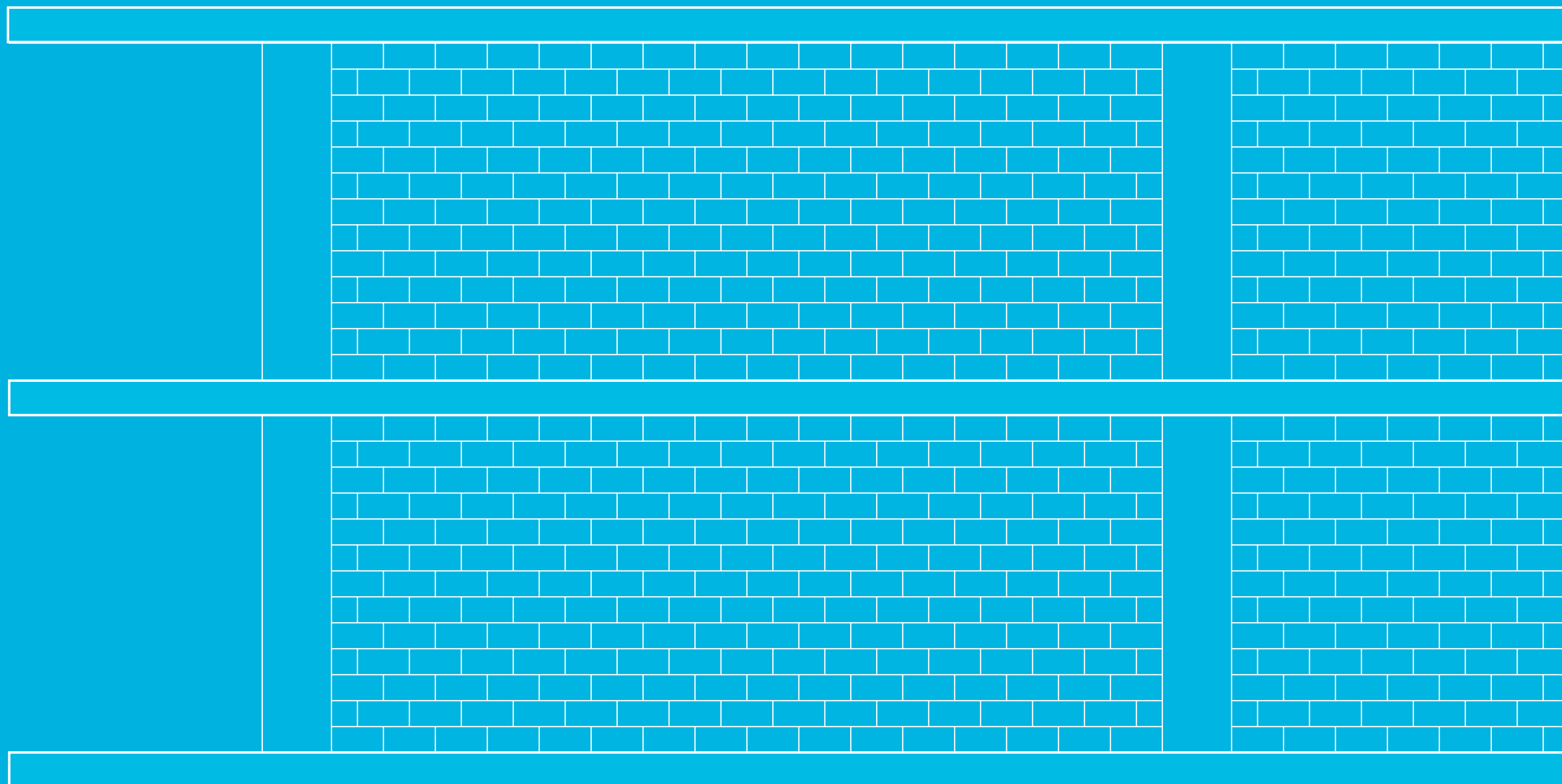
Guide 2:

CONCRETE FRAME



commissioned by:

ZERO CARBON HUB

www.zerocarbonhub.org

written by:

Richards Partington Architects

www.rparchitects.co.uk

in association with:

mpa The Concrete Centre

www.concretecentre.com

Richards Partington Architects
www.rparchitects.co.uk

BUILDING LOW CARBON HOMES

Published by NBS

What is Good Practice Construction?

Good practice in building can only be achieved through the collaboration of many parties throughout the processes of design, construction, assessment and commissioning. These guides explain some of the improvements in building techniques and processes that will be necessary for the delivery of low and zero carbon housing.

The guide will help designers and builders who are familiar with the new Fabric Energy Efficiency Standard and now want to work up well-insulated and airtight solutions and in-situ concrete framing. It is concerned with using pre-cast building fabric only and does not deal with energy supply, heating or mechanical ventilation.

This is one of a series of guides, produced with the assistance of industry sponsors. Each guide covers a different construction system and includes an explanation of the key issues, checklists for designers and contractors, together with a case study.

CONCRETE FRAME

Concrete frame construction in house-building is typically specified for large blocks of flats, where the number of storeys exceeds the limits of load-bearing masonry. The majority of new apartment buildings in the UK are medium rise developments and this booklet, therefore, focuses on medium rise construction (4-10 storeys).

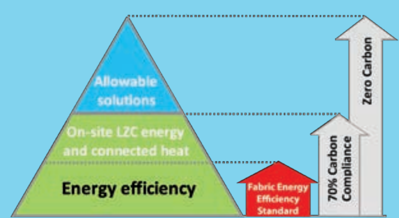
Concrete frame is an extremely versatile method of building, as the frame itself can be dimensioned to exactly suit the specific requirements of the building layout and site geometry. Furthermore, there are a wide range of options for infilling the frame and cladding the exterior. However, some of them are less well suited to achieving good practice levels of insulation and airtightness.

The best thermal performance with concrete frame construction will generally be achieved by having the insulation on the outside of the structure, not in an intermediate zone. Systems that require large numbers of structural fixings to bridge the insulation layer do not represent good practice. Similarly, framed infill panels within the concrete frame can have lower thermal performance and may be more difficult to make airtight when compared to externally insulated build-ups. Construction tolerances and frame deflections need to be carefully considered.

As an example of good practice, the diagrams in this booklet are based on solid block infill, a good way of providing airtightness, and an external insulated render system. The diagrams also address heat loss and thermal bridging issues for common areas, lift shafts and service risers.

FABRIC ENERGY EFFICIENCY STANDARD

Fabric energy efficiency is the foundation of the Government's zero carbon homes policy. It will ensure that all new homes are sufficiently well insulated and constructed to meet ambitious energy saving targets. It will discourage the tendency to use low and zero carbon technologies as an alternative to energy efficiency measures, by requiring energy demand to be reduced first.



The diagram on the right illustrates the hierarchy of measures, which together form the approach to zero carbon. 'Carbon Compliance' (a reduction in carbon emissions from 2006 levels) will be achieved by building homes to the Fabric Energy Efficiency Standard supplemented by on-site low and zero carbon energy sources. Full zero carbon will be achieved through the provision of 'Allowable Solutions', which include options for off-site renewable energy generation. The Fabric Energy Efficiency Standard is a performance standard that can be achieved by a variety of approaches. However, the guide gives an indication of the likely minimum U-value of each component of the building.

Key Issues

Houses built today have high levels of insulation, double glazed windows and often highly efficient heating systems. However, new houses are not often tested to see whether they are as energy efficient as predicted.

Research* has indicated that some new homes do not always meet the required standard in practice. So what can be done to close this performance gap?

The answer lies partly in better detailing and good quality workmanship, but above all it requires everyone involved in the project to be sufficiently aware of the issues to enable them to do their job well.

The key issues affecting good practice construction are:

1. **Thermal Performance**
2. **Thermal Bridging**
3. **Thermal Bypass**
4. **Airtightness**
5. **Sequencing**

* 'Lessons from Stamford Brook - Understanding the Gap between Designed and Real Performance' by Leeds Metropolitan University and UCL, 2007.

KEY

- Insulation
- Airtightness zone
- Air flow
- Thermal bridge
- Heat transfer

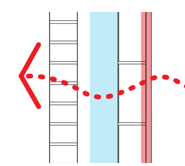
Issue 1: Thermal Performance

Each 'element' of the building envelope – a wall, a roof, a floor, a window or a door – has a role to play in minimising heat loss. The insulating effect of each of these elements is measured by its U-value; the lower the U-value, the better its thermal performance.

The insulating effect of a building's external envelope is normally the most important aspect of its thermal performance, since more heat is lost through the fabric than in any other way.

When U-values are calculated, the thicknesses and insulating properties for each of the different layers of material that make up the building element are taken into account, including fixings such as wall ties.

The phrase 'thermal mass' has become increasingly common in the context of best practice construction. It refers to the ability of materials to absorb and store heat. Heavy materials such as concrete, brick and stone have high thermal mass, which can help to stabilise internal room temperatures by absorbing excess heat from the air and releasing it slowly when conditions are cooler.



Heat loss through a wall. Increased levels of insulation will reduce the rate of loss.

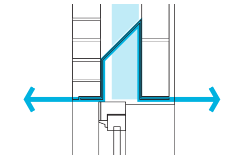
Issue 2: Thermal Bridging

Thermal bridges or cold bridges are weak points in the building envelope where heat loss is worse than through the main building elements. In a well insulated building thermal bridges can account for up to 50% of all heat loss.

There are two main types:

Non-repeating thermal bridges include items such as cills, lintels and jambs, which typically span between the inner and outer skins of a wall.

Geometrical thermal bridges occur at junctions between building elements, such as between the walls and roof, and at changes of geometry, for example a corner in a wall or a hip in a roof.

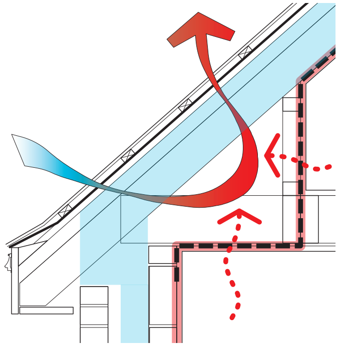


Thermal bridging through a standard steel lintel.

To conserve energy and to prevent cold spots where condensation and mould can form, thermal bridges need to be minimised. It is not possible to avoid all thermal bridging, but the effect can be minimised with careful detailing. It is more difficult to avoid thermal bridging caused by poor workmanship, for example mortar snots in the cavity or missing insulation. Even if thermal imaging cameras are used to detect the problem, it will often be too late to avoid expensive remedial works.

Issue 3: Thermal Bypass

Thermal bypass is the movement of unheated air within cavity party walls or through spaces such as under-floor voids and lofts, resulting in heat loss.



The thermal bypass occurs when the airtightness barrier does not follow the insulation.

The diagram above shows a thermal bypass effect at eaves level where cold air is able to permeate the insulation and carry away heat from the void between the insulation and the airtightness barrier.

Until recently thermal bypass was not widely recognised and so there is currently no method available to estimate its effect.

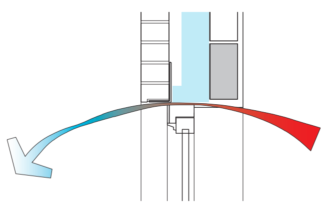
However, there are straightforward design measures that will help to limit or even eliminate thermal bypass heat loss. Ensuring that cavity walls are sealed top and bottom is essential. In other situations such as roofs it is particularly important to ensure that any airtightness barrier follows the line of the insulation to avoid creating unheated spaces between the two.

Issue 4: Airtightness

Airtightness means preventing air leaking through gaps and cracks in the external envelope and is defined by the rate at which air escapes when the building is pressure tested. Air leakage results in the loss of heated air from inside the building and can significantly increase fuel use.

Good practice construction requires air permeability rates to be much lower than the maximum level set by Building Regulations. A common strategy to improve airtightness is to clearly identify the airtightness barrier, which is the component within each part of the building envelope that provides an airtight seal. Particular care is needed where one part of the airtightness barrier meets another.

It is essential to ensure healthy living conditions for the occupants through adequate ventilation, but air leakage should not be relied on to provide this, as it was in the past. Instead, controlled ventilation either by natural or mechanical means should be provided in accordance with the Building Regulations.

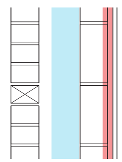


Air leakage can occur around badly fitting components such as window frames.

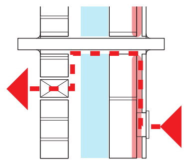
Issue 5: Sequencing

Out-of-sequence work can prevent other work stages from being completed properly, or damage work that has already been done, with serious consequences for the airtightness and thermal performance of the building envelope.

Before:



After:

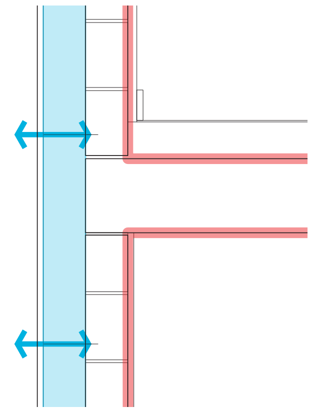


A services installation through a wall resulting in a difficult-to-seal air leakage path.

Out-of-sequence services installation is a major cause of air leakage from buildings. Holes and fixings for services can puncture airtightness barriers and can often be too awkwardly located to seal up afterwards.

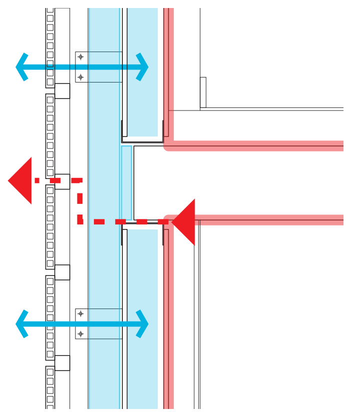
Properly planned projects include testing and inspections at key stages so that any remedial measures can be carried out in a timely and cost-effective manner. Early coordination between the designers and the construction team can help by agreeing suitable locations for services and developing strategies for effective making-good of any necessary openings.

CLADDING AND INFILL CHOICES



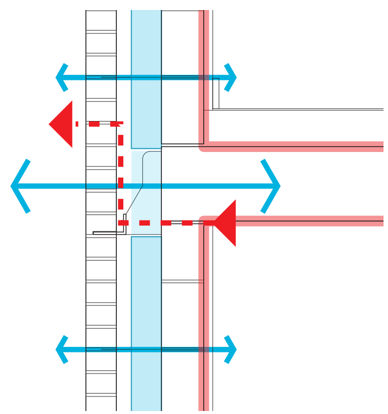
Insulated render systems on solid infill:

- Minimal cold bridging from mechanical fixings.
- No significant cold bridges.
- Easier to achieve airtightness with solid masonry infill, though tolerances and deflection must be considered.
- External skin can be more prone to damage in some situations.
- Limited range of finishing options compared to supported cladding or masonry.



Rainscreen systems with framed infill:

- Wide variety of finishes including metal, terracotta and fibre cement.
- Avoids 'wet' trades.
- Support brackets for cladding should be carefully designed - these may create thermal bridges.
- It can be difficult to achieve airtight seal around infill panels, especially with prefabricated panels.
- Services zone required to avoid damaging line of airtightness.



Supported masonry systems:

- Use traditional trades and skills.
- Masonry support angles can create significant cold bridging.
- Difficult to fit insulation around support brackets.
- Wall ties and wind-posts must be accounted for in U-value and bridging calculations.

CASE STUDY: One Brighton, Brighton

Project Information

One Brighton is a mixed-use development providing 172 apartments, 972 m^2 community space and 1206 m^2 commercial space. The project aims to provide a low-energy environment that is built to support BioRegional's ten principles of 'One Planet Living'.

First Phase completed in 2009.

Developer: BioRegional Quintain LLP in partnership with Crest Nicholson.

Research: BioRegional Quintain LLP, Feilden Clegg Bradley Studios, Natural Building Technologies (NBT).

Specification:

External wall: U-value: 0.21 W/m^{2}K
Roof: U-value: 0.19 W/m^{2}K
Floor: U-value: 0.19 W/m^{2}K
Windows: U-value: 0.80 W/m^{2}K
Curtain walling: U-value: 1.60 W/m^{2}K
Structural glazing: U-value: 1.80 W/m^{2}K
Rooflights: U-value: 1.80 W/m^{2}K
Doors: U-value: 1.00 W/m^{2}K
Thermal bridging: y-value = 0.04 W/mK
Airtightness: 5 m^3/(h.m^2)
Heating: Communal biomass boiler
Ventilation: Mechanical Ventilation with Heat Recovery (MVHR)
Power: Photovoltaics and bulk purchased renewable energy generated offsite

Ambition & Research

A primary objective of the developer was to design the project to achieve Zero Carbon. This means making buildings more energy efficient and delivering all energy with renewable technologies. The design team worked closely with NBT to select suitable materials for an energy efficient building envelope. This included taking a study trip to Germany where some of the construction techniques considered are more commonplace.

Key Design Criteria

- The building envelope was to achieve an average U-value that would exceed the 2006 Building Regulations.
- The external wall build-up was to be made of natural, breathable building products.
- An external wall insulation system was selected to minimise thermal bridging.
- A structure with high thermal mass was required to help maintain stable temperatures within the properties.
- Airtight construction to minimise heat loss through air permeability and make best use of heat recovery.

Design & Construction

- **Thermal performance:** The building uses a concrete frame with post-tensioned in-situ concrete floors. The frame is infilled with extruded clay blocks using thin-bed mortar. The frame, blockwork and exposed concrete soffits provide thermal mass to help regulate internal temperatures. The clay blocks are insulating, so the external insulation only needed to be 100 mm thick to achieve the target U-value.
- **Thermal bridging:** The insulated render system minimises repeating thermal bridges, as it avoids major fixings through the insulation layer. The reduction in joint size of the thin-bed blockwork also helps to reduce thermal bridging.
- **Thermal bypass:** There is insulation between the apartments and the common spaces, which are unheated. With this strategy designers should be aware of the potential for vertical risers and lifts shafts to become a route for thermal bypass.
- **Airtightness:** In-situ concrete floors provide a robust air barrier and do not require additional membranes. Tapes were used to seal joints between the frame and the infill, service penetrations and internal metal stud walling.
- **Sequencing** To ensure the design standards were actually delivered by the contractor, performance criteria were included within the building contract. The contractor also appointed NBT to provide specialist site supervision.

Testing & Monitoring

Air pressure tests indicated an average air permeability rate of 4, an improvement on the target of 5. This was despite initial air-leakage problems which were detected early and corrected. Heat loss testing and thermal imaging were carried out upon completion to determine actual heat losses and pinpoint any problem areas in the construction. These test results are due to be published by the Good Homes Alliance.

Summary

One Brighton illustrates a very effective approach to achieving the best performance with a concrete frame construction. The use of external wall insulation helped to reduce thermal bridging and achieve good airtightness. Keeping the design of the elevations simple has also helped to improve thermal performance because complex details often result in thermal bridging.
The project suggests that getting the contractual and on-site arrangements right is as important as the design itself.

© Feilden Clegg Bradley Studios

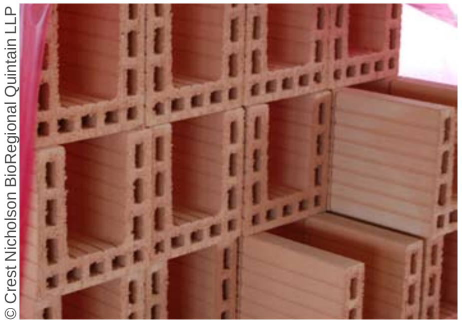
An insulated render external skin can help minimise thermal bridging. It also helps to simplify the façade design.

© Crest Nicholson BioRegional Quintain LLP

Wood fibre insulation is fixed directly to the thin-bed blockwork with plastic fixings. The blocks themselves are good insulators.

© Crest Nicholson BioRegional Quintain LLP

Tapes seal the joint between the blockwork and concrete floors where air leakage could occur.



© Crest Nicholson BioRegional Quintain LLP

Special hollow blocks are used to encase the wind-posts so that they do not interrupt the airtightness line.

How to use this chart

This page illustrates some of the common issues that can affect the energy efficiency of concrete frame construction. The information is split into three categories:

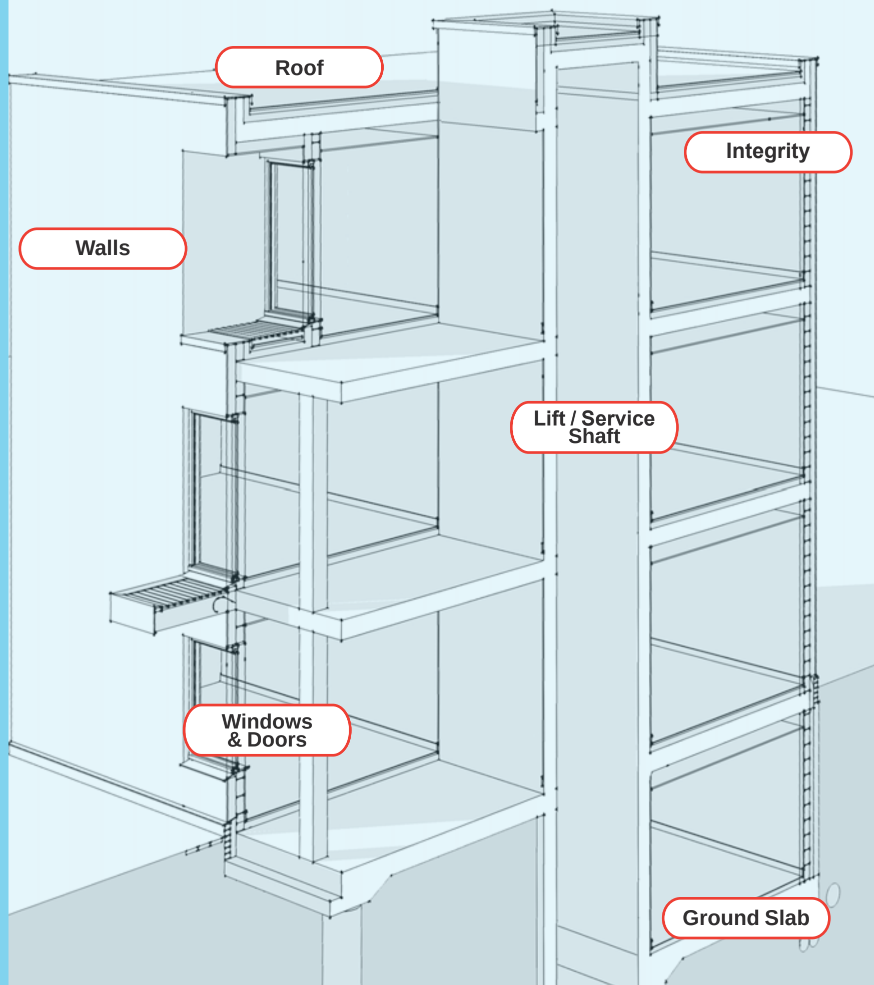
Common Issues: prompts which look at the principles behind achieving energy efficient concrete frame design.

Diagrams: to illustrate specific junctions where additional attention of designers and contractors will be required. The diagrams are intended to illustrate issues rather than present construction solutions.

U-value Guide: to the likely U-values the Fabric Energy Efficiency Standard will demand.

The prompts and diagrams have a common colour coding to differentiate whether issues concern thermal performance (red), thermal bridging (green), thermal bypass (yellow), airtightness (blue), sequencing of works (purple).

CONSTRUCTION ISSUES



Walls Likely Wall U-value: 0.18 W/m^{2}K

In U-value calculations consider all of the different conditions at column faces and slab edges as well as the typical infill. Make sure that thermal bridges for support systems and fixings are also accounted for.

Ground Slab Likely Ground Floor U-value: 0.18 W/m^{2}K (detached 0.14 W/m^{2}K)

The ground slab should be fully insulated. In concrete frame construction there may be areas where particular consideration is needed, for instance where the slab is suspended above an undercroft or where the slab is continuous with retaining structure and lift-pits.

Roof Likely Roof U-value: 0.13 W/m^{2}K (detached 0.11 W/m^{2}K)

Flat roofs usually present an opportunity to achieve high levels of insulation but be aware of the potential thermal bridges around parapets, upstands, kerbs and rooflights. Also consider the impact of rainwater outlets, drainage and services on the thermal and airtightness layers.

Windows & Doors Likely Window U-value: 1.4 W/m^{2}K (detached 1.3 W/m^{2}K)

Lintels that span between the inner and outer leaves should be avoided, as this will create a thermal bridge through which excessive heat loss will occur. Particular care needs to be taken where windows and doors are prefabricated rather than custom sized to site measurements. The closers and fillers used to take up construction tolerances are weak points in both the thermal and airtightness layers. Full height windows and balcony doors will have threshold and head details where the same weaknesses occur.

Lift / Service Shaft Likely Party Wall U-value - 0 (if sealed and filled cavity)

To avoid heat loss through thermal bypass, all uninsulated spaces such as lift shafts should be separated from the heated spaces with continuous insulation.

Integrity Airtightness - 3 m^3/(h.m^2)
Thermal Bridging - 0.05 W/mK (detached 0.04 W/mK)

A strategy for addressing airtightness and thermal bridging issues should be considered during the detailed design. In circumstances where proprietary cladding and infill framing are used there will be bespoke conditions that may not be covered by standard 'accredited' details for thermal bridging. Thermal bridging analysis or calculations may be required and manufacturer's performance data should be carefully scrutinised.

Disclaimer

This chart shows general points of principle for those designing and constructing low carbon homes. Practitioners should apply appropriate expertise in developing their own specific construction details.

COMMON ISSUES: PROMPTS

1 THERMAL PERFORMANCE:

- Review all the details for breaks in the continuity of the thermal insulation, especially around secondary framing.
- Clearly indicate where additional insulation is required to fill voids.
- Protect cavities and keep clear of mortar droppings.
- Tape insulation boards carefully to prevent air flow through gaps and behind insulation.
- Minimise the number of mechanical fixings and consider proprietary adhesive systems for fixing insulation.

2 THERMAL BRIDGING:

- Review the details and make sure thermal bridging is accurately accounted for in calculations.
- Ensure that the insulation layer is continuous, especially over composite constructions and where frame and infill meet.
- Build insulation in tightly around gaps under cavity trays, support angles and around wall ties and penetrations.
- Avoid bridging at balconies, canopies, cills and lintels.
- Ensure that cladding support systems are thermally efficient.

3 THERMAL BYPASS:

- Design out voids between heated spaces and the line of insulation, especially at service risers, balcony, recesses and party walls.
- Ensure that the airtightness barrier follows the inside line of the insulation layer.
- Seal floor voids from vertical cavities, especially party walls.
- Carefully design walls enclosing unheated corridors, lift shafts and service risers to prevent heat loss or bypass.

4 AIRTIGHTNESS:

- Make sure a continuous airtightness barrier is identified on all drawings.
- Are the locations of laps and wrapping clearly marked and communicated?
- Provide checklists to aid site supervision.
- Sequence other trades to ensure a continuous airtightness barrier to the inside face of the wall.
- Be aware of trades that may breach the airtightness barrier: electrics, mechanical services and finishes.
- Pay particular attention to details where there are variable gaps between elements to accommodate deflection or tolerances.

5 SEQUENCING OF WORKS:

- Parge coat applied before mechanical and sanitary fittings have been installed.
- Installation of all components that define the airtightness line coordinated, with minimum dependence on mastic sealant.
- Service penetrations through insulation coordinated with installers to ensure all gaps are sealed.
- Air pressure testing carried out at different stages of construction so problems are picked up early.
- Insulation to base of walls installed before floor goes down.

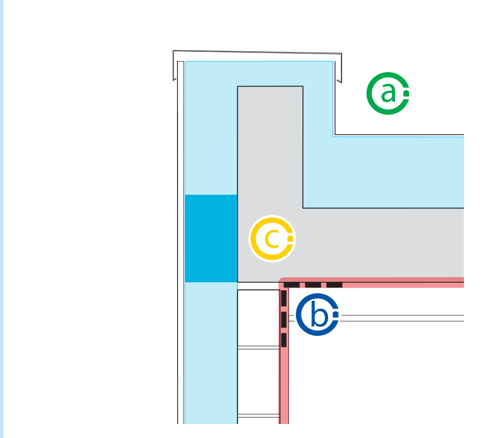
KEY:

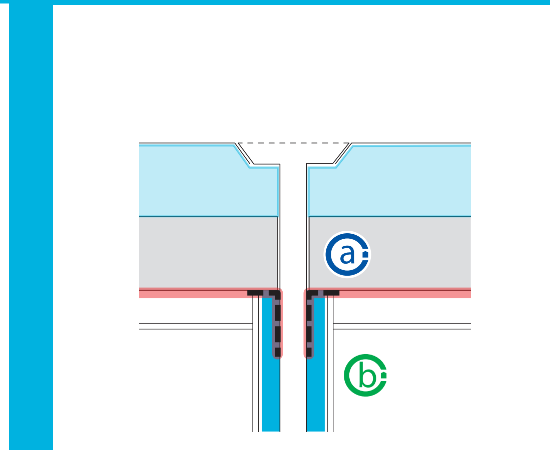
- Insulation
- Insulation particularly prone to accidental omission and where extra care is needed (insulation may need to be profiled/shaped to fit in these locations)
- Line of airtightness barrier
- Physical membrane used to form airtightness barrier where construction is prone to air leakage

ROOF DETAILS

ROOF 01: PARAPET

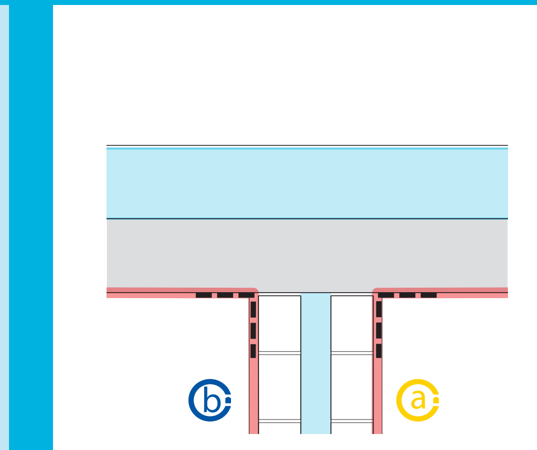
a. Provide insulation to each side of the upstand along the entire length of the parapet to minimise thermal bridging.
b. Infill blockwork must be carefully constructed to ensure airtightness, especially at the head of the wall.
c. Ensure there are no voids behind the insulation, especially where it passes over junctions between frame and wall.





ROOF 02: RAINWATER OUTLET

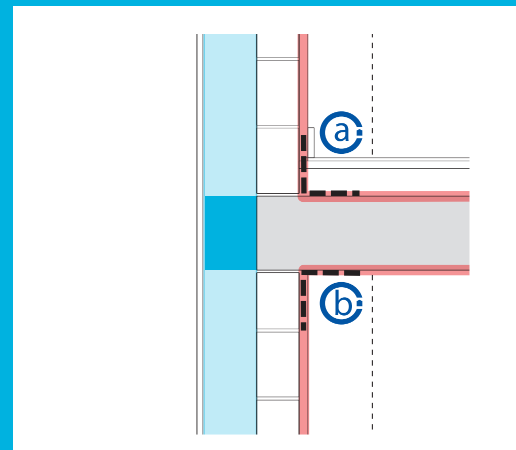
a. Ensure holes in slab around downpipes are filled to create airtight seal. Tape junction between downpipe and underside of concrete slab.
b. Downpipe to be insulated to reduce cold bridge. Unavoidable thermal bridge to be accounted for in calculations.



ROOF 03: PARTY WALL

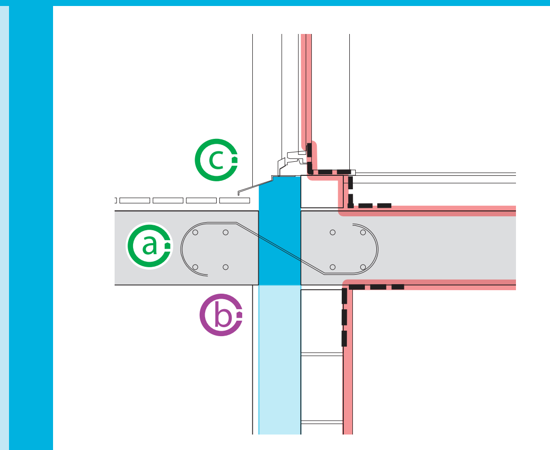
a. Consider a fully filled cavity to prevent heat loss.
b. Party wall blockwork must be carefully constructed to ensure airtightness. A parge coat or solid plaster finish is recommended.

WALL DETAILS



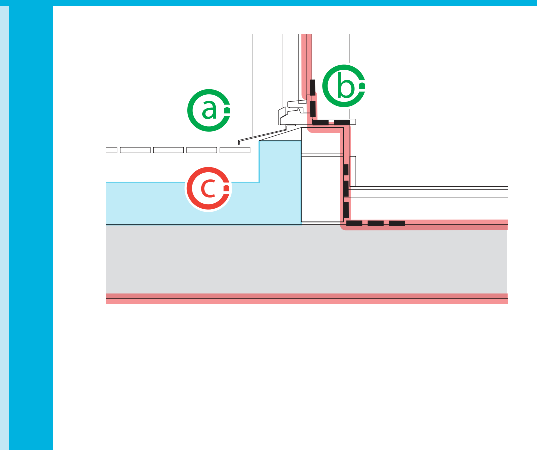
WALL - FLOOR 01: EXTERNAL WALL / PARTY FLOOR

a. Taping the junction between the concrete frame and the infill construction can help to improve airtightness and careful design is needed where there are deflection details, head restraints and wind-posts.
b. Infill blockwork must be carefully constructed to ensure airtightness, especially at the head of the wall. A parge coat or solid plaster finish is recommended.



WALL - BALCONY 02: BALCONY

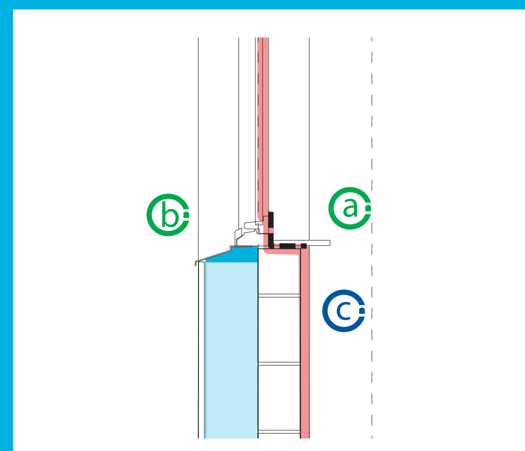
a. Use an insulated balcony connector to allow balcony reinforcement to connect to main slab structure while minimising thermal bridging.
b. Indicate on drawings the correct sequencing to ensure insulation can be fitted around balcony connector.
c. Beware of cold bridges caused by the door threshold and cill.



WALL - TERRACE 03: TERRACE

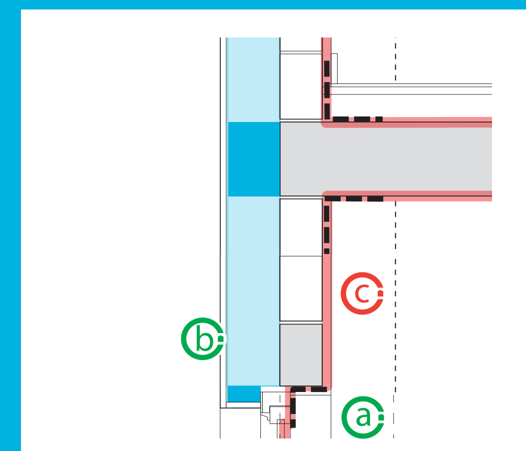
a. Insulate outer face of upstand to prevent thermal bridging.
b. Beware of cold bridges caused by the door threshold and cill.
c. Terrace may have less insulation to reduce the depth of the building. Make sure the heat loss calculations allow for this.

WALL DETAILS



WALL - WINDOW 04: WINDOW CILL

a. Ideally the window frame should overlap with the external wall insulation.
b. The window cill should bridge across the external insulation.
c. Internal finishes returned to window frame are unlikely to provide airtight construction; consider using an additional membrane and sealant.

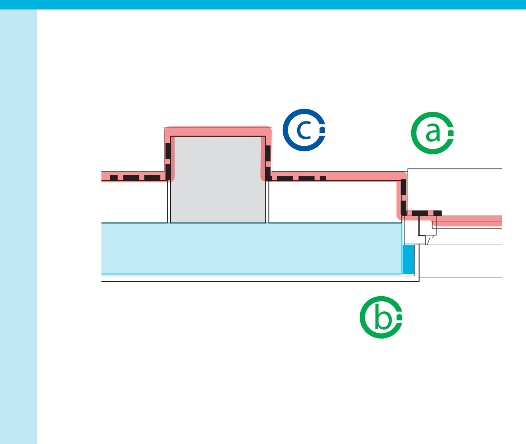


WALL - WINDOW 05: WINDOW HEAD

a. Ideally the window frame should overlap with the wall insulation.
b. Avoid using metal pressings around the window reveal that create a thermal bridge. Take extra care detailing for tolerances.
c. The infill above the window head can be awkward to detail especially where slab deflections and tolerances must be accommodated.

WALL - WINDOW 06: WINDOW JAMB

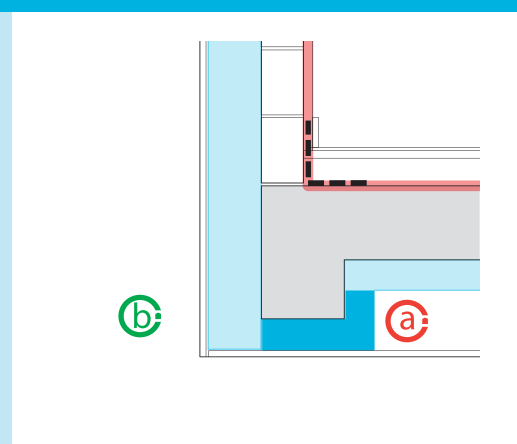
a. Window frame to overlap with wall insulation.
b. Avoid using metal pressings around the window reveal that create a thermal bridge. Take extra care detailing for tolerances.
c. Internal finishes returned to window frame will not provide airtight construction; use additional membrane and sealant.



WALL DETAILS

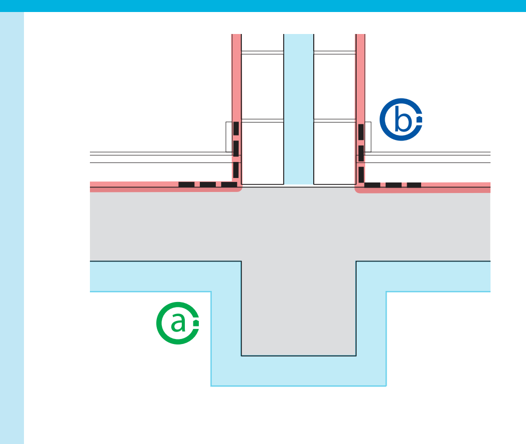
WALL - FLOOR 07: UNDERCROFT ENTRANCE

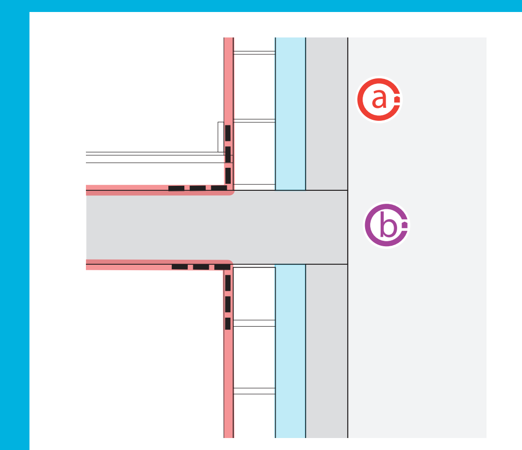
a. Where the soffits to unheated undercrofts are insulated, include any downstand beams.
b. Ensure tight-fitting overlap between wall and soffit insulation to prevent thermal bridging.



WALL - FLOOR 08: UNDERCROFT DOWNSTAND

a. Any downstand beams should be fully encased with close-fitting insulation to prevent thermal bridging.
b. The concrete slab is usually treated as the airtightness barrier, rather than relying on the floor finishes.

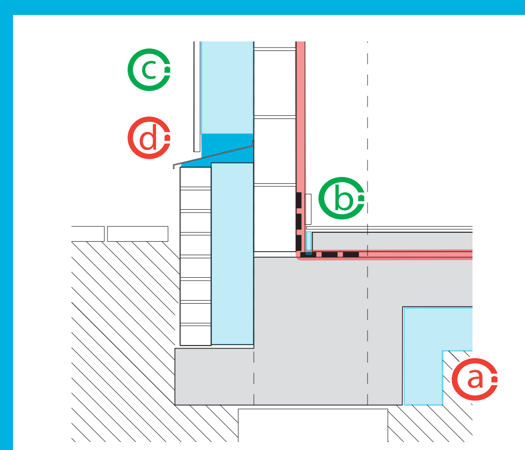




WALL - FLOOR 09: LIFT / RISER SHAFT

a. How are the walls to unheated service risers and lift shafts to be insulated? Some thermal bridging is inevitable through the edge of the slab - make sure this is allowed for in the heat loss calculations.
b. Indicate on drawings the correct installation sequence to allow fire stopping and services to coordinate with thermal insulation.

GROUND DETAILS

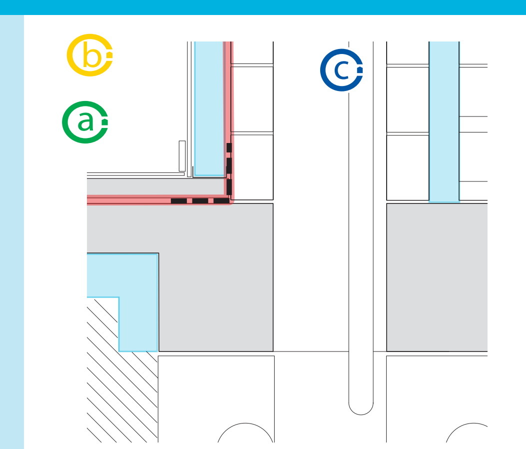


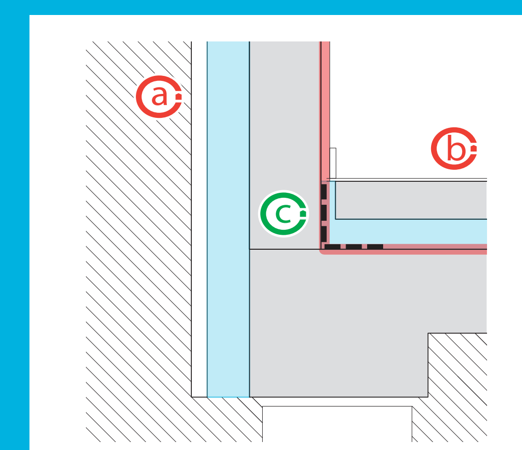
GROUND - FLOOR 01: FLOOR SLAB / EXTERNAL WALL

a. Insulation is laid continuously under ground floor slab, but beware of thermal bridges to column positions and at the base of shear walls and party walls.
b. Place vertical insulation at edge of footings and floor slab to minimise thermal bridging.
c. Ensure insulation is tightly placed against any flashings to avoid thermal bridging.
d. Unavoidable thermal bridge caused by flashings or support angles should be accounted for in heat loss calculations.

GROUND - FLOOR 02: FLOOR SLAB / MASONRY PARTY WALL

a. Place vertical insulation at edge of floor slab to minimise thermal bridging.
b. Party wall cavity to be fully filled with insulation to prevent heat loss by thermal bypass.
c. Party wall blockwork must be carefully constructed to ensure airtightness. All mortar joints to be fully filled. A parge coat or solid plaster finish is recommended.





GROUND - FLOOR 03: BASEMENT

a. Place insulation for basement on the outside of the retaining walls to form a continuous layer with the wall insulation above.
b. Lay insulation continuously over ground floor slab.
c. Place vertical insulation at edge of floor slab to minimise thermal bridging.