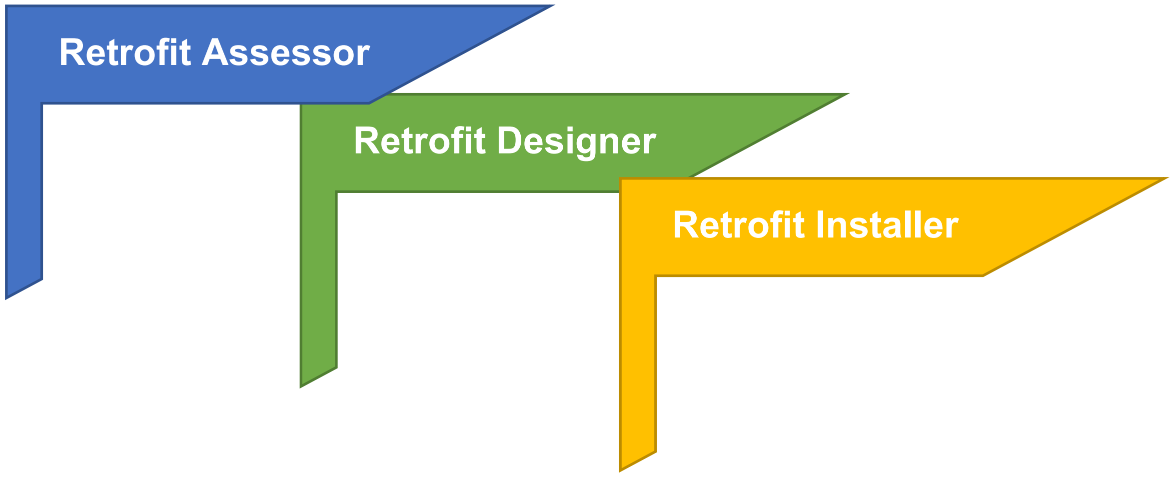
Internal wall insulation can be installed on most construction types provided the risks have been well understood and mitigated. Many houses built in the UK before 1930s are solid wall rather than cavity wall. The insulation of these buildings could apply external or internal wall insulation, but other factors like statutory planning protection (i.e. listings, conservation areas, etc.) or technical limitations (such as geometry or excessive external services) may point to IWI as the preferable or even the only option. However, 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.

The aim of this guide is to provide clear reference for designers, surveyors, project managers and installers considering the suitability of external walls to receive internal wall insulation. This guide may be used to assess viability of internal wall insulation or systems (IWI), the design of internal wall insulation, selection of materials including hygrothermal aspects and installation best practice.

The whole guide is recommended reading for any parties undertaking internal wall insulation, however some sections have been written specifically for the retrofit assessor or surveyor, the retrofit designer or the retrofit installer, and these are labelled and colour

[1] The carbon emission associated with demolition and new build are far greater than those associated with repair, maintenance and retrofit. Demolition also requires properties to be vacated whereas retrofit does not. Therefore retrofit should always be the first choice.

coded at the beginning of the chapters. Chapters that are applicable to all audiences have no colour coding.



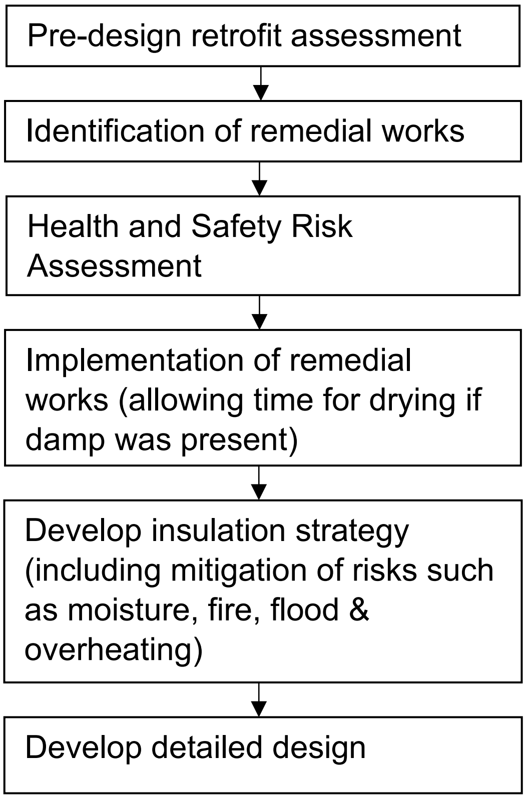
The guide does not cover the installation of cavity wall insulation (CWI) or external wall insulation (EWI) but will mention these methods for reference purposes when necessary. All possible steps should be taken to assess whether a wall is solid or cavity or has insulation already installed, including, where appropriate, intrusive works to understand the structure. Where it is not possible to assess it, all available evidence should be retained to demonstrate why this was not possible. Similarly, the wall should be assessed to ensure that it is in a suitable condition to receive IWI installation.

Any drawings or images in this guide are for general use and not prescriptive guidance.

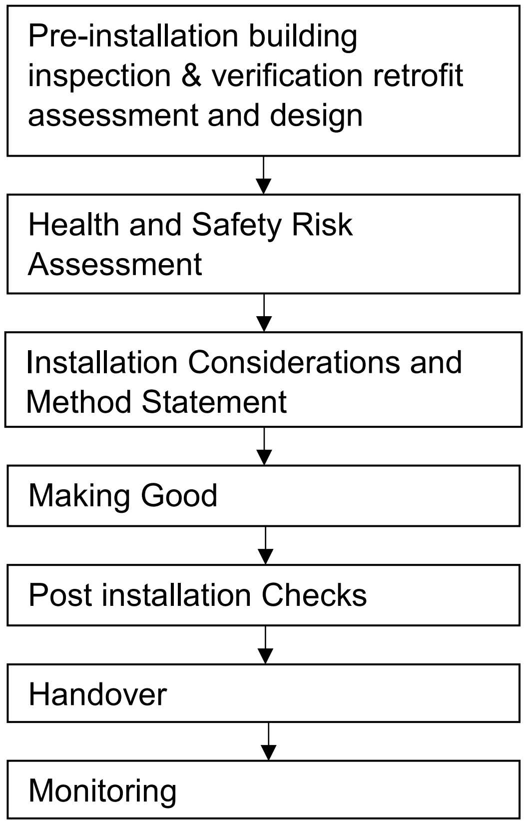
It is recommended, and mandatory for Government schemes, that assessment and design in accordance with the latest version of PAS2035 is undertaken before any IWI measure is installed. The assessment must be specific to that property and the type of insulation being considered for its suitability; or as a minimum (i.e. before the adoption of PAS2035), an assessment in line with the requirements of the relevant version of PAS2030.

The basic approach to assessment and installation can be summarised as follows:

IWI Assessment & Design process



IWI installation process



With special thanks to the AECB, Prewitt Bizley Architects, Green Building Store, Ofgem, Sarah Wigglesworth Architects, GDGC, SWIGA, the IAA, UKCMB, Trustmark, Carbon Co-op, Retrofitworks, Saint Gobain, Natural Building Technologies, BBA, STBA, MIMA, THS Inspection Services Ltd, Bierce Surveying and relevant system designers and installers for their input and support during the production of this guide.

2. Benefits

1. Thermal comfort can be significantly improved with IWI measures. IWI can help increase and maintain the internal temperature as well as providing a higher surface temperature, both of which contribute to an improved comfort.
2. Appropriately insulated walls can be beneficial for carbon reduction and the alleviation of fuel poverty.
3. The wall area is often the biggest exposed area of the thermal envelope, and in these cases, alongside glazing, they are often where most of the heat losses take place. Hence, its insulation can have the greater impact in terms of comfort, reduced emissions, and savings.
4. IWI can retain the building's external aesthetics and appearance when necessary, for example if the historical external facade needs to be retained or it is a conservation area. It may also be applied sensitively on listed buildings where internal features need to be preserved, but this will depend upon the nature of the internal features.
5. It might be the only option if there are technical limitations and it is not possible to insulate externally (space restrictions, neighbours' buildings, complex geometry such as bay window or moulding and projections, etc.)
6. With careful maintenance of the external walls, the insulation installed is preserved from external impacts (temperature changes and humidity, wind, capillarity, and diffusion moisture problems, etc.), so it does not need additional protection.
7. More flexible installation with regards to:
    - Climate conditions: IWI may be installed any time of the year regardless of the season or weather conditions. Although this is dependent on the external surface of the external wall being in good condition, and wet systems will dry more quickly in the summer months.
    - Additional ancillary costs: scaffolding is not necessary for its implementation reducing installation cost.
8. Internal insulation is certainly more disruptive for the occupants than external insulation, but it can be carefully planned within a medium term improvement plan to work around the client's budget and timescales.
9. The level of airtightness of a building should improve when installing IWI as it can improve the condition of an existing construction element and seal several uncontrolled air leakage pathways at junctions and edges.
10. Appropriately insulated walls should manage the moisture and condensation risk, allowing the wall to dry if it becomes wet and avoiding mould or fungus growth. Sufficient, controlled ventilation is key to managing internal humidity levels to allow drying and avoid interstitial or surface condensation.

3. Building Regulations

11. It is the responsibility of the assessor, designer and installer to consider whether the works being undertaken would be considered “Building Works” as defined by the Building Regulations.
12. For clarity, an internal partition wall separating one room or space from another (including party walls) and not forming part of an external wall is not considered a heat loss perimeter. Any such type of construction is excluded from this guidance.
13. The Fire Safety Bill published in March 2020 places beyond doubt that external wall systems (including IWI) fall within the scope of the Regulatory Reform (Fire Safety) Order 2005. Designers and installers need to follow current Regulations in England and the devolved nations[2] for high-rise buildings (NOTE the definition of a high-rise building varies between the devolved nations).
14. In England and Wales, the Building Regulations apply to most buildings and alterations to existing buildings. They contain a range of requirements in respect of how a building is designed or constructed. Analogous regulations apply in the devolved administrations.
15. In Scotland, reference should be made to Schedule 3 Descriptions of Building of the Scottish Building Standards, and work including the provision of services, fittings and equipment, not requiring a warrant. Unless the work is more extensive and may require an application for a Building Warrant to be made to the Local Authority.
16. In Northern Ireland reference should be made to the Building Regulations and specifically Part F (Conservation of Fuel and Power).
17. The Building Regulations in England 2010 provide that “building work” shall be carried out so that it complies with the requirements contained in Schedule 1. The definition of “building work” includes, but is not limited to:
    - the erection or extension of a building (which would cover new builds);
    - the material alteration of a building, which is either;
        - where the work would result in the building no longer complying with a previous requirement when it once did; or

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[2] Northern Ireland: Part B – Fire Safety: SI 115 of 2006 - (Part B) - Building Regulations (Amendment) Regulations 2006, Part B - Fire Safety 2017 Volume 2 Dwelling Houses: S.I. 57 of 2017 Building Regulations (Part B Amendment) Regulations 2017, Technical Guidance Document B - Fire Safety and Technical Guidance Document B - Fire Safety - Volume 2 Dwelling Houses.

Scotland: Building standards technical handbook 2020: domestic, section 2. Fire. and Building standards technical handbook 2020: non-domestic, section 2. Fire. (April 2021 Addendums)

England: Approved Document B (fire safety) volume 1: Dwellings, 2019 edition incorporating 2020 amendments and Approved Document B (fire safety) volume 2: Buildings other than dwellings, 2019 edition incorporating 2020 amendments

Wales: Approved document part B volume 1 (dwellinghouses), Approved document part B volume 2 (buildings other than dwellinghouses) and Building regulations guidance: amendments to the approved documents A, B (Volume 2) and C. (2006 edition incorporating 2010, 2016 and 2020 amendments)

    - a building, which before the work did not comply with a relevant requirement, being more unsatisfactory in relation to such requirements.

- the insertion of insulation into the cavity wall of a building; and
- certain other specific work which relates to energy efficiency requirements, including the renovation of individual thermal elements or change in the energy status of the building.

18. Schedule 1 Part B of the Buildings Regulations 2010 contains requirements for fire safety, which includes requirement B3, relating to internal fire spread (structure). This provides that the building shall be designed and constructed so that, in the event of fire, its stability will be maintained for a reasonable period, as referenced in Schedule 1 Part B of the Building Regulations 2010. In other words, if the project is "building work" for the purposes of the Building Regulations, the fire resistance requirements apply. Specific fire requirements also apply where the wall is adjacent to an attached or integral garage.

19. If there is any doubt over the compliance and handover (as specified in the latest version of PAS2030) of the installation, or whether Building Regulations apply, an independent report from Building Control confirming that they are content with the approach taken should be obtained, and this must be undertaken on a property specific basis.

20. An assessment of the ventilation requirement for the property must be undertaken in accordance with the requirements set out in the latest version of PAS2035. Part F of the Building Regulations requires that the building works (when completed) should not demonstrate a worse level of compliance with other applicable requirements of Schedule 1 than before the work commenced. i.e. "make it no worse". This is often not adequate for situations where internal wall insulation is being installed and therefore the process in PAS 2035 Annex C should be followed.

4. Building suitability assessment & risks

21. A retrofit assessment should include correct identification of the construction of the property as this can have a significant impact upon the retrofit design. Guidance can be found in Annex A - Wall construction and identification of this guide. Further information on construction types can be obtained by undertaking Retrofit Assessor training, or the AECB Carbonlite Retrofit course.

22. When assessing the suitability of an external wall for the installation of IWI, a Retrofit Assessor should undertake a building assessment as outlined in PAS2035. Table 1 below describes areas of risk associated with IWI which should also be included in the retrofit assessment.

23. For all actions and risks associated with existing moisture, remedial action may be required to remove or reduce the source of moisture. Any damp sections of the existing construction should be allowed to dry thoroughly prior to installation of IWI. The building should then be re-assessed to ensure it is in a suitable condition for IWI.

24. Some risks identified in the table below are mitigated in the retrofit design and are for the consideration of the Retrofit Designer, these are in green text.

Table 1 Pre-installation suitability and risks

Action	Assessing	Methodology and mitigation	Risk
Has an assessment been undertaken of how the measure may affect the significance of the building after installation, particularly if	Impact of the measure that may have a detrimental effect on the significance of the building	Completing a Heritage Significance Assessment based upon BS7913 as described in PAS2035. (Note: PAS 2035 allows the use of a simplified checklist for some buildings) Identify whether the IWI will have an impact upon the heritage significance. Take heritage significance into consideration when developing the retrofit design. Property may not be suitable for IWI.	Non-compliance with PAS2035, and negative impact on the significance of the building.

Action	Assessing	Methodology and mitigation	Risk
the building is defined as "Traditional"?			
Is the external ground level higher than the internal floor finish level in rooms in which IWI is being installed?	If insulating external walls of ground floor rooms, examining relationship of the internal floor and wall insulation to the potential risk of water penetration.	Visual inspection and measurement of internal and external finish floor level. If IWI to extend below external ground level then follow guidance in BS 8102:2009 Code of practice for protection of below ground structures against water from the ground.	Water penetration to any timber joists built into the wall, or wall plates. Reduced risk of drying due to internal wall insulation. Water penetration into internal wall insulation near ground. Significant risk of mould and spores and damage to internal render finishes by soluble salts.
Is there a functioning damp proof course (DPC)?	Rising damp in walls and evidence of DPC in good condition.	Visual inspection of rising damp and installed DPC, or by measurement if property is rendered to the ground.  **Figure 1 Repointing has covered DPC and is providing a moisture pathway across the DPC. The pointing would need to be removed in this situation (courtesy of the AECB Carbonlite Retrofit Course).**	Rot or decay of joist ends. Water penetration into internal wall insulation.

Action	Assessing	Methodology and mitigation	Risk
		 **Figure 2 Examples of visible rising damp (courtesy of the AECB Carbonlite Retrofit Course)** Remove pointing that bridges DPC. Install new DPC where none exists or if there is evidence of rising damp. Take into consideration when preparing retrofit design.	
Are external wall finishes (render, pointing, cladding) in good condition? Is there	If external finishes need repairing or cleaning prior to installation of internal wall insulation to prevent rain penetration into walls.	Visual inspection of external finish on walls. Identify any cracked or damaged render. Check continuity and quality of pointing. Check condition of coping stones on parapets. Repoint masonry using appropriate pointing to match the original vapour permeability. Note that there may be case where traditional lime-based pointing may have been	Rot or decay of joist ends. Water penetration into internal wall insulation. Further damage to external walls by

Action	Assessing	Methodology and mitigation	Risk
evidence of moisture in walls?	Effects the design of the IWI moisture strategy. Check plant growth not embedded in masonry and brickwork is not saturated or suffering from salt deposits.	repaired using incompatible cement-based pointing. This should be removed and replaced with pointing to match the original. Repair cracked or damaged render. Repair or replace damaged coping stones.  **Figure 4 Deterioration of pointing in brick work (courtesy of Aalborg University)** Check for evidence of spalling or frost damage, indicating saturated masonry.  **Figure 3 Frost damage in brickwork (courtesy of Aalborg University)** Check for blistering of paintwork and presence of salts deposits (usually powdery white crystals or coating) on	preventing drying to inside due to IWI installation. Saturated brickwork will take significantly longer to dry out once IWI has been installed so there is a need to, get saturation level down before installation commences. Consider the use of breathable brick cream once moisture content has been lowered.

Action	Assessing	Methodology and mitigation	Risk
		masonry walls. The presence of salts can be an indication of moisture problems and is often driven by rising damp which indicates a poorly functioning DPC. The source of moisture for any salt contamination, blistering or spalling needs to be identified and remedied, allowing the wall to dry out prior to installation of IWI. **Figure 5 Left photo: paint blistering, right photo: salt deposits (courtesy of Aalborg University)** 	
Are external wall finishes suitable for the severity of wind-driven rain exposure?	If the external walls are at high risk from wind-driven rain	Check exposure of building to be insulated and type of finish. See Building Regulations part C 5.9 for more detail. Install appropriate external wall finish in accordance with the wind-driven rain exposure zone (part C 5.9 of the Building regulations) or undertake appropriate hygrothermal risk assessment (see BS5250 for further guidance).	Rot or decay of joist ends. Water penetration into internal wall insulation.
Is guttering, flashings and external pipework in good condition?	If remedial works are required to repair external guttering, flashings and pipe work to avoid water leaking into walls.	Visual inspection of guttering, flashing, pipes and external walls for signs of leaks. Damp patches may be visible in brickwork. Use hose or other water source to check for leaks in external drainage.	Rot or decay of joist ends. Water penetration into internal wall insulation.

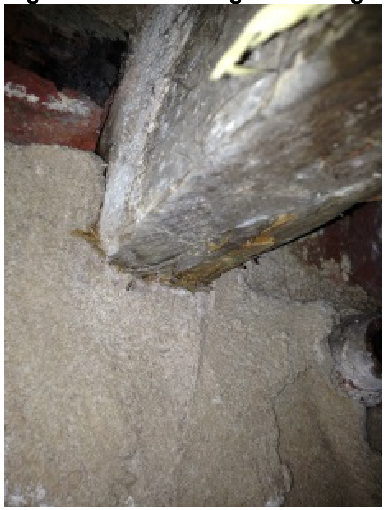
Action	Assessing	Methodology and mitigation	Risk
		Figure 6 Poor external drainage causing staining and blistering (courtesy of Aalborg University)  Repair all guttering, flashing, pipes or services so that water sources are taken away from the external wall without any wetting of the wall.	Saturated brickwork resulting in spalling.
Are the external walls covered by the definition in this guide?	Suitability to use this guide and methodology.	Verification that the wall does not have any existing external wall or cavity insulation.	Works should not be covered by this guidance.
Is there any evidence of damp, surface condensation, salts, fungus or mould growth	If remedial works need to be done to remove/reduce water source.	Visual inspection of all internal walls. Large areas of mould growth or condensation may indicate poor ventilation or underheating. Focused areas of fungus or mould growth may indicate thermal bridging or water ingress from elsewhere.	Water penetration into internal wall insulation. Poor indoor air quality.

Action	Assessing	Methodology and mitigation	Risk
on internal walls?		**Figure 7 Paint and plaster deterioration (courtesy of Aalborg University)**  **Figure 8 Damp in solid brick wall (from puddle in side passage, courtesy of the AECB Carbonlite Retrofit course)** 	

Action	Assessing	Methodology and mitigation	Risk
Are 100% of the external walls to be insulated?	Extent of external walls, presence of kitchens bathrooms and other permanent features on external walls.	Visual inspection of ability to access every external wall. Assessment of plans to remove kitchens, bathrooms and other permanent features. Follow guidance in Section 5. Design Principles, for less than 100% IWI.	Increased risk of surface condensation in uninsulated areas adjacent to internal wall insulation.
Is the existing internal finish of the external walls vapour closed?	Type of internal finish applied to external walls.	Visual inspection, which may involve removing layers of finishes applied to external walls. Remove or scarify all moisture closed layers (e.g. vinyl wall finished, wallpapers, gloss paint and gypsum plasters). Take care of asbestos risks.	Risk of moisture trapped between insulation and wall as existing finish prevents drying to outside.
Is the existing internal finish of the external walls flat and free from dust and loose materials?	If internal wall insulation can be fitted flush to the wall and that any adhesives will be able to fully bond to the existing wall.	Visual inspection of internal finish (once the moisture closed layers have been removed or scarified – see above). Remove loose materials, clean and repair such that the surface is flat and smooth for installation of the IWI.	Risk of insulation falling off the walls or air pockets forming on cold side of insulation which increases risk of interstitial condensation.
Are there any structural defects in the external walls?	If external walls need strengthening prior to installation of internal wall insulation.	Visual inspection. May require structural engineer and/or invasive investigations. Undertake remedial work upon structural engineers instructions.	Risk of further structural deterioration.
Are there any fixings or penetrations that currently	potential for thermal bridging and non continuous air barrier.	Identify and mark up all fixings and penetrations in existing walls. Ensure that a suitable design for the air barrier is available for all types of penetration.	Creation of a thermal bridge and air leakage, leading to heat loss and increased risk of

Action	Assessing	Methodology and mitigation	Risk
exist in external walls?		Ensure that fixings specified do not incur unacceptable thermal bridging (e.g. large metal brackets for radiators, or numerous metal fixings)	surface condensation and mould growth. Non-continuous air barrier leading to increased risk of thermal bypass (air leakage) and moisture penetration into the internal wall insulation.
Do any appliances use combustion?	if any wall ventilation is required for combustion devices	Visual inspection of combustion devices and any wall ventilation. Retrofit design should allow for adequate ventilation for combustion devices without compromising the performance of the internal wall insulation. Any materials that come into contact with a flue should be suitable to withstand heat.	Carbon monoxide risk or failure of the appliance to operate effectively. Heat damage to insulation and fire risk.
Are there any electrical installations on external walls?	Potential for electrical fittings to be covered up during installation.	Identify and mark up any light fittings or electrical connections that will need protecting or moving during the installation phase. Ensure that a suitable design has incorporated the safe operation of any such features such as light switches, sockets etc. When burying electric cables, the design and installation should always be checked by a suitably qualified electrician. The sizing of the cables may be critical. Follow IEE regulations regarding the derating of cables.	Overheating of fitting and fire risk.

Action	Assessing	Methodology and mitigation	Risk
Are the timber joists embedded in external walls free from infestation and rot?	Moisture content of the timbers and signs of decay an infestation.	Timber moisture content should not exceed 20% and IWI installation should not go ahead with moisture levels higher than 20 per cent in timber joists embedded in external walls. Timbers are generally understood to be free from the risk of decay below 20% moisture content. Measure joist ends as close to wall as possible, with a moisture metre with electromagnetic capability which allows greater accuracy and depth of assessment. The symptoms of severe decay in exposed timbers are usually obvious. However, some decayed timbers retain a surface veneer of sound wood, so thoroughly investigate all suspect timbers near to actual or potential source of dampness, and any showing evidence of fungal growth. Investigate by probing with a sharp implement like a bradawl: the presence of internal decay in large section timbers can often be detected by ‘sounding’ with a large hammer. Probe especially carefully where timbers such as purlins and joist ends, enter walls, because decay can be localised in the portions of timber embedded in the masonry.	Insulating walls around joist ends with already high levels of moisture, rot or decay can lead to adding additional stress to the timbers and accelerating their decay or covering up an existing problem (weather ingress, leaks etc.).

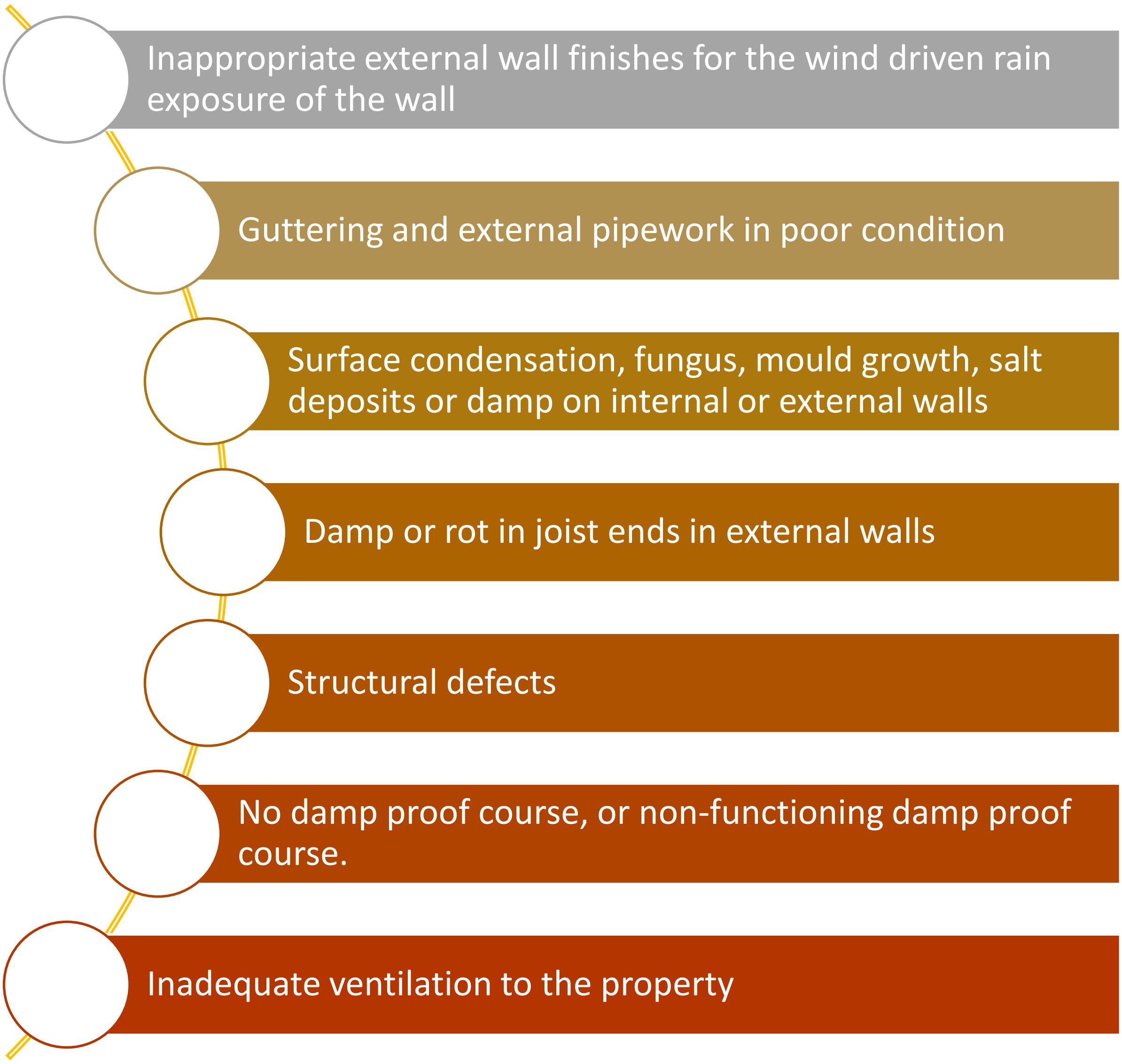
Action	Assessing	Methodology and mitigation	Risk
		Figure 9 Joist rotting at bearing   Figure 10 Deformation of wooden floor finish, indicating high moisture load, potentially to joist ends (courtesy of Aarlborg University)	

Action	Assessing	Methodology and mitigation	Risk
		Timber joists (or any timber) in external walls that have a moisture content greater than 20% should not have IWI installed around them. The source of moisture should be identified and removed, and the joists allowed to dry out prior to installation. Joists damaged by rot or otherwise, should be repaired.	
Is the current construction moisture open or moisture closed?	Potential for internal wall insulation to upset the moisture balance of the existing building.	Visual inspection of existing wall build up. May require invasive inspections e.g. in cavity walls. Identification of types of materials used in existing walls. Ensure that design of internal wall insulation does not upset the moisture balance of the existing walls.	Risk of increasing moisture levels in existing construction.
Has the building ever been flooded?	Potential for moisture related issues and high moisture content in existing fabric.	Inspection of River or coastal flood Maps available from the Environment Agency. Interview with occupant on history of building. Evidence of flooding related moisture in construction. High salt levels on wall bases and floors. If there is evidence of flooding then the IWI retrofit design must be capable of withstanding flooding without detriment to the wall-build-up.	Risk of high moisture levels in existing construction that may be trapped when IWI is installed.
Is there sufficient ventilation in the property?	Potential for high relative humidity levels after IWI is installed.	Assess ventilation system in accordance with PAS 2035 Annex C. If ventilation system is not appropriate then include in retrofit design.	Increased risk of interstitial condensation.
Is the property of loose aggregate (e.g. no fines) construction?	Potential for moisture related issues and high moisture content in existing fabric.	Inspection of construction of external walls. Inspection of external finish to external walls. Loose aggregate walls with no external weatherproofing should not have IWI installed.	Risk of high moisture levels in existing construction that may be trapped when IWI is installed.

Action	Assessing	Methodology and mitigation	Risk
		The retrofit design for IWI should include external weatherproofing if there is none, or it is not sufficient to protect the walls for wind driven rain.	
Is the property of non-traditional (non masonry) construction?	Potential for moisture related issues from not understanding the construction.	Inspection and research of construction type. Surveys should be carried out by a suitably qualified surveyor. There are a multitude of non-traditional (non-masonry) build types, and their construction needs to be understood such that an appropriate retrofit design can be generated. Many non-traditional constructions will not be suitable for IWI installation due to the properties of the existing structure (see 'no-fines' construction in the previous risk). Hygrothermal assessments will almost certainly be required during the design stage.	Risk of high moisture levels in existing construction, and/or risk of interstitial condensation.

25. The major risks from Table 1 have been summarised in Figure 11, and this should be reviewed, as well as the above table, throughout the IWI project. Risks may be uncovered during the initial assessment, design and/or installation processes.

Figure 11 Summary of major IWI risks



5. Materials

26. To improve the thermal performance of a wall by adding extra insulation, it will need to comply with the current relevant national building regulations. Currently, In England, Wales, Northern Ireland and Scotland the walls should achieve an 'improved' thermal transmittance (U-value) of 0.3 W/m2K, or where this is not technically or functionally feasible, then the walls should be upgraded to the best U-value possible, but not higher than the 'threshold' U-value of 0.7 W/m2K. In all circumstances, the U-value must be calculated in accordance with the conventions in the current version of BR443 conventions for calculating U-values.

27. To achieve an optimum U-value there are a range of materials available on the market that are appropriately certified for use as internal wall insulation. It is important that manufacturer's technical information is checked to see if the materials are appropriate for the situation where they are to be installed, and for details of Technical Approvals such as an Agrément Certificate for specific applications or refer to manufacturer's specification sheets to ensure the material is suitable for using as internal wall insulation.

Material Conformity

28. When assessing any material for use as internal wall insulation, there are a number of factors that should be considered, these are set out in Table 2 below.

Table 2 Material Conformity

Assessment	Requirement	Evidence
Are the materials suitable as IWI?	Consider if the material is suitable for use as internal wall insulation for existing buildings of the type being considered for the installation.	Case studies with monitoring of the same situations in which the IWI is being installed. Technical Approval such as Certificate of Agrément from the BBA or Kiwa, or Declaration of Performance covering usage and limitations. CE Marking or manufacturers' data sheet. European Technical Approvals. Appropriate hygrothermal assessment (see BS 5250 for more guidance)

Assessment	Requirement	Evidence
		of the specific situation in which it is being installed.
Do the materials have the appropriate fire rating?	Consider if the materials have the correct fire classification for the location and overall building height.	Reference to the Declaration of Performance and assessment of the characteristics and location of the insulation to be used.

6. Design Principles

29. Architectural junction details, showing airtightness layers, vapour control layers (VCLs (if needed)), insulation materials and structures should be provided for all relevant junctions, edges and corners associated with the IWI. These should be readily available on site at the locations of the junctions, edges and corners.

30. An airtightness and moisture strategy summary should be recorded and be available onsite for quick reference.

Thermal bridging

31. Internal wall insulation may be installed as a single energy efficiency measure or as part of a package of measures. Even as a single energy efficiency measure, thermal bridging is still important and designs shall show how insulation can be continuous around junctions, edges and corners. If this is not possible then thermal bridges should be mitigated. An example of thermal bridge mitigation might be to return insulation along thermal bridge junctions by a minimum of 400mm, although care should be taken to consider the moisture risk of the wall along which insulation is returned. All thermal bridges should be considered and assessed when installing internal wall insulation, the following are examples of thermal bridge junctions that might occur in internal wall insulation projects:

- Around window and door reveals; Using a thin insulation (<15mm) returned into the reveals is a good way to reduce thermal bridging. Figure 12 shows how window or door reveals may be insulated to reduce thermal bridging.
- Where internal wall insulation is interrupted by internal walls, party walls[3], intermediate floors, stairs or other permanent structures where they meet external walls;
- Where internal wall insulation meets ground floors;
- Where internal wall insulation meets ceilings/roofs;

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[3] Care needs to be taken at party walls when returning insulation along the party wall to mitigate against thermal bridging. Installing insulation and party walls can make the party wall colder and therefore increase the risk of condensation and mould growth in the neighbouring property if it is not suitably heated or ventilated.

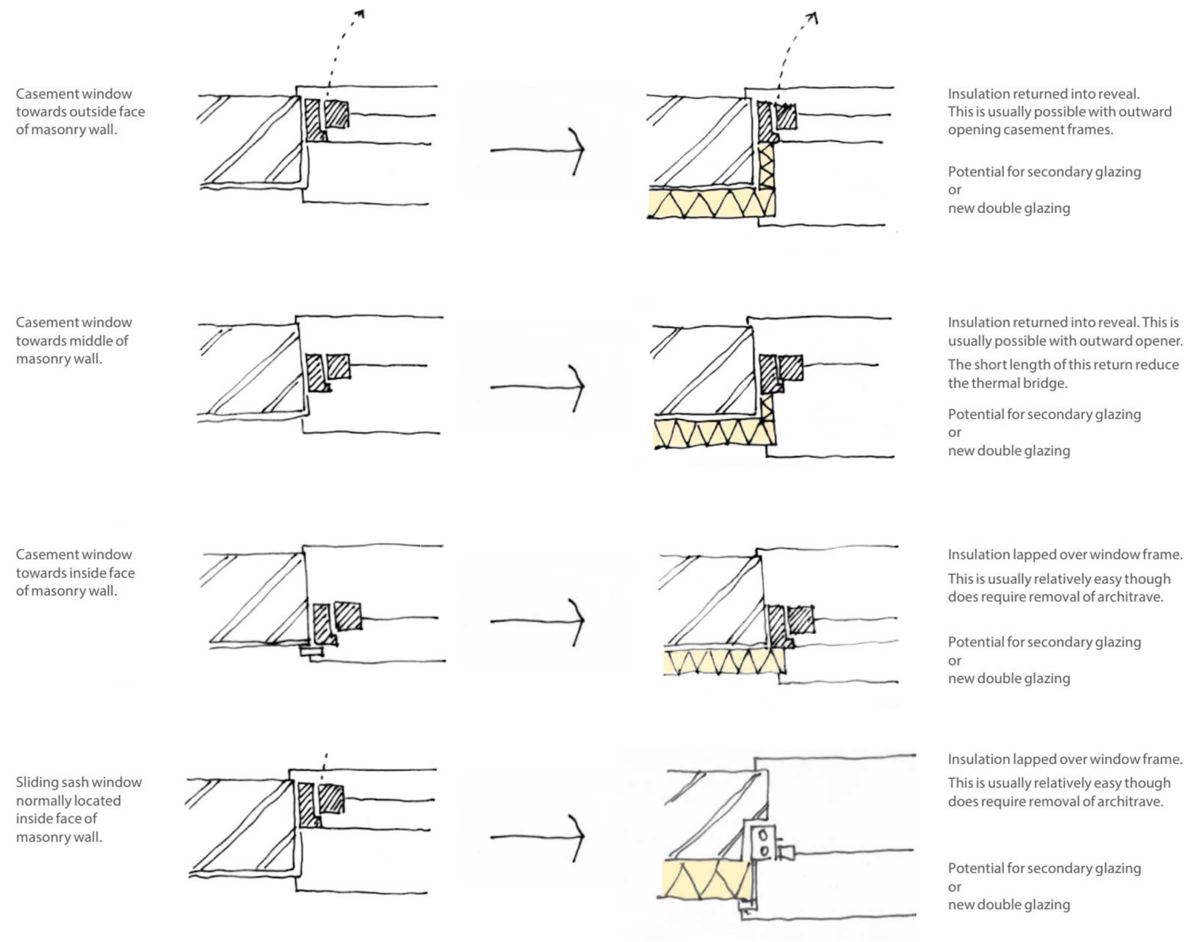

Figure 12 IWI for differing window positions, drawings shown in plan (courtesy of Bristol City council)

32. IWI can work well to avoid thermal bridges when combining energy efficiency measures such as solid floor insulation, loft insulation & window replacements since these offer the opportunity to have a continuous line of insulation around the property.

33. All thermal bridges should be mitigated to ensure a surface temperature factor (Frsi) > 0.75. If there is any doubt that the thermal bridge design will achieve this target then the surface temperature factor should be calculated in accordance with BRE's IP 1/06[4].

34. Thermal bridging may also occur when using framed internal wall installations. Vertical studs are repeated thermal bridges, but horizontal structures must also be taken into account. Metal framed insulation system should be avoided (without mitigation of thermal bridging) as metal is an extremely good conductor of heat. All framed systems will need a continuous layer of insulation, ideally on the cold side, to maintain a good internal surface temperature and avoid surface condensation and mould growth.

35. When targeting very low U-values (0.3 W/m^{2}K down to 0.1 W/m^{2}K) it becomes increasingly important to consider the impacts of thermal bridging and how well they can be managed. Low U-values may also carry a higher risk of

[4] IP 1/06 Assessing the effects of thermal bridging at junctions and around openings, BRE, 2006

interstitial condensation and damage to the existing fabric, but these risks can be reduced with careful design.

Airtightness layer

36. Air leakage into internal wall insulation systems carries a high amount of moisture and significantly increases the risk of interstitial condensation. An air barrier shall be installed in all internal wall insulation systems on the warm side. This is not the same as a vapour control layer (VCL), although some VCLs can double up as air barriers.

37. Any air barrier shall be specified such that is consistent with the moisture strategy of the system as outlined above. Vapour permeable and air tight barriers are available, these could be membranes, appropriate rigid boards or finishes such as lime render.

38. Air barriers shall be designed to continue around junctions, edges and corners which includes those junctions listed in clause 31. At these junctions between potentially different air barrier materials, proprietary airtightness tapes, adhesives or paints shall be specified that are appropriate to the situation. Products that are commonly used but do not form robust and reliable air barriers are duct tape, gaffa tape, aluminium foil tape, expanding foam, silicon sealant, decorators caulk, dot & dab plasterboard, skim finish, vinyl, plywood, flooring and masking tape.[5]

Moisture management

39. The best way to develop a robust moisture strategy for internal wall insulation is to design from first principles. This means that the designer should have a good understanding of moisture sources, storage and movement in building materials.

40. The internal wall insulation must consider the current moisture strategy of the building as well as the

    - orientation,
    - wind driven rain zone,
    - exposure,
    - external weather finish,
    - the wall construction,
    - internal moisture loads (occupancy and habits),
    - ground conditions (height, composition, drainage etc.), and

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[5] For more information on airtightness, refer to the Passivhaus Trust Guide ‘Demystifying Airtightness: Good Practice Guide, June 2020’.

- condition of the external wall and finishes.

41. Modern building techniques include vapour barriers, impermeable insulations and tend to be moisture closed, whereas traditional buildings have a moisture open approach.

42. Hygrothermal modelling should be used to assess moisture risk as advised in BS5250[6]. The simple Glaser method is only suitable for moisture closed and weathertight constructions, whereas dynamic hygrothermal simulation (using software such as WUFI or Delphin) should be used for moisture open constructions where wind driven rain or other moisture sources are present.

43. For non-traditional or system-build constructions, the hygrothermal properties of the existing material are important, but also the way that the materials have been joined or bonded together to form the wall. Some aggregate or panellised systems allow a significant amount of airflow through the walls, and may require additional weather proofing before installing IWI.

44. 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[7], 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 contains more information about this approach and illustrates a series of vapour open designs for internal wall insulation.[8]

45. The risk of interstitial condensation with internal wall insulation can be high due to warm internal air passing through or around the insulation and airtightness layers and condensing on the cold wall, and/or from external moisture within the masonry. The addition of a vapour barrier inside internal insulation (IWI) on solid walls used to be regarded as essential, partly due to inappropriate moisture risk assessment methods. However, it is now agreed that, in many cases, this may cause more harm than good. Therefore, a moisture open internal wall insulation build-up is recommended in the insulation of solid walls, or alternatively a moisture closed system with a ventilated cavity (of at least 25mm) on the cold side.

46. For walls with an impervious external cladding system, or cavity walls (that are in good functioning condition, with no moisture within the cavity), then these may provide an opportunity for the wall to dry externally and in these cases a moisture closed IWI system could be considered.

47. The thickness of internal wall insulation is an important factor in vapour permeability. The greater the thickness of insulation, the lower the vapour

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[6] BS5250 Code of practice for control of condensation in buildings

[7] A vapour control layer that varies its vapour resistance (an intelligent membrane for example), may be combined with a vapour open insulation to be consistent with the existing moisture strategy of the traditional building. This approach should be applied with caution, following the guidance from the manufacturer of the membrane for use in this specific situation. Hygrothermal modelling may be necessary to support this design approach.

[8] A Bristolian's guide to Solid Wall Insulation; A guide to the responsible retrofit of traditional homes in Bristol. Bristol City Council, 2015.

permeability of the final build-up. Vapour permeable and capillary active thin internal wall insulation (TIWI) will help to reduce moisture risks.[9] TIWI is also a benefit when considering insulated plaster as the installation process is simpler and drying times are reduced.

48. Moisture closed systems with a ventilated cavity enable the use of high-performance insulations, however the presence of the cavity will increase the thickness of the build-up and this may result in an unacceptable reduction in floor area. In these cases, a wind barrier should be installed on the cold side of the insulation.[10] In general, when specifying materials, the vapour permeability of materials should decrease from inside to outside, with the most vapour impermeable layer on the internal surface and most vapour permeable layer on the outer surface.

49. In systems that include ventilated cavities on the cold side of the insulation, the ventilation is essential to reducing the risk of interstitial condensation (see figure below).

Figure 13 Laminate board installed on timber stud cavity with NO ventilation, poor air barrier and poor external pointing. Black mould was found growing in the narrow space behind, feeding off the wet wallpaper[11].

50. This method entails the risk of heat losses through uncontrolled infiltration if the installation of an airtightness layer and of a wind tightness layer are not done properly. It is more common and suitable when the substrate is uneven or where a ventilated cavity is required between the existing wall and the insulation. This method should be used when the insulation is applied as insulated drylining.

51. In some instance where a vapour control layer is required, then a variable (or intelligent) vapour control membranes may be considered to reduce moisture

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[9] Thin Internal Wall Insulation (TIWI) Measuring Energy performance Improvement in Dwellings Using Thin Internal Wall Insulation, Summary Report, BEIS, Leeds Beckett University, Leeds Sustainability Institute

[10] Note that achieving a well-ventilated cavity with wind barrier may be difficult in reality, and will require careful design.

[11] Photo from the AECB Carbonlite Retrofit Course

risks compare with a fixed VCL membrane or product. Variable vapour control membranes allow limited drying in favourable humidity conditions inside the building as well as control of the amount of moisture allowed to enter the IWI from the room.

52. BS5250 Code of practice for control of condensation in buildings should be adhered to in the assessment, design and implementation of IWI.

Joist ends

53. Where IWI is being installed around joist ends that are embedded into a wall, the lowest risk option is to entirely remove the joists from the wall and rest on wall hangers or a thermally-broken steel joist. This will eliminate the risk of rotting or deterioration from a cold wall due to the installation of the IWI. Bringing joists away from the wall may also allow the IWI to extend down the wall uninterrupted and thereby avoiding thermal bridges.

54. If joist ends are left in existing walls then injection of boron paste may be considered. Boron paste inhibits mould and fungus growth, and prevents the joist ends from rotting.

55. Vapour permeable thin internal wall insulation (TIWI) of less than 40mm will help reduce moisture risks in joist ends. If necessary, TIWI may be placed only between joist ends, with thicker insulation above and below the joists.

56. Joist ends embedded in walls should be made airtight using vapour open products such as some airtightness tapes or lime render.

Ventilation

57. No insulation should be installed without assessing the ventilation system. A fully functioning, and preferably continuous ventilation system[12] should be in operation upon completion of the IWI insulation.

58. Positive Input Ventilation (PIV) should not be installed with internal wall insulation. The risk of interstitial condensation between the wall and the IWI is increased when using a ventilation system such as PIV, that actively pushes warm, wet air into the building fabric.

Interaction with other measures

59. Where other insulation measures are installed at the same time as the IWI, special attention should be given to thermal bridging, air tightness and moisture at junctions with others measures as outlined in the previous

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[12] Intermittent mechanical extract systems should not be relied upon for buildings with an air permeability of < 5 m^3/m^2hr.

sections.

Less than 100% IWI installation

60. There is a surface condensation risk if IWI is installed on only part of an external wall. This is because the external wall will become cold where the IWI is installed as it has been isolated from the room heating. Where the IWI finishes the cold exposed wall is more susceptible to surface condensation.

61. In some cases a hybrid approach with external and internal wall insulation may be possible, to ensure all external walls are insulated. These two insulation approaches work well where the building may be in a conservation area, and IWI is required on the front façade and external wall insulation may be used on the rear, ensuring the junction between the two systems (if any) includes appropriate overlaps to avoid thermal bridging.

62. A hybrid approach should ensure that internal wall insulation overlaps with external wall insulation by a minimum of 400mm. Changing frequently between IWI and EWI introduces thermal bridges and is not recommended.

63. Where 100% IWI is not economically or practically feasible on a single facade then the risks should be managed in the following ways;

    - uninsulated rooms must have a safe heating system that can achieve a minimum of 18 degrees C; and
    - only specific whole rooms, not parts of rooms may be left uninsulated; and
    - only kitchens, bathrooms, shower rooms, WCs (without openable windows) and utility rooms (wet rooms) may be left uninsulated; and
    - uninsulated rooms must have a continuous mechanical extract ventilation in accordance with the requirements of clause C3.5 of PAS2035; and
    - The resident of the property must be left with clear understandable written instructions on the importance of heating and ventilation in uninsulated rooms.

64. If the above points are not followed then partial IWI installation should not proceed. The flow chart below (Figure 14) summarises the guidance above.

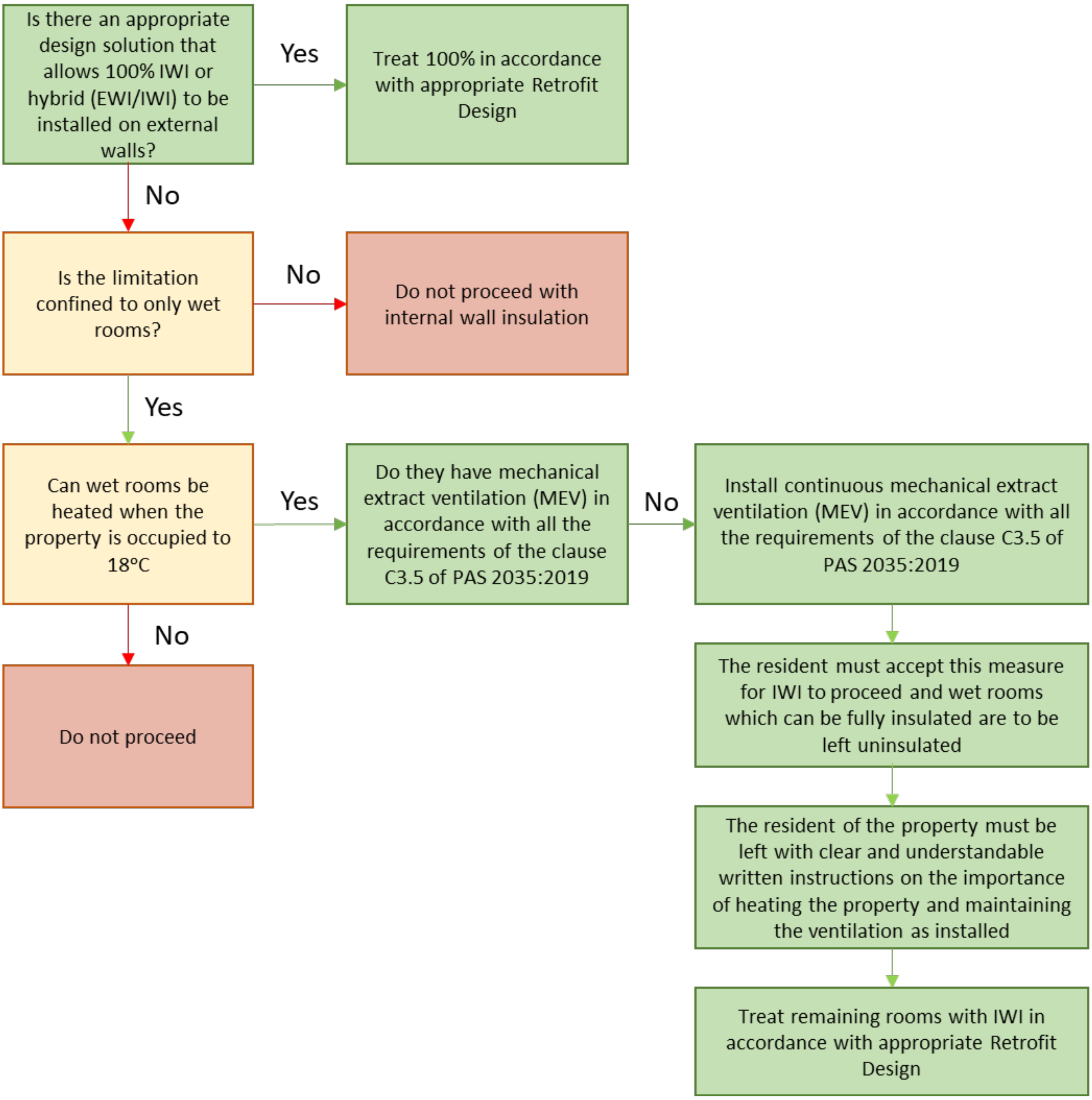

Figure 14 Flow chart to determine if less than 100% IWI is acceptable

Services and penetrations

65. Ensure that all the services (plug sockets, light switches, pipes, radiators, etc.) and fittings (skirtings, covings, shelves, cabinets, fitted wardrobes, etc.) accommodated on the wall-to-be-insulated are considered; Post-installation works will be necessary so that the above are properly reinstated.
66. Depending on the installation method selected, the services may inevitably penetrate the insulation layer, the VCL and/or the air barrier. These penetrations should be kept to a minimum and be properly sealed. If possible, a separate service cavity should be provided in front of the insulation, air barrier and VCL to eliminate the penetrations.
67. A schedule of penetrations should be provided, along with the appropriate sealing products for air tightness and/or vapour control.
68. Provisions should be made for their installation of heavier items on the wall-to-be-insulated; for instance, appropriate timber battens should be installed in the relevant areas to accept the load of any heavy fittings.

7. Installation

Pre-installation survey and risks

69. Upon receiving the retrofit design, the installer should satisfy themselves that the design is suitable for the building by undertaking a pre-installation building inspection as outlined in PAS2030. They should also check the information from the retrofit assessment, and that it has identified all the risks as laid out in Section 3 Building Suitability Assessment & Risk, in this guide. The installer should be satisfied that any remedial works have been carried out and that the wall is in a suitable condition for IWI to be installed.

70. The table below describes some of the major considerations for the installer upon receiving a retrofit design for IWI.

Action	Assessing	Methodology	Risk
Are the works to be undertaken defined as "Building Works" according to the current Building Regulations?	The Building Regulations 2010 provide that "building work" shall be carried out so that it complies with the requirements contained in Schedule 1	Consider if the works entail: 1. the erection or extension of a building (which would cover new builds); 2. the material alteration of a building. This is either: a. Where the work would result in the building no longer complying with a previous requirement when it once did; or b. In a building which before the work did not comply with a relevant requirement, being more unsatisfactory in relation to such requirement. 3. the insertion of insulation into the cavity wall of a building; and 4. certain other specific work which relates to energy efficiency requirements, including the renovation of individual thermal elements or change in the energy status of the building	Works being undertaken without correct permissions or approvals in place.
Has an assessment	If the installation to be undertaken will	Review of the scope of works to assess suitability in relation to:	Installation of the measure contravenes or results in the

Action	Assessing	Methodology	Risk
been undertaken for compliance with the Building Regulations?	result in non-compliance with the Building Regulations.	• workmanship, • materials, • structural stability, • fire safety, • management of moisture • ventilation. • overheating, and • thermal performance.	building no longer complying with the Building Regulations.
Have the risks identified in the retrofit assessment been mitigated by the remedial work or in a retrofit design?	If remedial work has been undertaken or if the retrofit design has mitigated any risks identified.	Review the retrofit assessment and identified risks. Establish if any remedial work has been undertaken and that sufficient time has been allowed for the building to dry if any moisture issues were identified. Establish if the retrofit design has accounted for the risks identified in the retrofit assessment, and that they are not exacerbated by the retrofit design.	Potential for structural or moisture risks due to existing condition of building.
Has there been an assessment of junctions with other insulation or construction elements?	Potential for thermal bridging and discontinuous air barrier at external wall junctions with, • ground floors • ceilings/roofs • window/doors • internal walls	Review of the Whole House Retrofit Plan and/or design package. Visual and potential invasive inspection (if appropriate) of: • the existing floor and roof conditions. Including any floor, loft, pitched or flat roof insulation that has been installed anywhere in the property; • The window and door installation situations; • The extent of internal walls, stairs and intermediate floors joining external walls;	Creation of a thermal bridge, leading to heat loss and increased risk of surface condensation and mould growth. Non-continuous air barrier leading to increased risk of thermal bypass and moisture penetration

Action	Assessing	Methodology	Risk
	• intermediate floors • stairs	to assess how these junctions will/can be resolved to avoid thermal bridging and install a continuous air barrier[13]. Particular attention should be paid to airtightness around joist ends that penetrate through internal wall insulation into external walls. If the design does not include continuous insulation or an air barrier, the contractor should raise this with the Retrofit Designer or Retrofit Coordinator to see if this was intentional.	into the internal wall insulation. Increased risk of rotting in joist ends that penetrate external walls through internal wall insulation.
Is the installation acceptable and appropriate?	Suitability of design and appropriateness to ascertain if the installation is suitable for the building.	Consider whether the installation would; • be non-compliant with any requirement stated by the designer /specifier; • compromise the functionality of existing air supply extract ventilation duct systems; and Consider if the site layout or conditions will impair the execution of the works in relation to appropriate access to the property and to the walls to be insulated;	Lack of ventilation to habitable spaces. Risks to safe working practices. Risk to the appropriateness of the building. Proximity of stored items that may result in damage.

[13] Note that an air barrier may be the same as a vapour control layer (VCL). However, an air barrier is always required, where a vapour control layer may not be. For example, in a moisture open internal wall insulation system design, an air barrier is required but the design is not likely to incorporate a vapour control layer. A vapour permeable air barrier should be selected in this case.

Action	Assessing	Methodology	Risk
Has the customer been given appropriate retrofit advice?	Suitability of design and appropriateness for customer.	Check whether the customer has been made aware of the level of disruption during works (including timescales and any furniture or disturbances that may occur) and ongoing maintenance needs for external walls and ventilation systems.	Customer unhappy with disruption Customer unable to maintain retrofit system, know how to make changes to their home or use new ventilation controls.
Does the retrofit design include upgrade of the ventilation system?	If ventilation is appropriate for improved air tightness associated with IWI	If ventilation improvements are not included within the retrofit design, check that this was intentional and that the retrofit ventilation assessment indicated a fully functioning and correctly sized ventilation system.	The ventilation is not sufficient for property, risk of condensation and mould growth.

Design principles for installers

71. A Retrofit Installer should be able to understand why a particular design has been chosen and to evaluate whether it is suitable for the building in question. Therefore, it is important to understand some design principles of IWI.

Thermal bridging

72. A thermal bridge is defined as an area of the building envelope where the insulation is:

a) discontinuous or thinner than the adjacent insulation;

b) has higher thermal conductivity than the adjacent insulation; or

c) has reduced effectiveness due to the building geometry;

Thermal bridges can lead to locally increased heat loss and therefore a locally reduced surface temperature. This in turn can lead to surface condensation and mould growth.

73. IWI will inherently have thermal bridges due to internal walls, party walls and intermediate floors. However, these can be mitigated, usually by returning a layer of insulation along the wall or floor that is causing the thermal bridge. This reduces the pathway for heat to escape to the outside. There are a few situations where this may not be recommended, or possible. One example might be on party walls. Insulating party walls may increase the risk of moisture issues in the neighbouring property.

74. If there are thermal bridges that haven't been mitigated in the retrofit design, the retrofit installer should raise this with the Retrofit Designer or Retrofit Coordinator to understand if this was intentional. Thermal bridges may have been modelled at the design stage to help design appropriate details, and choose the right thickness and type of insulation to help mitigate the thermal bridge.

75. Thermal bridging can also occur within a wall build-up as a repeated thermal bridge. For example, when timber or metal stud-work interrupts the insulation. Metal is extremely good at conducting heat and therefore will have a big impact on the performance of the system. A layer of continuous insulation should be installed across the stud-work to reduce the impact of the repeated thermal bridging.

Air barriers, vapour barrier and vapour control layers

76. An air barrier is a building material with properties that aim to prevent the passage of air through it. An air barrier may also be a vapour control layer or a vapour barrier, but it may be specified to have a very low resistance to the passage of vapour. Air barriers should be installed on all construction types to protect insulation and the building fabric from moisture carried in the air.

77. If there is no air barrier marked on the retrofit design, the retrofit installer should raise this with the retrofit designer and retrofit coordinator who should provide guidance as to what materials form the air barrier in their design.

78. Any air barrier that is specified should be consistent with the moisture strategy of the IWI system. Vapour permeable and air tight air barriers are available, these could be membranes, appropriate rigid boards or finishes such as lime render.

79. The moisture strategy describes how water vapour is controlled within the IWI system. The moisture strategy tends to fall into one of two categories; those that try to control the passage of water vapour (known as moisture closed), and those that allow the passage of water vapour (known as moisture open). Note that moisture closed is not the same as airtight.

80. For internal wall insulation, often the lowest risk approach is to use a moisture open design.

81. Air barriers shall be designed to continue around junctions, edges and corners and at these junctions between potentially different air barrier materials, proprietary airtightness tapes, adhesives or paints shall be specified that are appropriate to the situation. Products that are commonly used but do not form robust and reliable air barriers are duct tape, gaffa tape, aluminium foil tape, expanding foam, silicon sealant, decorators caulk, dot & dab plasterboard, skim finish, vinyl, plywood, flooring and masking tape.[14]

82. For moisture closed systems a vapour barrier or vapour control layer is used, and this must be sealed at all junctions, edges and corners using proprietary vapour control tapes or sealants

83. If vapour control layers or vapour barriers are specified, then these should be on the warm side of the insulation. If this is not the case, this should be raised with the Retrofit Designer or Retrofit Coordinator to see if this was intentional as there may be a risk of interstitial condensation.

84. Air barriers should also be installed on the warm side of the insulation. If this is not the case, this should be raised with the Retrofit Designer or Retrofit Coordinator to see if this was intentional as there may be a risk of interstitial condensation and/or thermal bypass.

Installation principles

Products & thermal bridging

85. Ensure that the correct insulation products are used in each situation. Some insulation products have a much better thermal performance. For example, aerogel is a very good insulating material even in thin layers (<20mm), and it is often used in window reveals where space is limited. Some products have specific moisture properties which may be essential to reducing the impact of

[14] For more information on airtightness, refer to the Passivhaus Trust Guide 'Demystifying Airtightness: Good Practice Guide, June 2020'.

moisture risks. All components of an IWI should match the retrofit design, including surface finishes and adhesives. If looking to propose alternative products, ensure these are checked with the Retrofit Designer and/or Retrofit Coordinator as being appropriate for the situation they are to be used, and that they are consistent with the retrofit design.

86. When installing either timber or metal stud-work within an insulation layer, keep stud spacings as wide as possible. Plan studwork carefully at junctions and edges to minimise the total amount of thermal bridging through the insulation layer.

Avoiding thermal bypass

87. Ones of the biggest risks to reducing the effectiveness of insulation when it is installed is allowing gaps within and through the insulation layer. This is known as thermal bypass and it can increase heat loss through an insulated wall by up to 300%. A robust and continuous air barrier on the warm side of the insulation will help to reduce the risk of thermal bypass, but it is also important to avoid gaps between insulation layer or between insulation boards or batts.

88. If installing rigid insulation board, the joints between the boards should be tightly butted to fit in corners, around doors and windows, and with each other. Vertical joints must be staggered; Before finishing, the installation of the boards should be inspected. Gaps greater than 10mm between the board connections and at the perimeter of the insulation should be properly packed out. Some rigid boards (e.g. PIR) may also be taped, especially if their surface forms the vapour control layer and/or air barrier.

89. If installing flexible insulation in stud work, a friction fit will help to ensure no gaps are formed. If the insulation requires cutting, it should be cut slightly wider than the space it is intended to fill to ensure that friction fitting is achieved in installation.

90. Sealing is also important around the perimeter of the IWI boards. If the retrofit design shows IWI boards meeting the floor, ceiling or other edges, then this should be adhered to.

Avoiding interstitial condensation

91. Interstitial Condensation is a type of condensation that may occur within an enclosed wall, roof or floor cavity structure, which can create moisture issues. It can only form on surfaces where there is an air gap. Some of the risk of interstitial condensation can be mitigated in choosing an appropriate retrofit design. Good installation practice is also important in reducing risk and all of the points in the section Avoiding Thermal Bypass will also help to reduce the risk of interstitial condensation.

92. Retrofit Installers should aim to minimise the air gaps between the insulation and the existing wall as this will reduce the risk of interstitial condensation. This can be achieved by:

- Using a liberal amount of adhesive to secure the insulation to the wall.

Dot and dab approaches have the highest risk of interstitial condensation and should be avoided as they leave air gaps behind the insulation. Ideally a continuous layer of adhesive should be applied to the wall.

- Using appropriate fixings of the correct number and spacings for the type of insulation, so that the insulation is held tightly to the existing wall.
- Using an insulated plaster directly applied to the wall
- Ensuring the wall is smooth and flat before internal wall insulation is installed.

The only exception to this is if a ventilation cavity has been specified behind the insulation, in which case a vapour permeable membrane will be installed to the back of the insulation, and the cavity between each stud spacing will be ventilated to outside at the top and the bottom of the cavity.

Services in relation with IWI

93. Where the retrofit design does not provide a cavity behind or in front of the insulation, the wall should be properly chased to accommodate the services (cabling, pipework, etc.). Any gaps should be sealed and the wall should be parged. After the installation of the insulation, the services will be extended through the insulation in particular areas. Any holes and gaps in the VCL and/or air barrier should be properly sealed with appropriate tape. If the wiring is encapsulated in, or directly behind the insulation, you should check that the cables do not require derating.

94. Any penetrations of the air barrier or the vapour control layer that cannot be avoided should be sealed appropriately. These penetrations include:
    - Waste pipes & SVPS
    - MVHR ducts
    - Incoming water, gas, oil, electricity, data, and district heating, as applicable
    - Flues, including air supplies to wood burning stoves or similar, where other precautions including fire risk need to be considered.
    - Connections to external services, such as entry phones, outside lights, external taps and sockets, security cameras, satellite dishes

95. A schedule of penetrations, their dimensions, orientation, and the applicable sealing method should be provided as part of the retrofit design. Sequencing is important since a number of items e.g., EPDM (rubber) gaskets, may need to be fitted prior to the installation of the penetration. Ideally, the gasket is fitted loosely around the penetration (e.g., ductwork, plumbing or electrical services) whilst it is being installed, and once the ductwork or other services are fixed in place, then the gasket can be taped back to the air barrier. This prevents any off centre stretching of the gaskets which can cause air leakages. For existing services, gaskets may not be suitable and therefore

other airtightness products should be considered. All service alterations should be carried out by a suitably qualified person.

Damp Proof Courses

96. It is worth noting that rising damp is quite uncommon in well-built, traditional buildings in the UK. When there is an apparent case, careful examination of the wall and any proposed remedy should take place to identify whether another potential cause, such as a broken drain or alterations in the surrounding landscape elements that deposit water directly into the wall, is present. If this is not the case, specialist advice from a qualified professional should be sought. Any rising damp should have been identified in the retrofit assessment and any remedial work completed so that the wall is dry prior to installation of IWI.

97. Please note that tanking of one or two sides of a wall is not a recommended remedy of rising damp, as the drying-out through evaporation will be reduced and the moisture content of the wall will be increased, leading to moisture-related issues.

98. The installation of a Damp Proof Course to prevent capillary rise might be considered as an essential step in severe cases, however, this solution should not be considered for walls that to date have not manifested signs of dampness even in the case that internal wall insulation will be installed.

99. There are three types of DPCs, physical, injected, and electro-osmotic retrofit DPCs, for more detailed information on the installation of DPCs, please refer to Annex C.

8. Post-installation checks

100. Monitoring the hygrothermal performance of the IWI system post retrofit and examining the temperature/relative humidity levels in locations within the build-up that are considered high-risk (e.g. embedded timbers) is good practice.

101. It is essential that any issues or special considerations that were identified at the assessment stage are carefully considered and appropriately addressed in accordance with the relevant standard.

102. Many serious moisture-related problems may be hidden from view for some time prior to their effects being felt (for example when there is interstitial moisture build-up, behind linings or in joist or rafter ends; or in slowly accumulating levels of mould or dust mites).Therefore, completion of a building project should not be considered to occur at practical completion of works, but when the building is in equilibrium (after the input of new materials and systems) and when it has been shown to be operating safely for the long term. In some situations, this will mean that completion is after two years, but in others with less certainty and higher risks, this may be considerably longer.

103. All post installation checks should be evidenced by survey notes and supported by photographic evidence at mid and post-installation stage. Such evidence must include suitable referencing to identify the precise spatial area of the work that it relates to.

104. It is recommended that photographs are taken before and during installation to evidence the following:

- Existing stripped back internal wall, floor joists at ground and intermediate floors, and external wall condition.
- Installation of appropriate vapour control barrier (if needed) in accordance with the design and manufacturer’s instructions.
- Clear and ventilated cavity behind IWI where relevant and installation of breather membrane.
- Installation of an appropriate air barrier in accordance with the design and manufacturer’s instructions.
- Taping or sealing of air barrier and/or vapour control layer at junctions edges and corners.
- Installation of insulation product to thickness specified in the design, with no gaps.
- Dry external walls pre and post IWI installation.
- Services passing through IWI in good condition.
- Treatment of inter-floor voids.

Maintenance

105. Although IWI itself requires little or no maintenance, other works associated with an IWI installation will inevitably require maintenance to avoid potential problems. Examples include installation & maintenance of ventilation systems, gutter & RWG clearing, replacement or repair of external drainage systems or installation/repair of appropriate external wall finishes including pointing & render.

106. Handover of buildings should include clear and informative maintenance manuals and web-based information. If possible, maintenance programmes should be established, and where owners or occupiers cannot maintain their fabric and services themselves, options for external assistance and contracts should be provided. Automated reminders about maintenance may be advisable.

Customer care and handover

107. It is the responsibility of the Retrofit Installer to ensure that the appropriate information is provided to the Retrofit Coordinator, or directly to the customer at handover. Further guidance on customer care is given in Annex B Customer Care & Handover, of this guide.

9. Health & Safety

108. The surveyor or installer should be mindful of the Health and Safety at Work Act and follow all guidance and specific requirements of this regulation, and in particular the requirements of the Work at Height Regulations 2005. Further guidance is available from the Health and Safety Executive website: www.hse.gov.uk

109. The Construction Design and Management Regulations (2015) applies to all construction projects and defines Health and Safety responsibilities throughout a construction project, including the roles of principal designer and principal contractor.

10. Training and Vocational Competence

110. All competency requirements for the surveying, assessment, installation and checking shall be in strict compliance with the relevant Building Regulations.

111. For retrofit designers, the Carbonlite Retrofit course offered by the AECB is recommended as it offers a high level of detail and in-depth evaluation of retrofit risks.

112. For all retrofit professionals, the level 5 Retrofit Coordinator qualification is recommended as it offers an overview of retrofit systems & technologies and their associated risks.

113. For traditional buildings, the retrofit guidance wheel, developed by the Sustainable Traditional Buildings Association (STBA) gives high level guidance on retrofit risks in traditional buildings. This is a highly visual tool and can be useful in communications with the client.

114. For all retrofit professionals working with traditional buildings, the Level 3 qualification in Energy Efficiency and Retrofit of Traditional Buildings is recommended.[15]

[15] This qualification varies in the devolved nations: the Level 3 Award in Energy Efficiency and Retrofit of Traditional Buildings, Scottish Level 6 Award in Energy Efficiency Measures for Older and Traditional Buildings; and the Welsh Level 3 Award in Energy Efficiency Measures for Older and Traditional Buildings

Annex A – Wall construction and identification

The typical construction method of the UK houses has changed over the decades. A great part of the current building stock is built with traditional methods of construction (mostly brickwork solid walls and cavity walls), although in the mid-20th century various new ways of building or non-traditional methods were introduced (i.e. timber frame, metal frame, in situ concrete or precast concrete). The most prevalent method of construction was solid wall until the late 19th century when the cavity wall type was introduced. This construction type has developed significantly since then and remains the dominant method of construction to date. Other traditional construction methods may be found such as cob and timber frame[16].

In order to identify the type of wall construction there are several factors to consider, including year of construction, materials, wall thickness and masonry patterns.

Late in the 19th century, most houses had at least one-brick thick walls. Thicker walls might be found in buildings over 2 storeys, usually reducing in thickness at each upper-floor level. Front walls of most houses were often built in Flemish bond, while rear or hidden by render wall were laid in Garden wall bond[17]. Bricks will vary in aesthetics, but also their moisture properties and their durability, which resulted from local clay variation, method of manufacture and fashion.

Stone was also used as a construction material for the external walls, particularly for prestigious buildings or in upland areas, due to its availability. A variety of styles of rubble walling can be met in Victorian houses. Prior to the industrial revolution when canal transport and large brickworks were prevalent, vernacular construction used what was at hand: stone, timber frame with infill etc. Brick really took off from around 1700. Stone walls are typically thicker than the brick walls, so whereas a one brick wall (215mm) might be suitable for a house, a stone wall would be of a thickness of 325mm and up to 600mm in areas of high wind driven rain exposure.

Later in the 19th century, cavity walls were introduced and gradually accepted as a form of construction. The most common construction system for cavity walls, included two half-brick leaves with a 50mm cavity. Steel or wrought iron wall ties were used to tie the two halves of the wall at regular intervals. Facing bricks were used for the external leaf of brickwork and commons for the internal. While cavity construction took over generally, solid walls were still used sometimes on the same building. From 1930s to 1950s, cavity walls' construction changed a little, in terms of mortars which became cement-based, prior to which lime mortar was more common. This is important because lime mortar allows moisture to transfer more readily than cement-based mortar. Additionally, for their inner leaf, blockwork became the more

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[16] Whilst the general recommendations found in this guide for IWI will apply to the majority of construction types, the detailed installation and assessment guidance for these less prevalent constructions will be dealt with in a later comprehensive IWI guide.
[17] Homes through decades, NHBC Foundation, 2015

common material, with the blocks made with an aggregate of stone or industrial waste, often clinker and breeze.[18]

All the types of construction in Figure 15 can be found in a Victorian street. From left to right:

- Solid 9” brick;
- early form of cavity with headers used as ties recessed c.30mm on inner face (built 1869);
- rat trap bond (also here with bricks used ‘on edge’ with headers as ties);
- ‘true cavity’ wall with iron ties.

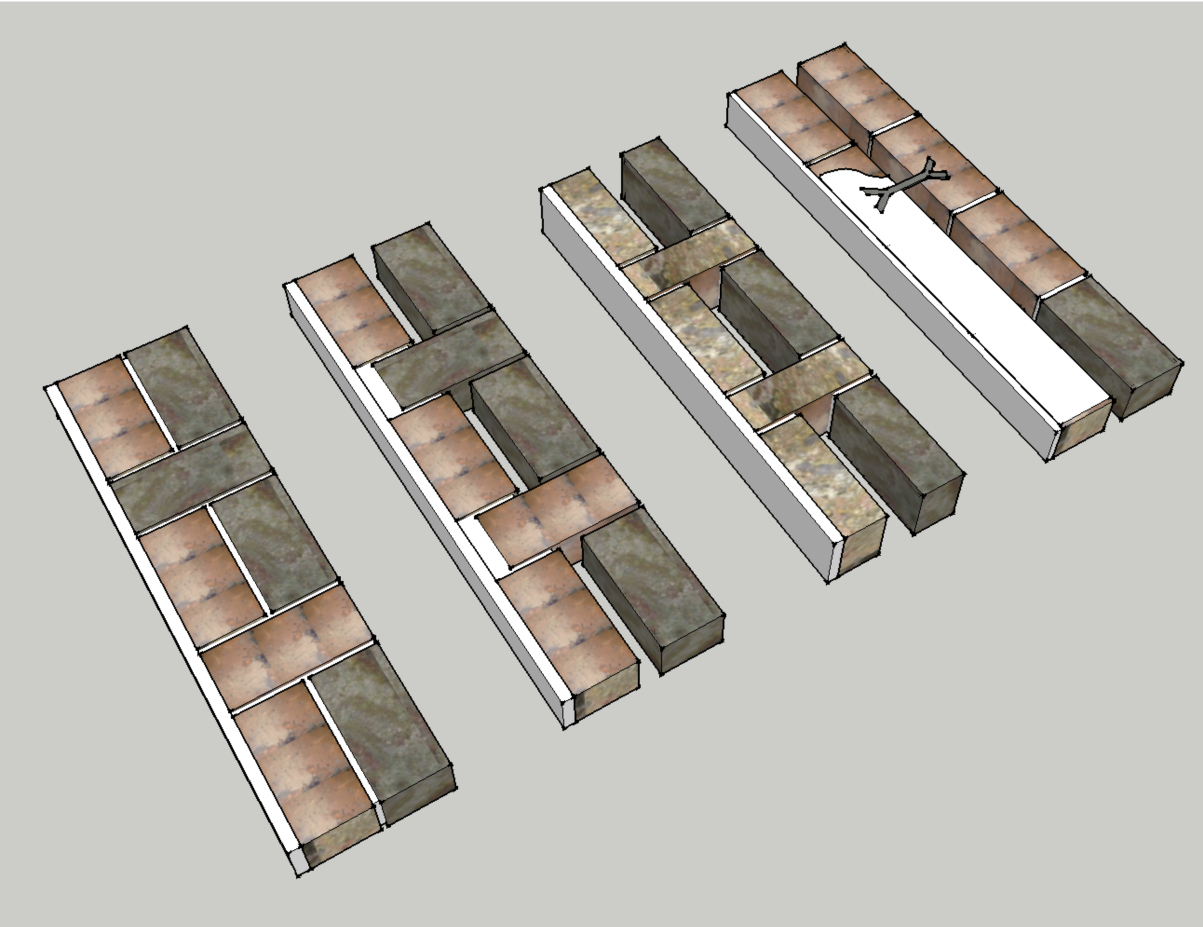


Figure 15 Early cavity wall types

[18] Homes Through the Decades, NHBC Foundation, 2015

Typical characteristics

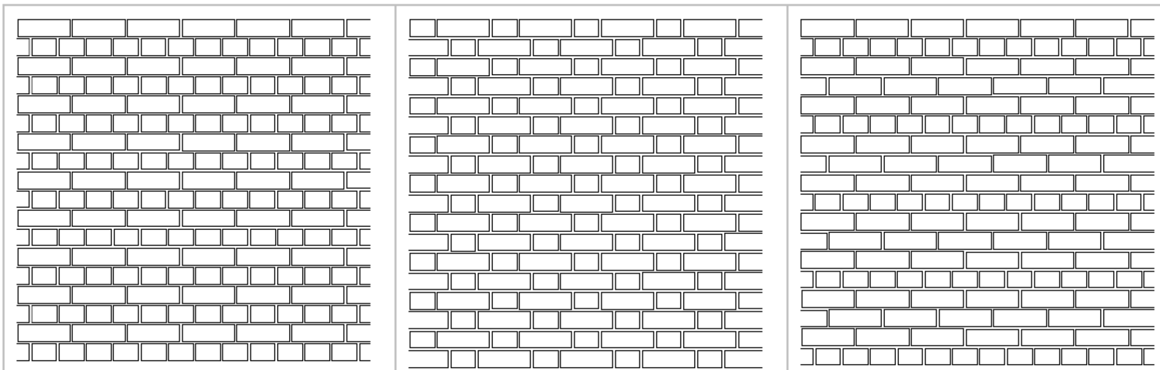
Table 3 below shows typical characteristics for solid walls, and

Figure 16 shows typical brick configuration to help identify solid walls.

Table 3 Typical characteristics for solid walls

Construction period	18th, 19th, and 20th century until approximately 1930 (Georgian, Victorian and Edwardian construction styles).
Thickness	225 mm for brick (345mm thick for lower walls of buildings over two stories- brick and a half) plus internal plaster and external rendering, if applicable. Up to 600mm thick for stone walls.
Material	Brick or stone.
Pattern	English, Flemish or Garden Wall bonds. Both the long face of the brick and the short face or 'header' showing in a regular pattern. Stone wall patterns vary and stones could be random sizes and shapes, or more regular rectangular blocks that could be roughly coursed like bricks.

Figure 16 Typical solid wall brick configurations[19]



English bond | Flemish bond | English garden wall (3 courses)

Table 4 below shows typical characteristics for cavity walls and Figure 16 shows typical brick configurations to help identify cavity walls.

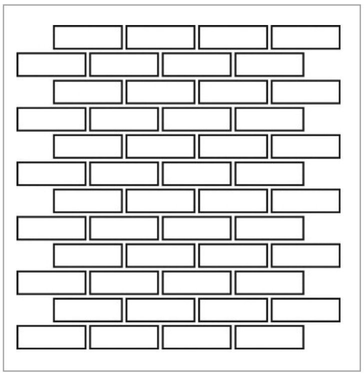
Table 4 typical characteristics for cavity walls

Construction period	20th century from approximately 1930 onwards.
Thickness	Minimum 250mm (375mm for one brick thick external leaves) plus internal plaster and external rendering if applicable.
Material	Brick external leaf, brick or block internal leaf.
Pattern	Commonly stretcher or running bond.

[19] Solid wall heat losses and the potential for energy saving, classification of solid walls, BRE, 2016

	All the bricks laid end to end with only the long face of the brick or 'stretcher' showing.

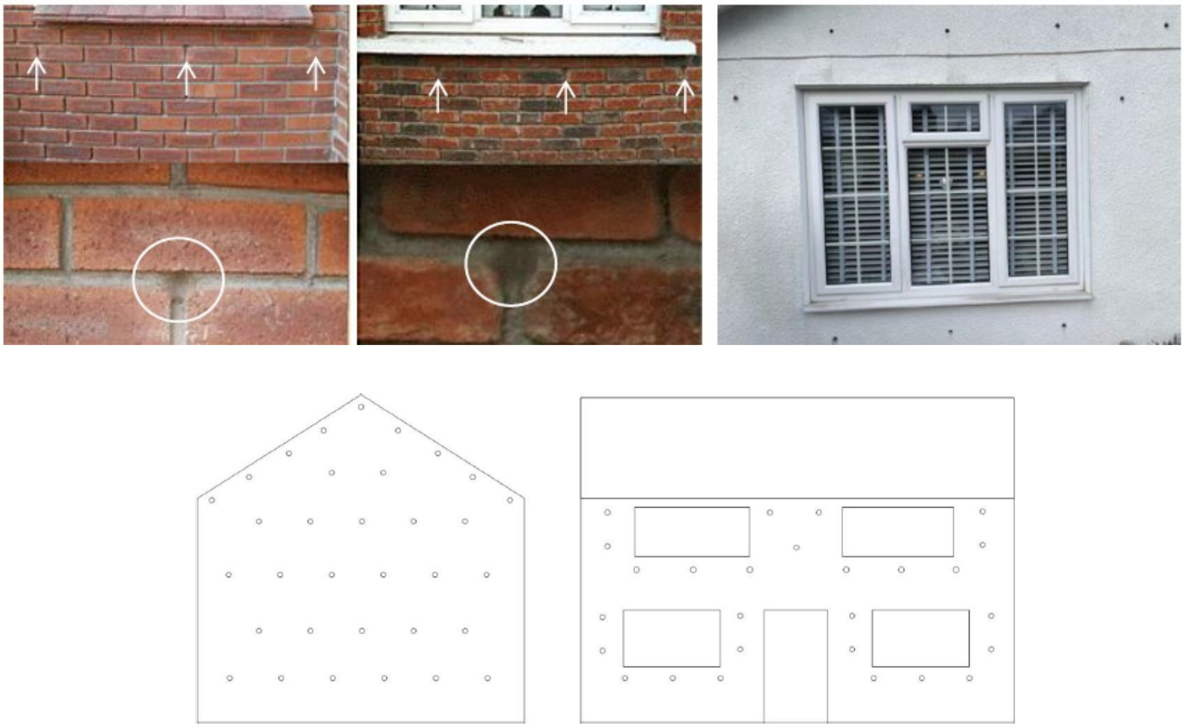
Figure 17 Typical cavity wall brick configurations



Stretcher or running

Since 1965, when building regulations mandated a maximum U-value of 1.7 W/m2K for external walls which was then tightened to 1 W/m2K in 1975, cavity walls should have a layer of insulation in the cavity between the inner and outer walls but traditionally this space was empty. A system was introduced in the 1970s to inject insulation into these cavity walls, a series of holes are drilled into the mortar between the bricks and then injected with the insulating materials, then mortar is created to match the existing colour. These holes can be used to identify an insulation filled cavity wall. The drill holes for cavity wall insulation differ but are approximately 18-25mm in diameter and at 1m intervals. Typically, the holes are drilled into the mortar joints and are located at the base of the mortar joint between the bricks. The holes are aligned in a specific predetermined pattern, typically there is a high concentration of drill holes around windows and doors and also under waste pipes and vents. Holes and drill patterns for cavity wall insulation are shown in Figure 18.

Figure 18 Typical cavity wall insulation drill holes and patterns in brick and rendered properties[20]



Masonry walls could have also been insulated externally. External insulation normally consists of insulated boards cladded to the exterior and rendered. This will make fully rendered walls harder to identify, but there is an evident increase of the wall thickness. Some typical details can be recognized, for instance steps in the outer layer of terraced houses or semidetached properties (when only one of them has external insulation installed). Although the following are not examples of best practice, the external wall insulation may stop above damp proof course (DPC) level and services ducts embedded in this layer are also indicative of external wall insulation.

When identifying external wall construction, it is important to confirm all wall types, especially if there have been extensions or there might be parts of the house built at a later year and consequently with different construction methods.

Sometimes, it may be necessary to do invasive works[21] to identify the type of wall, for example if there is no evidence of what is behind a rendered outer layer, and it is always essential when confirming the presence and condition of cavity wall insulation. In a boroscopic inspection a 10mm diameter hole is drilled through the wall that is to be investigated and the boroscope is inserted through the scope hole. The void can then be visually inspected or recorded by camera or video. Expert

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[20] ECO Reporting Working Group Guide 2020
[21] Take caution and adhere to current health and safety procedures when undertaking invasive works due to the prevalence of asbestos in existing buildings.

thermal imaging[22] can also help identifying the type of wall by assessing the surface temperature, presence and location of thermal bridges, etc. (i.e. if cavity wall or external wall insulation has been installed the building will present homogeneous wall surface temperatures

[22] Thermal imaging should only be carried out by a trained operative as it is extremely sensitive to different materials and external weather conditions.

Annex B – Customer Care & handover

Installing IWI (Internal Wall Insulation) is disruptive to the residents and the properties involved. It is therefore essential that thorough discussions with the resident and consumer take place before any work commences.

The installer shall advise clearly, as a minimum, the following aspects of the works:

- the extent of any disruption that may be caused by the chosen installation method (removal of fittings and or fixtures, skirtings, wall fabric and finishes, floor covering and/or floorboards);
- any additional works that may be required to facilitate the installation of insulation (use of scaffold, lighting rigs, repair of defects, additional ventilation etc);
- the time anticipated to undertake the works, and any deviation from this during the works caused by unforeseen issues; and
- the extent of any making good that is included in the work being carried out (redecoration etc); and
- where relevant, safe and secure storage of materials on site; and
- the cost of the works, and any deviation from this during the works caused by unforeseen issues; and
- the contracts that the customer is expected to sign up to with the installer; and
- any warranties that will be made available to the customer on completion of the works and how to redeem these.

The following general customer care guidelines should also be followed:

- Verify that the address for installation is correct, and the assessor, designer and installer identify their credentials to the customer.
- Explain to the customer the purpose of the visit and what they can expect.
- Use shoe protectors/covers when entering the property and conduct themselves appropriately.
- Advise the customer of any precautions needed e.g. removal of materials or possessions that restrict access to the wall prior to assessment or installation.
- With the customers permission, remove and protect materials and possessions if the customer is unable to do so.
- Put down dust sheets where required, to protect the customer’s property.
- Following completion of the works all packaging/waste materials must be removed from site and properly disposed of.
- Clear up any mess as soon as possible and dispose of waste in the appropriate manner.

- Ask for permission if the customer’s toilet facilities are needed.
- Avoid disputes with the customer or responding negatively to any complaints or criticism.
- Carry out a check of any pre-existing problems or defects, repair any defects that require attention and declare them to the customer before starting work and report on the pre-installation check sheet.
- If any damage is caused, however small, the customer should be informed, and the matter subsequently reported to the organisation responsible for carrying out the work. The customer should be informed that the matter will be dealt with appropriately and quickly.
- The customer should be fully informed of the work being carried out, including explanation of any areas that are not accessible (these may be whole rooms if floorboards are lifted, or dangerous structures such as scaffold towers, scissor lifts, or lighting rigs and transformers). Additionally, any openings or hazards should be appropriately cordoned/barriered or hazard tapes applied.
- Any specific safety considerations as recommended by the manufacturer of the product or system utilised should also be followed.

A customer handover checklist may be used as follows:

- [ ] Maintenance manuals for IWI associated measures (e.g. new ventilation systems, external wall finishes)
- [ ] Operation manuals for IWI associated measures (e.g. new ventilation systems)
- [ ] Physical inspection of installed IWI and associated measures
- [ ] Visual check that consumer is able to operate IWI associated measures (e.g. ventilation system)
- [ ] Simple explanation of ‘less than 100% IWI’ risks where wet rooms may have been uninsulated, and instructions on how to manage these risks.
- [ ] As-built construction details, specifications, and designs.
- [ ] Relevant warranties, insurances and/or guarantees.
- [ ] Information about the importance of ventilation and the implications of turning any ventilation off or down
- [ ] Commissioning records for any IWI associated measures (e.g. ventilation system)
- [ ] Guidance on the air barrier, what it is, where it is, and how to fix through it if necessary.

Annex C – Installation of DPCs

Physical DPCs

Physical DPCs can only be placed in brickwork or coursed stonework and are not suitable for random flint walls or rubble-infilled walls. Usually, thick walls can rarely be treated and it can be dangerous to attempt installations of this type for structural reasons if the walls have settlement cracks.

The only certain way in all circumstances of introducing an effective DPC into a wall is to insert a new physical membrane. Techniques for doing so have improved over recent years and the cutting of an old lime/sand mortar bed joint through the entire thickness of a 225mm solid wall should, in most cases, present no problems.

A tungsten-carbide tipped chainsaw is usually used and the cut made short lengths of about 1m at a time. The membrane is loaded with mortar and inserted, and a slate or plastic wedges used in the remaining gap to prevent settlement. Eventually, the cut is back-filled with mortar. In the standard solid 225 mm brick wall, the entire thickness of the wall can be cut from one side but great care has to be taken that all water and gas pipes and electrical wiring are moved out of the way. A new DPC, regardless of type, should if possible be inserted below the level of an existing suspended timber floor and as close as possible to the top screed of an existing solid floor. Any gap between horizontal DPC and solid floor membrane should be closed if necessary with a tanking type of treatment.

The advantages of the physical techniques are that the membrane can be extended internally to form a vertical DPC between any solid floors and the horizontal course, and the membrane (usually flexible black polythene) is resistant to all acids and alkalis normally encountered in building materials.

Chemical injection systems

Chemical injection systems can be used in most types of structure, although flint walls and rubble-infilled walls can be difficult to treat successfully.

Methods for installing a chemical DPC currently include high pressure, low pressure or gravity fed.

High-pressure injection (generally used for solvent-based products):

- Solid walls
  - Up to 120 mm thick: inject from one side
  - Up to 230 mm thick:
    - Drill from both sides and inject, or
    - Drill and inject from one side with the drill hole being extended and reinjected
  - Over 230 mm thick: drill and inject from one to both sides, with the drill holes

extended and reinjected progressively, with incremental drilling 100 mm in brickwork or 150 mm in masonry.

- Cavity walls
    - Treat as if each leaf is a separate solid wall and check to ensure that any debris in the base of the cavity is removed.
- Random rubble walls
    - Initially treat as for cavity walls, with the rubble fill injected subsequently.
    - High-pressure injection is undertaken using pressures of 700-900 kPa until exudes out of the masonry mortar bed joints to form a continuous band along the DPC line.

Low-pressure injection (generally used for aqueous systems, both true solutions of siliconated and microemulsion silanes or alkyl/alkoxy siloxanes);

- The DPC material is injected at a pressure of 150-500 kPa with each hole injected singly. The volume of fluid injected should be monitored and compared with the manufacturer's recommendations.

Gravity feed (used for aqueous systems, usually siliconates);

- Solid walls
    - Up to 120 mm thick: gravity feed from one side, terminating beyond the centre of the wall.
    - Greater than 120 mm thick:
        - Drill holes from one side to within 40 mm of the far face, or
        - From both sides with holes in line, terminating about 40 mm from the centre, or
        - Staggered with holes terminating within 40 mm of the far face.
    - The volume of fluid required to conform to the manufacturer's recommendations for a given wall thickness should be calculated and the process continued until all the material has been absorbed.

Hand insertion (used for injection mortars and ready-to-use thixotropic materials).

Injection mortars,

- Half-brick walls
    - Rake out the mortar to between one-third and one-half its depth and soak. Apply the injection mortar by trowel, ensuring the joints are fully back-filled to within 8 mm of the face.

Injection mortars,

- Solid walls, up to 460 mm thick:
    - Drill holes at an angle of depression of 30o to a depth equivalent to the thickness of the wall, or
    - To the same depth from both sides at staggered centres of up to 230 mm, or

- To 40 mm beyond the centre of the wall at staggered centres at nominal spacings of 115 mm.

Ready-to-use thixotropicmaterials,

- Solid walls
    - Drill holes at the base of the perpends and at a spacing of 100-150 mm in the chosen mortar course to terminate between 10-40 mm from the far face of the wall.

Ready-to-use thixotropic materials,

- Cavity walls
    - Treat from one side or treat both leaves as if they are separate walls.
    - The thixotropic material is applied by cartridge gun, caulking gun or hand pump. The delivery tube should be inserted to the full depth of the hole and the hole filled to within 10 mm of the surface avoiding air gaps.
    - The treatment of rising damp by various chemical injection systems is perhaps best summed up by the general statement that all injection techniques are likely to be less effective in non-uniform materials and where moisture contents are quite high at the injection level. Fortunately, in practice, the latter condition is rare: evidence suggests that most cases of genuine rising damp involve low enough moisture levels for an injection technique to have a significant effect, As rising damp is a seasonal effect, injections are best varied out in late summer when water tables are at their lowest and the walls are relatively dry.

Electro-osmosis

Lastly, in terms of the electro-osmosis damp proof systems, there is little laboratory and field evidence of their effectiveness, therefore caution is suggested when a solution such as this is examined.