

Retrofit Materials & Methods

Materials Components Properties
USE: Rev 15; 11/09/2017 London



Scope:

- Whole Problem Plan
- Whole House Plan
- Whole terrace plan community upgrade
- Risk management

Scope:

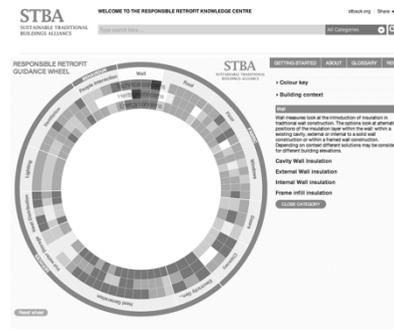
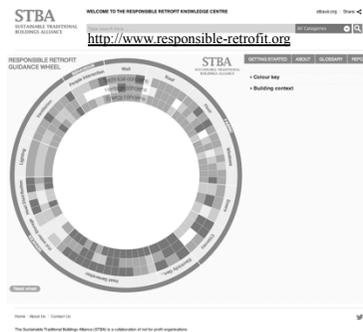
- Thermal Insulation and surrounding materials, applications and finishes
- Materials applications properties
- Materials and methods
- Strengths and weaknesses
- Appropriate applications
- Retrofit applications
- Retrofit Risks
- Risk management

Whole Problem Plan

Understand the right question(s)
before you try
to find the right answer

Risk: No joined up thinking

- Look at insulation in isolation
 - at your peril,
 - 10 minutes to introduce the problem
 - A life time to understand the solution
- Ignore valiancy:
 - one thing's ability to react with another
 - Not just at a chemical level
 - Physics of building
 - Science of materials
 - Crunching of numbers
- You need a 'whole problem plan'
 - know the destination
 - so you don't make wrong choices on the journey





Risks

- **Inadequate survey**
 - Using limited knowledge & guesswork
 - Bats & Birds not expected
- **Lack of understanding of physics**
 - Poor design & choice of materials
- **Interstitial or surface condensation**
 - Mould: asthma
 - Toxic mould
 - Death by Insulation
- **Destruction of Historic Fabric**
 - Frost damage or rot

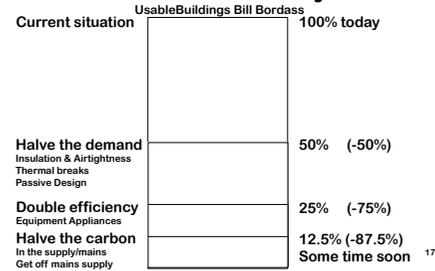
Risks: Inadequate survey

- **Inadequate surveyor**
 - Using limited knowledge & guesswork
 - Energy Performance Certificate (EPC)
 - EPC have shown how bad this can get
- **Limited access to tools**
 - Limited extent of surveys
- **Bats & Birds not expected**
 - Tell tale signs missed
 - Difficult to detect unless a BAT expert

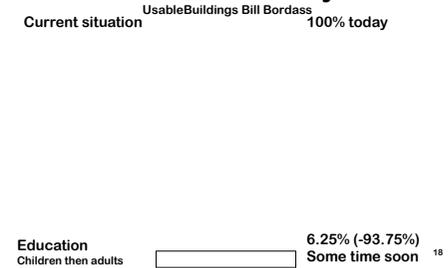
Risks

- **Assumption:**
 - About existing construction
 - About existing insulation measures
- **Inaccurate:**
 - Guesswork on thicknesses
 - based on normal construction
- **Estimation**
 - About benefits of improvements
- **Inappropriate proposals**

Achieving 80% Carbon Reduction is easy!



Achieving 80% Carbon Reduction is easy!



| Insulation thicknesses required to achieve a U-value of 0.2W/m ² K | |
|---|--|
| Cellular glass (Recycled glass e.g. Foamglas) | |
| 235mm | Cellulose fibre |
| 220mm | Glass wool fibre |
| 210mm | Rock wool fibre Slag wool fibre insulation |
| 190mm | Extruded polystyrene foam |
| 185mm | Polyurethane foam with CO ₂ |
| 180mm | Expanded polystyrene |
| 150mm | Polyurethane foam with pentane |
| 135mm | Phenolic foam |
| 130mm | Polyisocyanurate foam |
| 120mm | Phenolic foam with foil face |
| 95mm | Polyisocyanurate foam with foil face |
| 75mm | Aerogel blanket |
| 25mm | Vacuum insulation |

Don't let Thickness be your only criteria for success

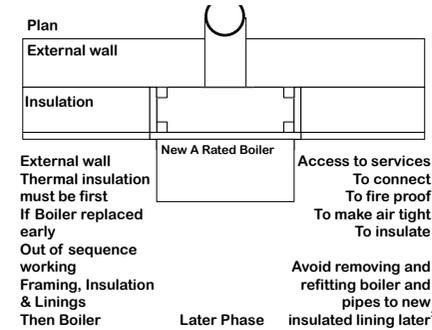
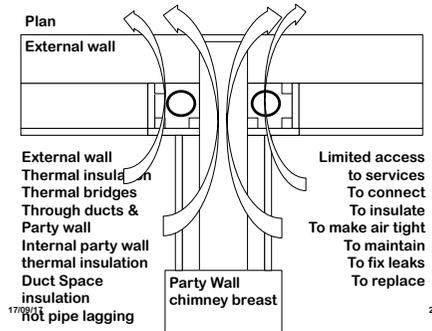
Whole House Plan

Plan the Journey

- Know your destination
- Then your meanderings all lead to the same destination
- Without detours
- Without going round in circles
- Without treading the same path twice

House plan

- Showing the final insulation regime
- Modify the services installations with the final insulation regime in mind
- Avoid servicing > undoing services > insulating > re-servicing
- Or avoid services and insulation in the same place or insulate first
- Radiators not on the external wall
- Insulate in patches then service
- Insulate wall then boiler
- Insulated underfloor heating and no radiators



Whole Terrace
Plan
Community Upgrade

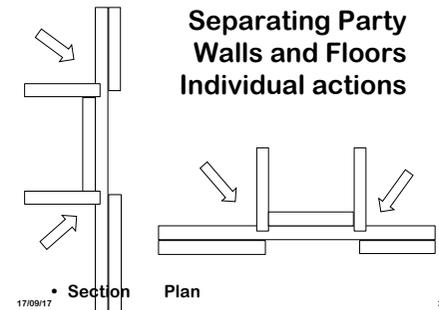
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Terraces: one at a time or many

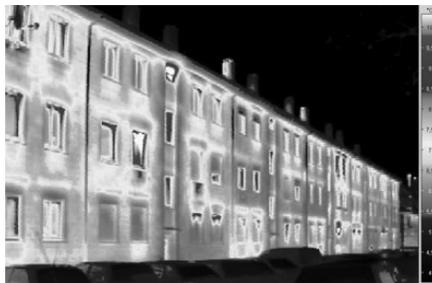
- If many people operate independently the interfaces between inconsistent approach will cause thermal bridges and patchy buildings
- Passivhaus refurbishment projects in Germany
- Bulk buying brings the costs down to affordable levels
- PAYS-like funding means all can engage
- Pay as you Save
- Preceded and tested GreenDeal
- Golden Rule

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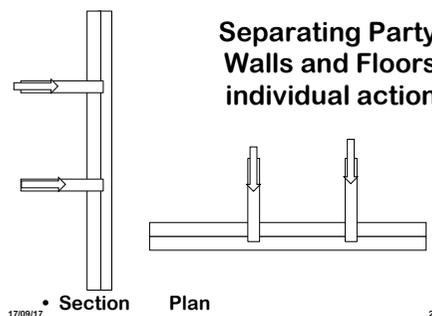


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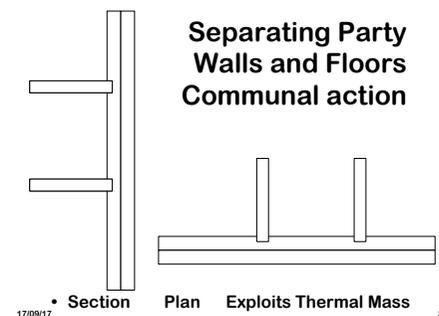


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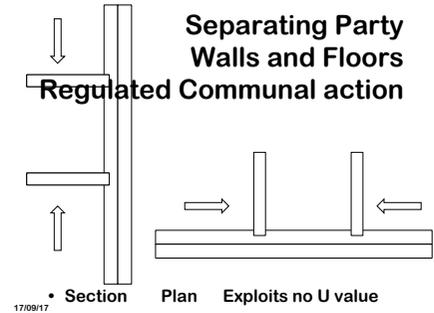
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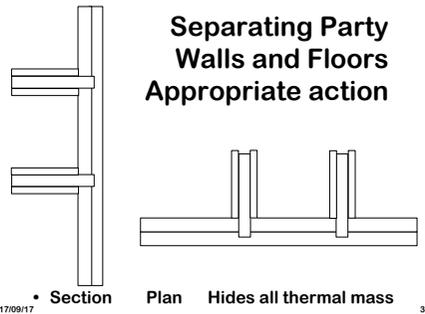
- Party walls: Cavity construction
 - Uninsulated (thermally) for acoustic isolation
 - No fire barriers or cavity compartmentation
- No U value requirement,
 - inadequate U value provided
- Cavity acts as chimney for heat loss from rooms to go to attic
- Timber framed need only be insulated one leaf
- Leeds Met Uni Research highlighted issue
- BRAD L1A has been revised
- But U values still appear to be 0.00 W/m2.K³²

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Retrofit: Materials & Properties



Choice of materials

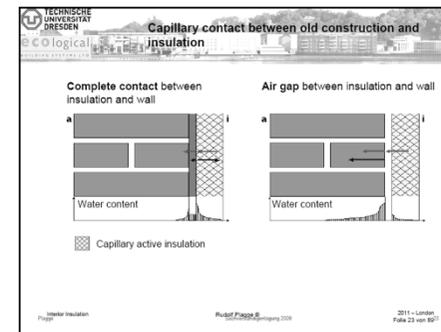
- Air space
- Mineral wool
- Expanded or extruded Foamed plastic
- Sprayed foaming plastic
- Cellular glass
- Cellular mineral
- Aerogel
- Plant based
- Cellular mineral
- Calcium Silicate
- Multifoil

Choice of material properties

- Trapped air:
 - insulation k and R values
- Open celled:
 - moisture and heat permeable, open, breathing,
- Closed cell:
 - Moisture and heat resistant
- Lightweight open materials:
 - insulating k and R values
 - Easy air movement through
- Dense materials:
 - Slow air movement through
 - Thermal mass and Decrement delay
- Surface resistivity:
 - Resists some heat from being drawn out of surface
 - Foil face also air tight, if jointed

Airspaces

- Trap air
 - Holds spores
 - Holds moisture vapour
 - Holds VOCs and other air pollutants
- Can be ventilated
 - To remove moisture vapour and pollutants
 - Facilitate wind washing to blow heat from surfaces
 - Increase air/wind leakiness
- Fluctuates in temperature
 - Can draw heat from surfaces
 - Can warm surfaces
- Can be a route for thermal flanking/thermal bypass
 - Can enable Eddie currents and stack effect
 - Can be a place for heat to dissipate into
- Provide acoustic isolation
 - But surfaces can 'talk' across cavities
- Can separate inside from outside
 - Prevent capillary attraction (if wide enough) minimum 8 mm.
 - Prevent moisture transport



Surface emissivity

- Outer and inner faces
 - of walls, roofs, floors
- Ability to absorb or release heat
- Zone outside of material's face
 - is part of this property
- Emissivity level
 - depends on the material at the surface
 - Reflective foils can reduce some heat loss
 - Steel trough formwork to concrete floor
 - Prevents exploitation of thermal mass

Low emissivity surfaces

- Foil face
 - E.g. Aluminium, Aluminised polyethylene
- Low radiation from surface
- Heat reflection back inwards
- Need air space adjacent to them to be effective
- Probably needs space both sides
- Takes up a lot of space that could have been insulation

Combustibility

- The ability of a material to combust into flame under heat or flame exposure
- UK test: BS 476:Part 6 is
- EU test: EN 13501-1
- A1 = Non-combustible
- A2 = Limited Combustibility
- B = Low risk
 - (adds flue to the file, releases smoke and releases smoldering droplets)
- C = Medium Risk (ditto)
- D = High Risk (ditto)
- E & F = Very High Risk (ditto)

Surface Spread of Flame SSoF

- Fire Performance or Property
- Enables flames to move across surfaces
- Depends on the materials at the surface
- E.g. Aluminium foil bonded to materials
- Reduces SSoF to BS 476:Part 7 Class 1
- Flames to not spread easily
- Damage the low SSoF to expose the substrate's properties

Class 0

- UK Building Regulations Approved Document B
- A combination of:
 - non-combustibility to BS 476:Part 6
 - low spread of flame to BS 476:Part 7
- It may be one material or:
 - non combustible core
 - low surface spread of flame facing

Combination

- Euro-Class EN 13501-1 Class C core is Medium Fire risk
 - A fuel in a fire situation
- BS 476:Part 7 Class 1 Surface Spread of flame facing
- If the facing is damaged in the construction stage
- A fire will find the substrate and turn it into a fuel

Retrofit: Materials



Stone, slag and glass mineral wool:

- Hydrophobic
 - Performance diminished when moist
- Middle of the road k values
- Low cost and used everywhere
 - Including all the wrong places
- Wide range of densities for applications
- Open pore
 - Moisture permeable
 - Air permeable
 - Heat permeable
 - Wind washing vulnerable
- A1 Non-Combustible or A2 limited combustibility
- Middle of the road LCA EPD PEF

Expanded or Extruded Foamed plastic

- Closed cell
 - Not moisture permeable
 - Not moisture absorbent
- Good k values
- If foil faced
 - low emissivity
- vapour barriers essential in vulnerable construction
 - Timber is vulnerable construction
- EN 13501-1 B low - F Very high fire risk
 - Flame retardant grades available
- High LCA EPD PEF

Sprayed foaming plastic

- Good airtightness
- Not moisture absorbent
- Not moisture permeable
 - Will drive moisture through adjacent stuff
 - Can rot timber
- Can entomb nature
- Can be very unhealthy to sensitive people
- EN 13501-1 B low – F Very high fire risk
 - Flame retardant grades available
- High LCA EPD PEF

Sprayed moisture permeable foamed bio-plastic

- Good airtightness
 - Until it shrinks
 - Can remain in a state of tension if bonded to surrounding surfaces
 - Can tear readily
 - Can be months later
- Good k value
- Moisture Permeable
- Won't rot timber
- Can entomb nature
- EN 13501-1 B low – F Very high fire risk
 - Flame retardant grades available
- Middle LCA EPD PEF
- Bio-plastic versions rare in the market

Cellular 'foamed' glass

- Strong, loadbearing
- High decrement delay
- Poor k values but remains effective
- Moisture resistant
- Vapour resistant
- Dimensional stability
- Frost vulnerable: Saturation possible
 - Should be protected by flood coat on roof
 - or membranes if buried
- A1 Non-Combustible

Cellular mineral:

- medium decrement value
- medium thermal mass
- Closed cell
- Airtight
- Thermal bridge by mortar joints
- Low moisture absorbency/permeable
- E.g. AAC Autoclaved Aerated Concrete
- Load-bearing

Extruded fired mineral

- Fired clay cellular block
- Extruded: hollow cells hold air still
- High decrement: Long path through cell walls
- High thermal mass at surface
- Thin bed joint: negligible heat loss
- Air leaky perpend
 - needs airtight coating: clay or lime plaster

Extruded cellular mineral

- Lime binder
- Lightweight insulating aggregate
- Extruded: hollow cells hold air still
- Medium decrement: Long path through cell walls
- Medium thermal mass at surface
- Lime mortar: neutral joint heat loss

Aerogel

- Excellent k value (better than plastics)
- Moisture permeable
- Moisture mass
- Decrement delay
- E.g. Spacetherm by Proctor Group
- Used in thermal bridge solutions
 - At perimeters abutments of insulation
 - At services interfaces
- LCA EPD PEF (no information yet)

VIPs Vacuum Insulation Panels

- Best k value available
- Hollow metal foil panel, plastic spheres supporting structure, vacuum inside
 - Foil edge and joints can let it down
 - Once punctured don't work
- High embodied energy and carbon
- Modular in nature
 - No modification on site
 - How do you deal with perimeters?
- Made to order?
- LCA EPD PEF (no information yet)

Plant based:

- Hygroscopic (absorbs moisture vapour)
- Moisture permeable
- High or low density
- Rigid: spanning
- Soft: squeezey
- Medium to high decrement delay
- Excellent acoustic insulation
- Long fasteners needed: available in UK
 - Imported from Italy, etc.
- Low LCA EPD PEF
- Carbon Negative (sequestration)

Calcium silicate:

- Open cell,
 - lightweight,
 - Moisture permeable,
- Capillary action
 - Moisture transport
- Decrement delay
- Discourages mould anti-bacterial
- Developed for historic fabric compatibility
- Very low Life Cycle Assessment (LCA)

Multilayer foil Insulation:

- Low emissivity (theoretical calculations)
- Needs air spaces both sides
 - Or each layer?
- Poor k value (optimistic literature) (Poor R)
- No thermal mass
- No decrement delay
- Vapour resistant (pierced by stitching)
- Reflective: need PPE: Eyes & skin
- Use where architect or conservation officer prevent anything else
- Don't use on their own
- Potentially low LCA
 - (very little material used)

Application of insulation

- Correct size & quantity for application
 - Avoid any/excessive compression
- Accurate sizing to fit
 - Airtight, no gaps, corners, abutment,
 - No compromises
- Correct edge profile
 - Sealed abutted
 - T&G jointed
- Offset lapped & 90 degree layers
 - minimise thermal bridging
- Cross battens to minimise thermal bridging
- Avoid metal fasteners & adhesives
 - Compress, offer up, release
 - Gravity

**Retrofit:
Components**



**Supporting materials
Components**

- Vapour barriers
- Breather membranes
- Airtightness layer
- Wind tightness layer
- Breathing Sheathing Board
- Breathing Roofing Membranes
- Multifoil Breathing Roofing Membranes

Vapour barriers

- Used inside of insulation/construction
 - Used with Breather Membranes outside
- Vapour resistant
 - Vapour check if inadequate
- Leaks are inevitable
 - Leaks can be harmful
 - Sealing of leaks is exceptional
- Compromise is inevitable
- Compromise is unacceptable

Breather membranes

- Used outside of insulation/construction
 - Used with vapour barriers inside
- Walls or roofs (framed constructions)
 - Weather protection (until covered)
- Vapour permeable
 - Building paper
 - Polyethylene/Polyolefine
 - Can be 'intelligent'
 - properties vary with atmospheric moisture
- Long protection fibres can be harmful to bats through entanglement
- Traditional bitumen impregnated fibre
 - Very few bats trapped in short fibres

Airtightness layer

- Used inside of insulation/construction
 - Used with wind tightness layer outside
 - Usually timber/metal framed
- Materials:
 - Some paper and cellulose
 - Polyethylene/Polyolefine
- Airtight
- Vapour permeable
 - Can be 'intelligent':
 - variable properties with atmospheric conditions

Wind tightness layer

- Used outside of insulation/construction
 - Used with air tightness layer inside
- Materials: polymer
- Vapour permeable
 - Can be 'intelligent'
 - properties vary with atmosphere
- Wind tight
- Weather resistant
- Can be roofing underlay, often is

BRM Breathable/Breathing Roofing Membranes

- Used outside of insulation/construction
 - Used with air tightness layer inside
- Vapour permeable
 - Polyethylene/Polyolefine
 - Can be 'intelligent'
 - properties vary with atmosphere
- Wind tight
- Weather resistant
- Currently under BCT investigation
 - Research ongoing
 - So far all long chain fibres risk bat entanglement/entrapment/death by starvation

Breathing Sheathing boards

- Used outside of insulation/construction
 - Used with air tightness layer inside
 - Often used outside of structural framing
- Rigid and span over framing
- Vapour permeable
- Wind tight
- Weather resistant (some two grades)
- Usually thermally insulating
- Usually acoustically insulating
- Can eliminate thermal bridges
 - through structural framing
- Low LCA EPD PEF
- Biogenic Sequestered Carbon

Multifoil Breathing Roofing Membranes

- Used outside of insulation/construction
 - Used with vapour barriers inside
- Vapour resistant but punctured by stitching: so vapour permeable
- Wind tight but punctured
- Weather resistant but punctured
- Can be thermally insulating
- Can be acoustically insulating
- Can be reflective Sun glasses PPE
- Has no decrement delay

Retrofit: Supporting Accessories

Supporting materials Components

- Meshes (supporting insulation)
- Netting (supporting insulation)
- Trays (supporting insulation)

Metal Meshes

- Can exclude insects and permit others
- Used to support insulation
- Were recommended
 - for bats to hang from in place of BM or BRM
 - Sharp internal acute angles
 - Jagged cut edges
 - Can trap bats and birds
 - No longer recommended
- High embodied Energy

Netting support to Insulation

- Support thermal insulation in timber floors
- Separate services from insulation
- Avoid up-rating of electrical cables
- Maintain void for down-lights
- Stapled into place
- Very complicated to install
 - Labour intensive, slow, inaccurate
 - Inconsistent insulation zone probable

Insulation support trays

- Support thermal insulation in timber floors
- Simplification of installation of insulation top or bottom of cavity
- Separate services from insulation
- Avoid up-rating of electrical cables
- Maintain void for down-lights
- Double skin polycarbonate, very thin
- Scored for folding
- Punched for air/moisture passage
- Stapled into place
- Liked by installers & all adjacent trades

Retrofit: Proofing



Proofing material Components

- Damp proof membranes
- Damp proof but vapour permeable membranes
- Damp/Gas proof membranes
- Drainage and trickle layers
- Thermal Breaks
- Cavity Fire & Smoke barriers

Damp proof membranes

- Below ground bearing floor
- Below any thermal insulation
 - to keep it dry and effective
- Ground water resistant
 - If joints lapped and bonded
- Ground gas/vapour resistant
 - if joints lapped and bonded

Damp proof but vapour permeable membranes

- E.g. Bentonite clay powder between geotextile layers
- Sourced from USA
- Below ground bearing floor
- Below any thermal insulation
 - to keep it dry and effective
- Ground water resistant
- Ground vapour resistant only when wet
- Ground vapour permeable when dry
- Ground gas Radon Methane permeable

Damp/Gas proof membranes

- Below ground bearing floor
- Below any thermal insulation
 - to keep it dry and effective
- Above any ventilation labyrinth
- Ground water resistant
 - If joints lapped and bonded
- Ground vapour resistant
 - If joints lapped and bonded
- Ground gas Radon Methane resistant
 - If joints lapped and bonded

Drainage and trickle layers

- Below ground bearing floor
- Below any thermal insulation
 - to keep it dry and effective
- Allows water downwards
- Resists ground water upward transport
- Won't stop water table rising
- Not ground gas resistant
- Not flood resistant

Retrofit: Thermal breaks

Thermal breaks: Floor/wall

- In inner leaf of external wall
- In loadbearing internal walls
 - aligned with floor insulation
- To stop thermal flanking through wall at perimeter of building and internal walls and their abutments
- E.g. Cellular glass and bitumen coating
- E.g. Extruded plastic with loadbearing metal posts

Thermal Breaks: Foundation/Wall

- Below ground cavity external wall
- Cavity usually filled with concrete to ground level
- To occupy space that could fill with ground water
- To prevent water getting into cavity insulation
- To prevent thermal flanking through perimeter wall below ground floor
- Cellular glass, bitumen coated, profiled

Thermal break: Wall opening jamb closer

- Linking inner leaf to outer leaf
- Was brick
- then block inner leaf with block slithers
- Then purpose made block return
- Always cutting and waste
- Then insulated/damp proof course/ties / opening former
 - pvc extrusions
- Now wide cavities: avoid closers use plywood box frame and cavity insulation

Thermal breaks: Lintels

- Hardwood
- Concrete: precast, prestressed, insitu trough lintel thermal bridge
- Extruded fired clay trough lintel
- Steel compound sections
 - Steel thermal bridge
 - Insulated core (non functional)
 - 2 piece lintels: Plastic thermal break
- Pultruded mineral/fibre reinforced
 - Limited span thermal break
- Steel inner-pultruded outer composite

Thermal Break: Wall ties

- Galvanized mild steel
 - Can be bent and galvanizing will fail
 - Have rusted away
 - Have been coated in plastic
 - reacted with plastic foam cavity insulation
- Stainless steel
 - Longer to suit wide cavity
 - 2 part, connected to complete
 - Sharp protrusion, risk of harm
- Pultruded mineral/fibre rod & drip ring

**Thermal Break:
Window and Door Jamb**

- In solid masonry external walls
- Add high performance window/door
- Add wall insulation:
 - external or internal
- Creates thermal bridge diagonally between window/door and internal/external insulation
- Insulated jambs: very little space so high performance is needed
- 5 to 20 mm Aerogel to jambs

**Thermal Breaks:
External Wall Insulation**

- Thick external wall insulation
- Perimeters:
 - ground level,
 - above pitched or flat roof abutment,
 - eaves behind gutter
- Services interfaces
 - Behind SW&VP
 - Behind Gutter and Downpipes
- Foil wrapped Aerogel and metal profiles
- Any other interfaces
 - Plastic spacers

**Retrofit:
Cavity Barriers**

Cavity Fire & Smoke barriers

- Non-combustible materials
- Used in construction containing cavities
- To subdivide the cavity into small areas
- To reduce risk of smoke, heat, fire, flashover or confined space explosion jumping from one cavity to another
- Preventing the fire progressing from one part of the building to another

**External Envelope &
Services Apertures**

- Outgoing:
 - Boiler Flues/Balanced Flues
 - Extractor Fans/with heat recovery
 - WC overflows
 - Soil Waste and vent Pipes
- Incoming:
 - Power, Electricity,
 - Communications, Telephone,
 - Broadband, Cable, TV aerial, Satellite Dish
- Holes cut, services inserted, aperture sealed
- Air/Wind tightness, Acoustic, Thermal, Fire

**Retrofit:
Finishes**



Finishing materials

- Gypsum plaster and skim
- Cement render
- Lime render/plaster
- Clay render/plaster

Gypsum

- Plaster or skim
- Lightweight thermally insulating normally
- Dense versions available
- Moisture resistant
- Low absorbency
- No moisture transport
- Needs to be removed if insulating solid masonry internally

Cement Render

- Internally
- High Thermal mass
- Decrement delay
- Closed to moisture permeability
- moisture resistant
- Condensation risk high
- Needs to be removed if insulating solid masonry walls internally

Cement Render

- Externally
- Strong
- Weather excluding
 - Drying shrinkage cracks lets it in
- Closed to moisture permeability
- Moisture resistant
- Traps internal moisture
- Never apply over historic fabric

Lime render

- Externally
- Soft and weak
- Moves with soft weak background
- Less likely to crack
- Moisture permeable, open
- Slow set, carbonation
- Breathing
- Anti septic, anti moulds
- Alkali and potentially harmful
 - Not for DIY

Lime plaster

- Internally
- Moisture permeable, vapour open
- Slow set, slow carbonation
- Breathing
- Moisture mass
- Low condensation risk
- Anti septic, anti mould
- Alkali and potentially harmful
 - Not for DIY

Clay plaster

- Moisture permeable
- Dries but not set: easy to repair & DIY
- Breathing
- High Moisture mass
- High density
- High decrement
- Low condensation risk
- Absorbs radiation
- Absorbs smells

Decoration

- Oil based
- Micro-porous stains & paint
- Lime wash
- Clay based finish

Oil based

- Skin forming
- Traps moisture
- Moisture resistant
- Barrier to vapour
- Condensation resistance needed
- Mould resistance needed
- Use on inside of external joinery

Micro-porous stains and paints

- Weather resistant
- Vapour permeable vapour-open
- Breathing
- Use on outside of external joinery

Lime wash

- Moisture vapour permeable
- Anti-septic
- Use inside or outside of vapour permeable construction
- Whitewash
- Also available with colour

Clay based finish

- Moisture permeable
- Breathing
- High Moisture mass, but thin
- High density, but thin
- Decrement, but thin
- Low condensation risk
- Absorb radiation
- Absorbs smells
- Available with long life mineral colours

Insulating paints

- MPs ambition!
- Wishful thinking?
- Its partly about nanotechnology and spray apertures
 - Is there a health risk?
- Its also about aerogels
- Low condensation risk?
- Low emissivity and bounces heat back
 - Warm to touch

Retrofit: Risk Management



Delegate's Proposal and my reactions

- Risk Management:
 - Go ahead with unproven solutions
 - but monitor and inspect
 - Inspection access compromises integrity
 - Go ahead but make it undoable
 - Like EA's Sacrificial Construction in flood plains
 - Don't do it to too many
 - Too many to correct if it goes wrong
 - People have to live in your experiments
 - and put up with your error correcting exercises
 - Do many different experiments
 - to a few buildings at a time
 - Do understood, designed, competent things to many buildings at the same time

Feedback

- These files are created by generalists with a big dollop of green flavour
- These files are updated from time to time
- We are not experts so from time to time these file may get out of date or may be wrong.
- If you feel that we have got it wrong please let us know so we can put it right¹⁵

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- Brian Murphy BSc Dip Arch (Hons+Dist)
 - Architect by Training
 - Specification Writer by Choice
 - Environmentalist by Actions
- Greening up my act since 1989
- Founded National Green Specification 2001
- Launched www.greenspec.co.uk 2003
- Created: GBE at <http://greenbuildingencyclopaedia.uk> 2015
- E BrianSpecMan@aol.com
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