LIGHT STEEL FRAMING IN RESIDENTIAL CONSTRUCTION

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SCI PUBLICATION P402

LIGHT STEEL FRAMING IN RESIDENTIAL CONSTRUCTION

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FOREWORD

This publication has been based on the original SCI publication P301 (published in 2001); it has been revised to include current design and construction practice. Reference is made to the Eurocodes and the UK National Annexes which form the basis for the current British Standards.

Preparation of this publication has been carried out by Mr E Yandzio, Mr A G J Way and Prof R M Lawson.

The production of this publication was assisted by the following individuals and organisations including members of the Light Steel Forum; their assistance is gratefully acknowledged:

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CONTENTS

SUMMARY

This publication provides information and guidance on the construction of light steel frames in general applications for residential construction, which includes single family houses and apartments. Light steel framing systems use galvanized cold formed steel sections as the primary structural components, which can be assembled as prefabricated panels.

The publication addresses aspects of design within the scope of the Building Regulations (England and Wales). It also covers construction practice and detailing of light steel frames and their interfaces with other materials and components. The information is generic and focuses on general construction principles.

Detailed design information is given on structural design and robustness, serviceability of floors, thermal and acoustic performance, and fire resistant design. Design guidance presented is in accordance with Eurocodes.

INTRODUCTION TO LIGHT STEEL CONSTRUCTION

Light steel framing is generally based on the use of C or Z shaped steel sections produced by cold rolling from strip steel. Cold formed sections are generically different from hot rolled steel sections, such as Universal Beams, which are used in fabricated steelwork. The steel used in cold formed sections is relatively thin, typically 1.0 to 4.0 mm, and is galvanized for corrosion protection.

Cold formed steel sections are widely used in many sectors of construction, including mezzanine floors, industrial buildings, commercial buildings and hotels and have gained a significant market share in the residential sector. This publication presents general guidance and details on the use of light steel framing in residential construction, in ways which meet the requirements of the Building Regulations in England and Wales. However, much of the guidance will also be applicable to the use of light steel framing in other sectors.

The main forms of construction include load-bearing frames, and infill walls to steel or concrete framed buildings. Increasingly mixed use buildings are designed, for example where residential units are located over retail or commercial space, in which case light steel frames are supported by a steel or concrete structure for the levels below. Light steel framing is also used in modules, although detailed guidance on modular construction is not within the scope of this publication, for guidance on modular construction see SCI publication P302[1] and ED014[2].

Examples of housing and residential buildings constructed using light steel framing are shown in Figure 1.1 to Figure 1.3. For further information see also SCI publications ED011[3] and ED012[4].

Figure 1.1 Housing using light steel framing

(Photo courtesy of Kingspan Steel Building Solutions)

Figure 1.2
Housing using light steel framing built over a supermarket
(Photo courtesy of Metek UK Ltd.)

Figure 1.3
Medium-rise accommodation building using light steel framing
(Photo courtesy of Fusion Building Systems)

1.1 Methods of construction

The basic building elements of light steel framing are cold formed sections which can be prefabricated into panels or modules, or assembled on site using various methods of connection. The different forms of construction are reviewed in the following sections. In most systems, the walls are manufactured as storey-high panels of up to 3 m length, as shown in Figure 1.4. The C sections are generally 80 to 150 mm deep and are placed singly or in pairs at 600 mm centres, depending on the required compression resistance of the wall.

The floors can be installed as individual C sections of 150 to 300 mm depth at 400 mm or 600 mm centres but they can also be manufactured as panels and supported on the walls as shown in Figure 1.5. Often the floors are designed to support bathroom pods which may weigh up to 0.5 Tonne, as illustrated in Figure 1.6.

Modules may also be constructed using light steel framing, in the form of wall, floor and ceiling panels, as shown in Figure 1.7.

Figure 1.4
Light steel framing using pre-fabricated panels
(Photo courtesy of BW Industries)

Figure 1.5
Pre-fabricated cassette flooring supported on light steel walls
(Photo courtesy of Kingspan Steel Building Solutions)

Figure 1.6
Pre-fabricated bathroom pods combined with light steel framing
(Photo courtesy of Metek UK Ltd.)

Figure 1.7
Modular construction using light steel framing
(Photo courtesy of Ayrshire Framing)

1.1.1 'Stick-build' construction

In this method of construction (illustrated in Figure 1.8), discrete members are assembled on site to form columns, walls, rafters, beams and bracing to which cladding, internal lining and other elements are attached. The elements are generally delivered cut to length, with pre-punched holes, but connections are made on site using self-drilling self-tapping screws, bolts, or other appropriate site techniques. This is less often used for larger buildings but can be used for self-build and other smaller projects.

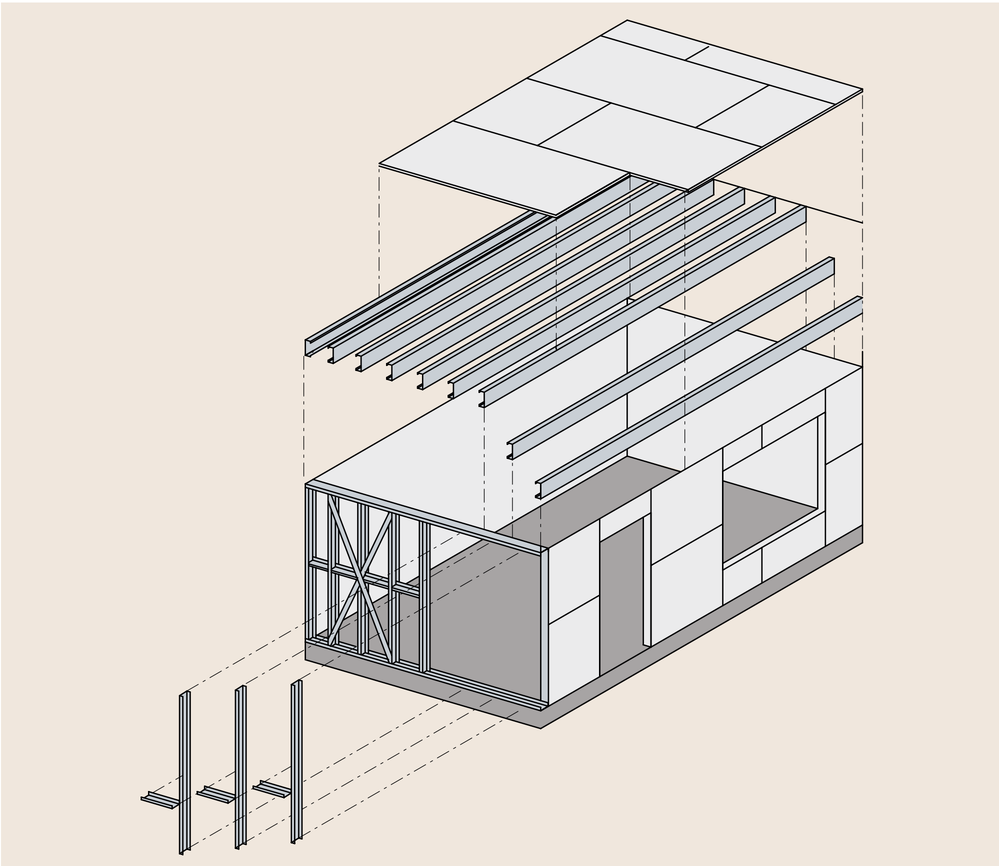


Figure 1.8
'Stick-build' site construction using wall studs and floor joists

The advantages of ‘stick-build’ construction are:

- construction deviations and modifications can be accommodated on site
- connection techniques are relatively simple
- manufacturers do not require the workshop facilities associated with panel or modular construction
- large quantities of light steel members can be densely packed and transported in single loads
- components can be easily handled on site.

The main disadvantage is that ‘stick-build’ construction is labour intensive on site, compared to the other methods of light steel framed construction.

1.1.2 Panel construction

Wall panels, floor cassettes and roof trusses may be prefabricated in a factory and later assembled on site, as in Figure 1.9. For accuracy, the storey-high panels are manufactured in purpose-made jigs. Some of the finishing materials may be applied in the factory, to speed on-site construction. The panels are connected on site using conventional techniques (bolts or self-drilling screws).

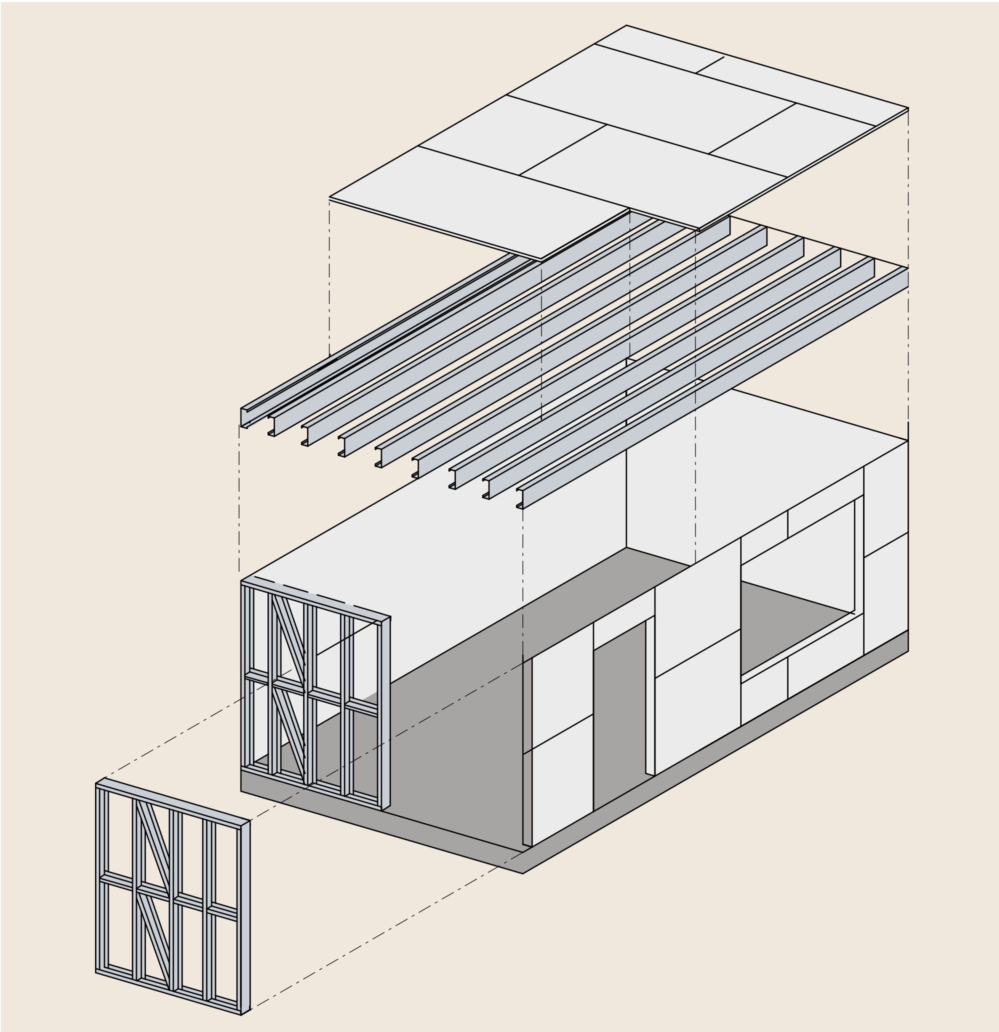


Figure 1.9
Site assembly of light steel wall panels

The main advantages of panel construction are:

- window and door openings may be introduced in the panel manufacture
- the speed of installation of the panels on site is faster than stick-build
- panels can be lifted mechanically in the factory and on site
- high quality control and accuracy due to production in factory conditions
- reduced site labour costs
- scope for automation in factory production
- health and safety is improved because off site manufacture is five times safer than on-site construction.

The geometrical accuracy and reliability of the panels and other components is very good because panels are prefabricated in a factory environment. The accurate setting out and installation of foundations is a key factor to achieve rapid assembly of the panels and to obtain the maximum efficiency of the construction process.

1.1.3 Modular construction

In modular construction (Figure 1.10), units are completely prefabricated in the factory and may be delivered to site with all internal finishes, fixtures and fittings in place. Units may be stacked side by side, or one above the other, and connected to form the stable finished structure.

Modular construction is most cost-effective where large production runs are possible for the same basic configuration of modular unit. This is because prototyping and set-up costs, which are essentially independent of scale, can be shared across many units. Health and safety is also improved because off-site manufacture is five times safer than on-site construction.

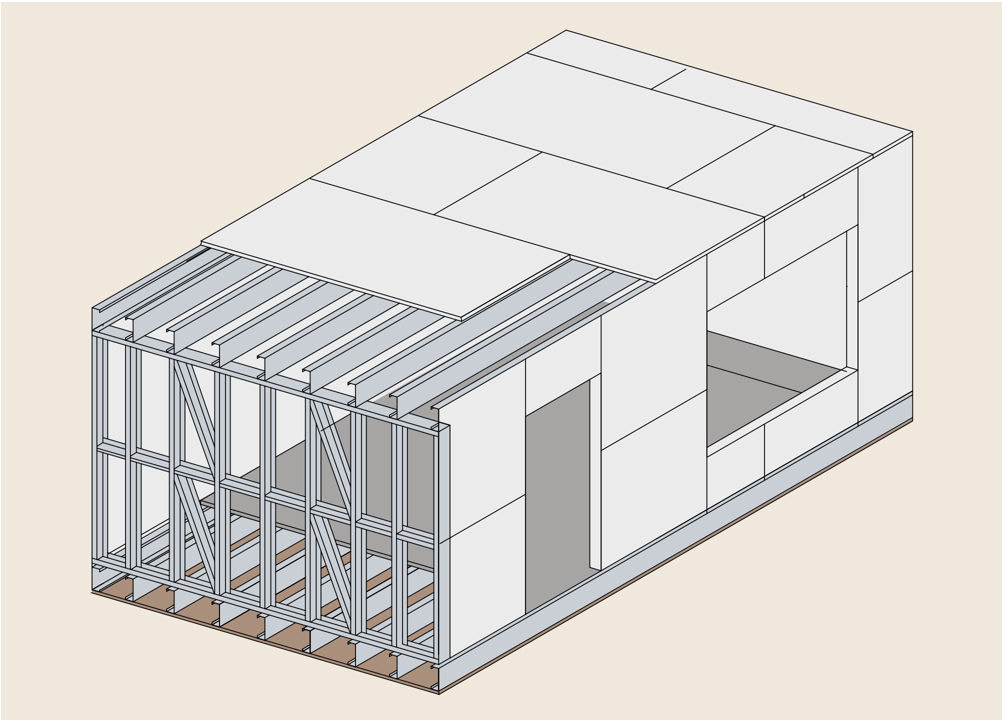


Figure 1.10
Modular construction using light steel framing

1.1.4 Platform and 'balloon' construction

Panels may be assembled in either 'platform' or 'balloon' construction. In platform construction, walls and floors are built sequentially one level at a time, so the walls are not structurally continuous, as illustrated in Figure 1.11.

In 'balloon' construction, the wall panels are much larger and are continuous over more than one storey. Such panels are more difficult to erect than single storey height panels and have to be temporarily braced whilst the floors are installed. The main advantage of this approach is that loads from the walls above are transferred directly to those below. Balloon construction is rarely used currently. The external cladding or finishes are generally installed and attached to the frames on-site.

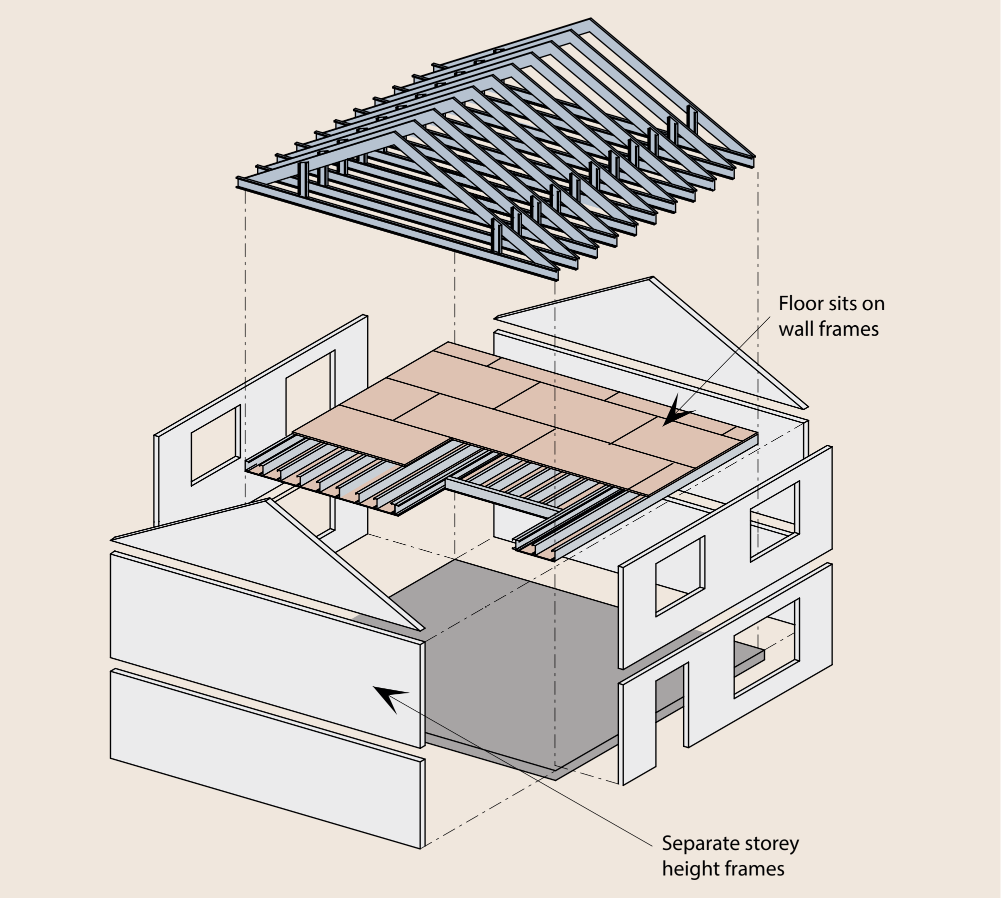


Figure 1.11 'Platform' form of panel construction

1.1.5 Infill wall construction

Infill walls are built between the floors of steel or concrete frames and are designed to resist wind loading and to support the weight of the cladding. They typically consist of 100 mm deep C sections for walls up to 3 m height and 150 mm deep C sections for taller walls. They are generally installed as individual elements within a top and bottom 'track' that allows for relative vertical movement with respect to the supporting structure. A good example of infill wall construction is shown in Figure 1.12. Infill walls may also be manufactured as large panels. Further information on infill wall construction is given in Section 10.1 and in SCI publications ED013[5] and ED017[6].

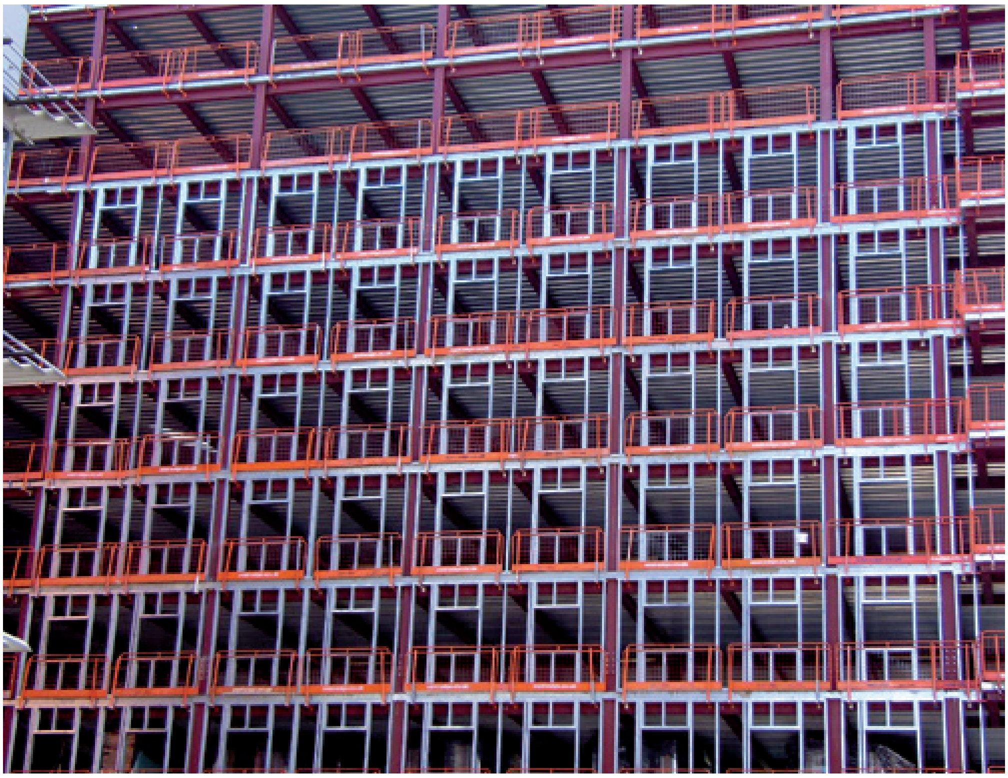


Figure 1.12
Light steel infill wall construction in a steel framed building

1.1.6 Balconies

Balconies may be manufactured as lightweight prefabricated units and attached to the light steel walls via steel plates or connected to square hollow section posts that are installed as part of the light steel framework package. A good example is shown in Figure 1.13.

Figure 1.13
Light steel balcony units attached to light steel framing
(Photo courtesy of Kingspan Steel Building Solutions)

1.1.7 Material properties

The galvanized strip steel, from which the light steel framing is formed, is generally supplied in grades of S350 to S450 to BS EN 10346:2009 [7]. These designations indicate a yield strength between 350 and 450 N/mm^2. The strip steel is galvanized with a minimum G275 coating. Cold formed steel sections are usually rolled from galvanized sheet steel that is 1.0 – 4.0mm thick (1.2 to 2.4 mm is typically used). The normal thickness of zinc coating (275 g/m^2) has excellent durability performance, see Section 3.1.

1.2 Why use light steel frames

The design of housing and residential buildings is influenced by many factors, including requirements for sustainability, and thermal and acoustic performance. The environmental need to conserve land use, whilst improving the social characteristics of the built environment also have a direct effect on the choice of constructional system. The pressure for more efficient and sustainable construction processes to meet these challenges has led to a demand for off-site manufacture and improved quality in the performance of the chosen construction technology.

Steel constructional technologies have achieved a high market share in the commercial building sector and the same technologies are used in housing and residential buildings where the main benefits include speed of construction, higher levels of quality, reliability and longevity, and the ability to provide more adaptable use of space.

Steel is a quality assured, dimensionally accurate, high strength, long life, adaptable, reusable and recyclable product. There is an established infrastructure of manufacture, supply, design and detailing, which is well covered by the latest design standards and certifications.

Light steel framing uses galvanized cold formed steel sections as the main structural components. These sections are widely used in the building industry and are part of a proven technology. Light steel framing is used in the form of load-bearing structures and in infill façade walls to steel and concrete framed buildings.

Architects and specifiers are able to extend the successful application of steel by using light steel frames as an economic and versatile form of construction for residential buildings.

This publication provides guidance on the design and detailing of light steel framing in modern residential buildings in ways which comply with the Building Regulations in England and Wales.

1.3 Scope of publication

This publication addresses the design of houses and residential buildings in the context of the Building Regulations in England and Wales. It presents means of satisfying the Regulations when using light steel framing and gives appropriate design tables and details.

This document is not an Approved Document to the Building Regulations but gives best practice in this progressing technology.

Sections 2 and 3 present general principles and the later sections demonstrate details which satisfy these principles.

1.4 Building Regulations 2010

Recent trends towards introducing new legislation in the UK focus on a combined approach where legislation forms one part of an integrated set of measures which include regulation, economic instruments, guidance, demonstration and setting targets.

Increasingly, many of the UK regulations arise as a result of the requirements of the European Union. These requirements, generally take the form of 'directives', which result in the member countries of the EU modifying their own laws.

In England and Wales, a single set of Building Regulations applies. Different regulations apply in Scotland and Northern Ireland. This document principally addresses the English and Welsh regulations.

Statutory Framework

The statutory framework for controlling the standards of building construction is given in the Building Act 1984. The Act is implemented by means of the Building Regulations 2010[8] together with a number of formal amendments to the Regulations. The Building Regulations generally set performance requirements for building work, including the erection of new buildings and material changes of use of existing buildings. Practical guidance on ways of meeting these requirements is given in separate Approved Documents[9]. The Approved Documents (ADs) also refer to materials and product standards for technical requirements. There is no obligation to adopt the solutions shown in the ADs, if the designer wishes to demonstrate compliance in some other way.

The Approved Documents to the Building Regulations have been revised at various times since 1991. There are currently 14 'Parts'.

Part A*	Structure	2004
Part B*	B1 and B2 Fire Safety	2006
Part C*	Site Preparation and Resistance to Contaminants and Moisture	2004
Part D	Toxic Substances	1992
Part E*	Resistance to the Passage of Sound	2003
Part F	Ventilation	2010
Part G	Hygiene	2010
Part H	Drainage and Waste Disposal	2012
Part J	Combustion Appliances and Fuel Storage Systems	2010
Part K	Protection from Falling, Collision and Impact	2013
Part L*	L1A, L1B, L2A and L2B Conservation of Fuel and Power	2013

Part M	Access to and Use of Buildings	2004
Part N	Glazing and Safety in Relation to Impact, Opening and Cleaning	2013
Part P	Electrical Safety	2013

The parts marked with an * are particularly relevant to the use of light steel framing in residential applications and are addressed in this publication.

Note that Part A includes 2010 and 2013 amendments. Part B includes 2007, 2010 and 2013 amendments. Part C includes 2010 amendments. Part E includes 2004 and 2010 amendments. Part L of the Building Regulations was revised in November 2013 and aligns with energy performance requirements proposed by the Zero Carbon Hub in their publication *Defining a fabric energy efficiency strategy for Zero Carbon homes* [10].

GENERAL REQUIREMENTS OF THE BUILDING REGULATIONS THAT AFFECT LIGHT STEEL FRAMING

2.1 Structural performance

2.1.1 Building Regulations Part A: Structure

In Schedule 1 of the Building Regulations, Part A sets out requirements that buildings shall transmit permanent actions and variable actions to the ground safely and without excessive deformation that could impair stability.

Approved Document A gives guidance on the requirements for loading in buildings and provides information on acceptable designs in masonry, timber and steel construction. Light gauge steel framing is included.

In 2013 the Department of Communities and Local Government (CLG) revised Approved Document A of the Building Regulations, by withdrawing references to British Standards and replacing them by Eurocode references.

The permanent actions and variable actions from wind and snow should be taken from BS EN 1991-1, Actions on Structures [11]. A typical self-weight for a timber boarded, light steel floor is 0.33 kN/m^2. The design variable actions given in the Approved Document are shown in Table 2.1.

Table 2.1 Variable actions as specified in the Approved Document to Part A of the Building Regulations

ELEMENT	LOADING
Roof	Distributed load 0.75 kN/m^2 or concentrated load 0.9 kN
Floors	
Above ground storey	Distributed load 1.5 kN/m^2 or concentrated load 1.8 kN
Communal areas	Distributed load 2.0 kN/m^2 or concentrated load 2.7 kN
Corridors, staircases, etc.	Distributed load 3.0 kN/m^2 or concentrated load 4.5 kN
Ceilings	Distributed load 0.25 kN/m^2 and concentrated load 0.9 kN

The Approved Document also lists Codes of Practice and British EN Standards for structural design and construction, which can be used to meet the requirements for structural stability. For light steel framing, the structural performance should satisfy BS EN 1993-1-3 [12] and BS EN 1993-1-5 [13] when subject to these loads. BS EN 1993-1-3, however, is only a 'supplementary' Part of Eurocode 3 and has many references to the general rules in BS EN 1993-1-1. For structural robustness requirements, reference is to be made to BS EN 1991-1-7 [14].

2.1.2 Member resistance

The structural design of all cold formed steel sections is currently covered by the provisions of BS EN 1993-1-3. BS EN 1993-1-3 is a limit state design code and the principal design requirements concern:

- Effective section properties.
- Design of members in compression or tension.
- Design of members in bending.
- Design of members subject to combined bending and axial load.
- Web crushing due to local point loads.

The design of floors is generally controlled by serviceability limits rather than bending resistance. BS EN 1993-1-3 does not give specific recommendations for residential floors, but, as explained in Section 6.2, serviceability limits should be stricter for these floors than for general applications. Light steel C section members are relatively weak in buckling, unless restrained by the flooring or walling material at points along their length. At the supports or under high local loads, additional stiffening cleats are normally required to prevent web crushing.

When using C section studs, bridging pieces or straps may be fixed horizontally between the vertical studs to improve the buckling capacity of individual studs in their minor axis direction. Double C sections are much more resistant to buckling than single C sections, and generally no intermediate restraints are required.

2.1.3 Stability

All load bearing structures must have adequate stiffness to control movement under horizontal loads and have a vertical bracing system to transmit loads to the foundations.

There are three principal means of providing stability of frames in the vertical plane: integral bracing, X bracing and diaphragm action. The two bracing configurations are shown in Figure 2.1. The use of X bracing in a 5 storey building is shown in Figure 2.2.

Integral bracing

C sections are fixed diagonally between vertical studs within the depth of the stud walls. The diagonal bracing members must be securely connected to the vertical studs to ensure the transfer of their forces in tension and compression.

X bracing

Crossed, flat straps of thin strip steel are fixed on the external faces of the studs. These straps act only in tension and may sag unless pre-tensioned during installation. The crossed flats should be fixed to every vertical stud.

Diaphragm action

Walls, floors and roofs are often sheathed with suitable board materials (e.g. plywood, OSB, chipboard, cement particleboard, specialist gypsum-based boards) for use as

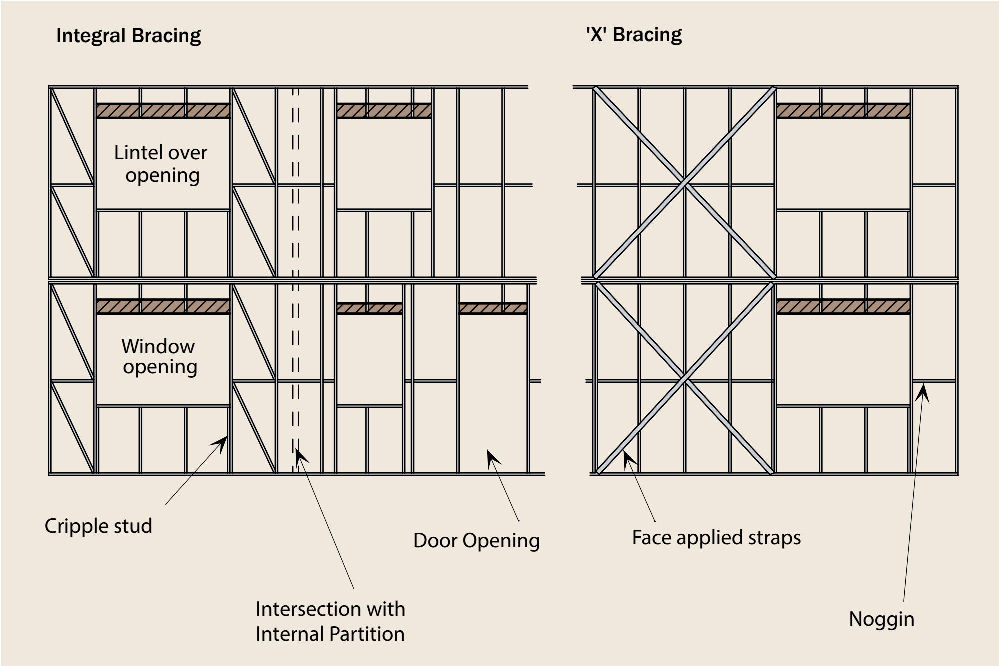


Figure 2.1
Typical braced frames

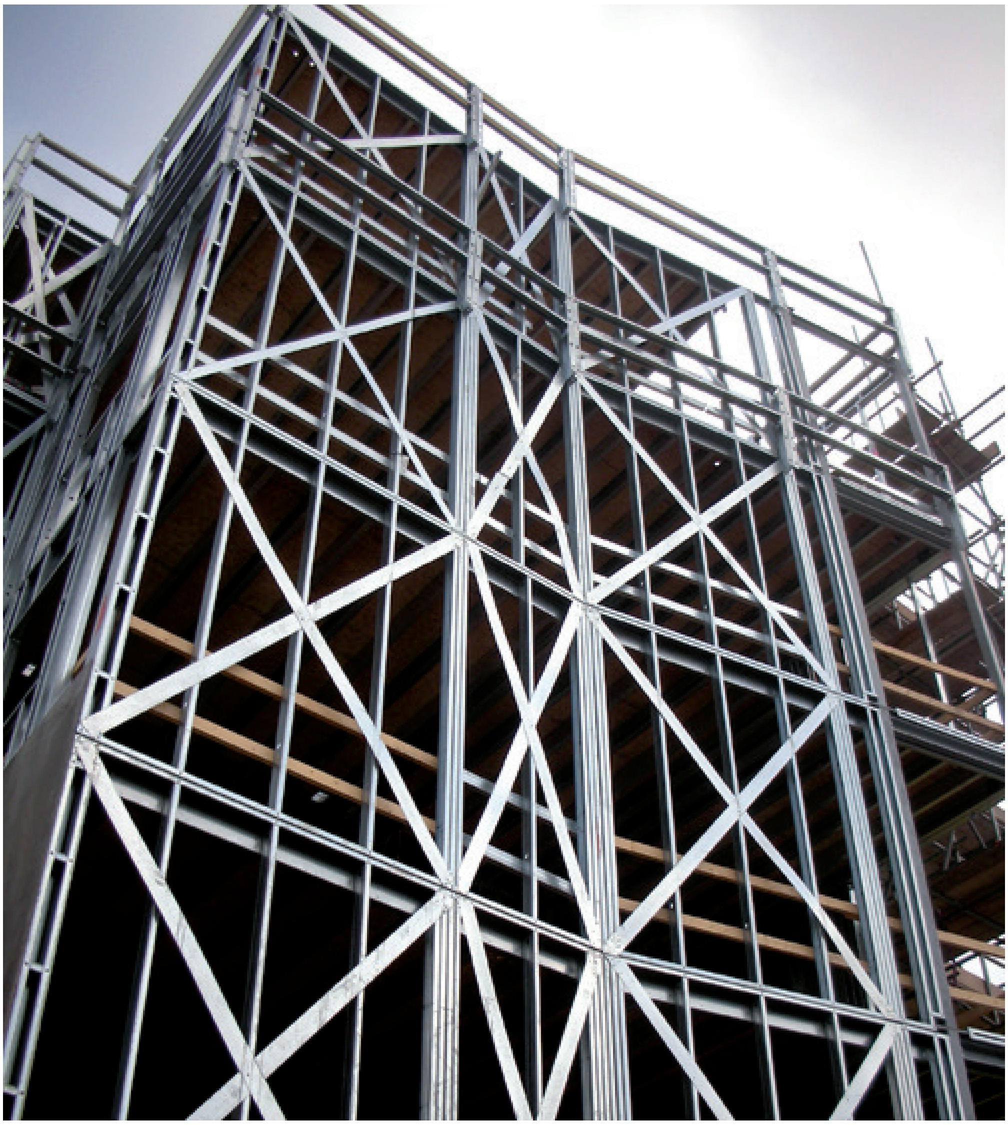


Figure 2.2
X braced frames in a multi-storey building
(Photo courtesy of Metek UK Ltd.)

structural diaphragms for the transfer of forces to bracing or to the foundations. Effective diaphragm action is achieved by fixing these board materials to the light steel members with self-drilling self-tapping screws, or the equivalent, at a maximum spacing of 300 mm. The screw spacing should not exceed 150 mm at the edges of the panels. Care is to be taken that once diaphragm walls have been installed, holes are not cut in these walls as diaphragm action resistance could be compromised.

Diaphragms are also commonly used in the horizontal plane of the floor and in the plane of the rafters. The floor should be designed for the transfer of shear loads to the braced walls. Where large openings are provided in the diaphragm, it is important to ensure that load paths can be maintained. Eurocode 5 [15] provides a method which may be adapted to apply for the detailed design of light steel framing diaphragms. Regarding the limits on the proportions of diaphragms, Eurocode 5 suggests that a deep beam analogy may be assumed, provided that the span is less than six times the width of the diaphragm.

Holding down

The above three methods of providing stability of frames are all valid means by which wind loads can be transferred to foundations. Provided that the eccentricities of loads applied to holding down points are minimised, loads can be transferred to the foundations without causing excessive deformation of the bottom rail or sole plate. In domestic-scale structures, the sole plate is often a light C section through which the holding-down bolts are inserted directly to the foundations. For multi-storey buildings a more substantial detail is usually required, see Section 4.3.

2.1.4 Serviceability requirements

Serviceability design concerns limitation of deflections due to loading and the control of vibrations. Appropriate limits are specified, depending on the application (see Section 6.2.1 for floors and Section 7.1 for walls).

2.1.5 Robustness of light steel frames

The term ‘robustness’ when used in the context of building design relates to the ability of the structure to withstand accidental actions without the excessive spread of damage, also known as avoidance of disproportionate collapse. In this sense, robustness is synonymous with structural integrity.

The essential principles of robustness, which apply across all forms of construction and materials, are summarised below:

- Robustness relates to the ability of a structure to limit the effects of accidental events such as explosions, impact or the consequences of human error.
- The structure does not have to be serviceable after the event. Large deformations and plasticity are permitted. It is expected that the structure will need to be repaired before it can be re occupied. In some cases, it may need to be demolished.

The objectives of robustness design are:

- To restrict the spread of localised damage and to prevent collapse of the structure disproportionate to the original cause.
- To ensure the safety of the structure while building occupants make their escape and the emergency services are in attendance.

Structural robustness and design to avoid disproportionate collapse is a requirement of Building Regulations. The requirement to design and construct buildings to have robustness and avoid disproportionate collapse under accidental design situations is also given in BS EN 1990. Details of how the requirement should be met are given in BS EN 1991-1-7.

Detailed guidance on the design of steel framed buildings for structural robustness in accordance with BS EN 1991-1-7 is provided in SCI publication *Structural robustness of steel framed buildings* (P391)[16]. However, for light steel framed buildings specific interpretation of the Eurocode design methods is required.

The required level of robustness is dependent on the building class, which is related to the size, type and use of the building. The same building classification system is given in Approved Document A, and BS EN 1991-1-7. A summary of the robustness requirements for each building class is given below:

- Class 1 – Provided the building has been designed and constructed in accordance with the rules given in EN 1990 to EN 1999 for satisfying stability in normal use, no further specific consideration is necessary.
- Class 2A – Effective horizontal ties should be provided.
- Class 2B – There are three alternative design methods:
  - Tying
  - Notional removal
  - Key element
- Class 3 – A systematic risk assessment should be carried out.

The guidance given in BS EN 1991-1-7 is material independent. The only guidance that is specific for light steel framing is found in the UK National Annex, where it states in §NA.3.1 that:

> *In the case of lightweight building structures (e.g. those whose primary structure is timber or cold formed light gauge steel), the values for minimum horizontal tie forces in expression A.1 and A.2 should be taken as 15 kN and 7.5 kN, respectively.*

Note that the tying design method in BS EN 1991-1-7 requires minimum horizontal tie forces of 75 kN to be accommodated. The direct application of this guidance to light steel structures would prohibit the economic use of light steel. This is an anomalous situation, since light steel multi-storey structures are generally constructed using a large number of regularly distributed structural elements, with a high degree of connectivity and structural integrity. In most applications, the provision of continuous ties between the components is straightforward because of the multiple inter-connections.

Tying design method for light steel structures

The guidance provided in this section may be taken as complementary to the Eurocode guidance given in BS EN 1991-1-7.

Effective horizontal and vertical ties should be provided.

Horizontal tying arrangements, generally similar to those described in Clause A.5 of BS EN 1991-1-7, should be arranged in continuous lines wherever practicable throughout each floor and roof level in two directions approximately at right angles.

Light steel members acting as ties, and their end connections, should be capable of resisting the following factored tensile loads, which need not be considered as additive to other loads acting on the members:

- For floor joist ties: $0.8\,(g_k + \psi_1 q_k)\,sL$ but not less than 5 kN/m width perpendicular to the span of the joist
- For internal ties: $0.8\,(g_k + \psi_1 q_k)\,sL$ but not less than 15 kN
- For peripheral ties: $0.4\,(g_k + \psi_1 q_k)\,sL$ but not less than 7.5 kN

where:

g_k	is the characteristic value of the permanent action per unit area of the floor or roof (kN/m^2)
L	is the length of the tie between vertical supports (m)
q_k	is the characteristic value of the single variable action (imposed floor or roof load) per unit area (kN/m^2)
s	is the mean transverse spacing of the ties (m)
ψ_1	is the combination factor for accidental design situations from EN 1990.

Horizontal tying members at the periphery of the building should be connected back to the rest of the structure.

If the vertical loads are resisted by a distributed assembly of closely spaced elements, the tying members should be similarly distributed to ensure that the entire assembly is effectively tied. The forces for anchoring the vertical elements at the periphery should be based on the spacing of the elements and taken as 1% of the factored vertical load in the element.

If the main structural elements are discrete columns, the horizontal ties anchoring the columns nearest to the edge of a floor or roof should be capable of resisting a factored tensile load, acting perpendicular to the edge, equal to the greater of the load for an internal tie, or 1% of the factored vertical design load in the column acting at that level.

All splices in primary vertical elements, including connections between wall panels above and below, should be capable of resisting a tensile force equal to the largest design vertical permanent and variable load reaction applied to the column from any one storey. Such accidental design loading should not be assumed to act simultaneously with permanent and variable actions that might be acting on the structure.

The system of bracing, whether discrete members or diaphragm panels providing resistance to horizontal forces, should be distributed throughout the building such that, in each of two directions approximately at right angles, no substantial portion of the building is connected to a means of resisting horizontal forces at only one point.

Notional removal for light steel structures

If the conditions for the tying method are not met, the designer should check each storey to ensure that disproportionate collapse would not be precipitated by the notional removal of vertical load bearing elements, considered one at a time.

Load-bearing light steel walls require consideration of the notional removal of a length of wall panel equal to 2.25 times the storey height. This length of panel is conservative because of the one-way spanning characteristics of the light steel components.

Volumetric/modular construction differs from other forms of construction in that there is far more connectivity, such that a stack of modules may tolerate the notional removal of a whole module. It is better to use a “scenario-based” approach to review such cases, such as the removal of one support member. BS EN 1991-1-7 provides a method for this approach.

In the notional removal check the load combination for accidental actions should be used, as given in EN 1990 equation 6.11b.

In all cases, the test for localisation of damage is that the portion of the building at risk of collapse should not exceed 15% of the area of the storey or 100 m^2 (whichever is less) within that storey and the storey above. A similar area of the storey below could be loaded with debris from above. Hence, up to a total of 200 m^2 of floor area may be assumed to be at risk of collapse.

Key element design for light steel structures

If the notional removal of a vertical load-bearing element would risk the collapse of an area greater than the allowable limit, then that vertical load-bearing element (length of wall) should be designed as a key element. For key element design the following should be adopted:

- An accidental design action of 34 kN/m^2 should be applied.
- The load combination for accidental actions and corresponding partial load factors should be applied. This will result in a reduced design axial load in the vertical load-bearing elements.

- Plasterboard cannot be assumed to still be intact after an accidental event. Therefore, lateral restraint provided by the plasterboard should be discounted for key element design.

Masonry clad structures

In general, light steel structures only offer lateral support to masonry cladding and the self-weight of the masonry is transferred directly to the foundations. Disproportionate collapse of the masonry cladding during an accidental event is unacceptable and special measures are to be taken to ensure this does not occur.

2.2 Fire resistance

Steel does not add to the combustible contents of a building and therefore the fire safety measures are largely concerned with prevention of structural failure and with means of escape.

2.2.1 Building Regulations Part B: Fire safety

Approved Document B is published in two volumes. Volume 1 deals solely with dwellings while Volume 2 deals with other types of building covered by the Building Regulations. Where very large (over 18 m in height) or unusual dwelling houses are proposed some of the guidance in Volume 2 may be needed to supplement that given in Volume 1. Designers should also consult BS 9991:2011 [17], the code of practice for *Fire safety in the design, management and use of residential buildings*.

Buildings must be constructed so that if a fire occurs:

- The occupants are able to escape to a safe place.
- Fire spread over the internal linings of the walls and ceilings is inhibited.
- Stability is maintained for a sufficient period to allow evacuation of the occupants and access for firefighting.
- Fire spread within the building and from one building to another is kept to a minimum and satisfactory access and facilities are provided for fire fighters.

Guidance in Approved Document B is given for:

- The design of means of escape for dwellings.
- The choice of lining materials for walls and ceilings.
- Measures to ensure that the load bearing elements of the structure of a building remain stable for an appropriate period of time during a fire.
- Sub-division of the building into compartments by fire-resisting construction, such as walls and floors.
- Sealing and sub-division of hidden voids to inhibit the unseen spread of fire and smoke.
- Protection of openings and fire stopping in compartment walls and floors.

Generally, there is no requirement for fire resistance of the structure of single-storey dwellings, unless they affect other buildings, i.e. resistance to internal fire spread.

For houses and apartments of 2 to 3 storeys, 30 minutes fire resistance must be achieved for all elements of the structure. This requirement generally increases to 60 minutes for walls and floors separating two dwellings. Any residential buildings with storeys that are more than 5 m above the ground floor require at least 60 minutes fire resistance for the structure and, in this case, separating walls must also be constructed of materials of limited combustibility. A fire resistance of 90 minutes, or even 120 minutes, may be required for taller apartment buildings. Any basement storey may require additional fire separation.

Further recommendations of the Approved Document relate to the use of materials for internal linings which have Class 1 (or better) for rate of flame spread, other than in small rooms below 4 m^2 (in residential buildings). Cavity barriers are required in any concealed cavities within the construction at junctions with compartment floors and walls and at intervals not greater than 20 m.

The Approved Document states that for a building located within 1 m of the site boundary, the fire resistance of an external wall must be provided by non-combustible cladding such as brickwork. Due regard should be taken of unprotected areas and openings.

In residential buildings, the travel distance is limited to a maximum of 7.5 m from the exit of the dwelling to the entrance to a fire protected stairway or lobby. If this is not satisfied, separate fire protected doors are required in the corridor. Maximum travel distances are presented in Figure 2.3 for two floor layouts, one being a corridor access and the other being access from a lobby. Some relaxations are permitted for 'small buildings' less than 11 m high, i.e. 4 storeys. Active measures of smoke control would normally be required if these distances are exceeded.

Fire resistance is required to ensure that the structure remains stable in fire, depending on the height of the building, which is defined as to the top of the highest floor. Current fire resistance requirements are defined in Table 2.2, together with the approximate number of storeys for each fire resistance class. The height of the top floor in this table is measured from the upper floor surface to ground level on the lowest side of the building.

For mixed use buildings, other fire resistance and means of escape requirements may apply.

Table 2.2 Fire resistance requirements in Approved Document B of the Building regulations (England and Wales)

PARAMETER	FIRE RESISTANCE (MINS)			
	R30	R60	R90	R120
Max. height (m)*	$\leq$ 5 m	$<$ 18 m	$<$ 30 m	$\geq$ 30 m
Max. number of storeys**	2	6	10	$>$ 10

* Defined to top of highest floor surface level
** Typical depending on storey height

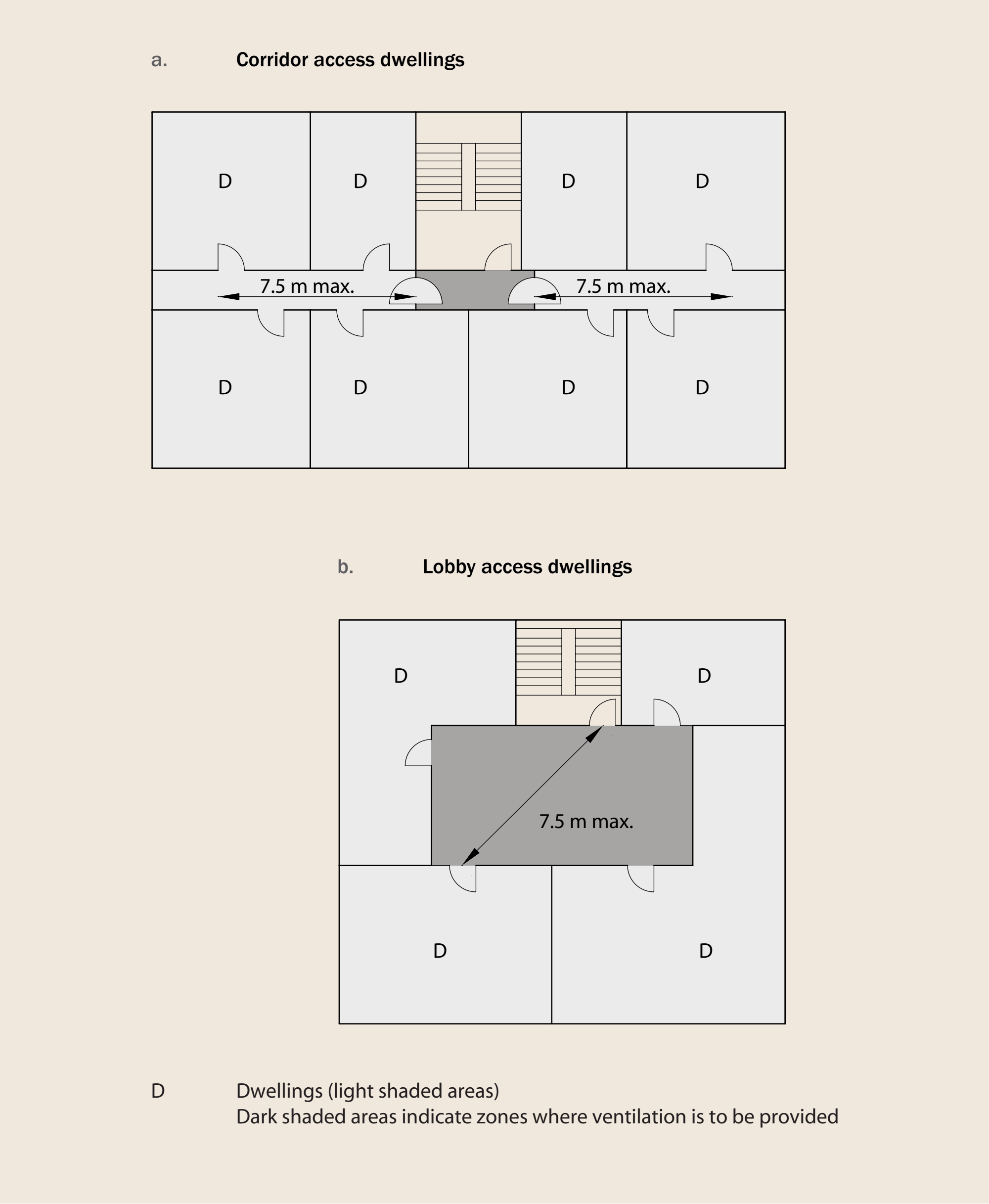


Figure 2.3 Minimum escape distances in residential buildings

2.2.2 Fire protection of light steel framing

Fire protection to the structural elements in light steel floors and walls is usually provided by fire resistant plasterboard, as illustrated in Figure 2.5 and Figure 2.6. Plasterboard offers the following protection:

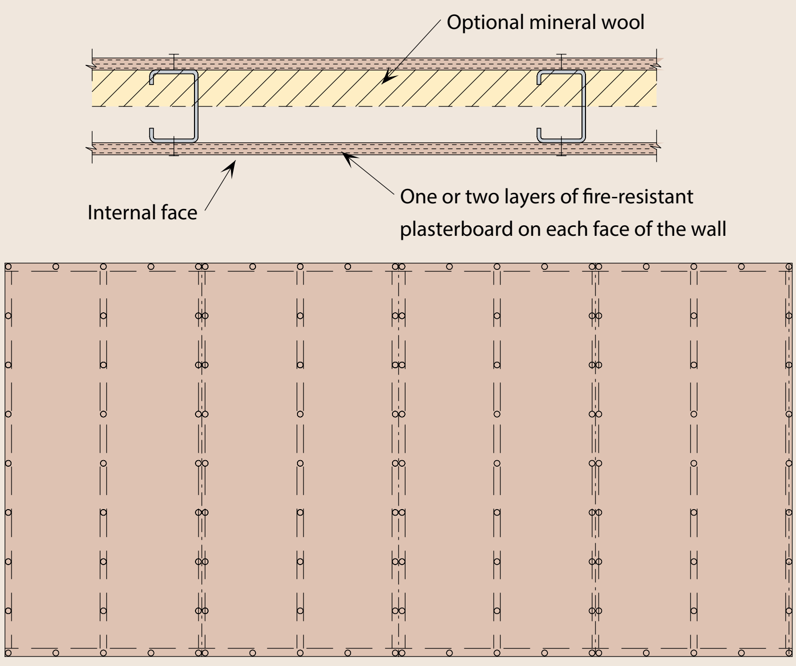
- For load bearing and infill walls in steel frames, 30 minutes fire resistance is achieved by a single layer of 12.5 mm fire resistant plasterboard on each face of a steel stud wall.
- For load bearing walls, 60 minutes fire resistance is achieved by one layer of 12.5 mm fire resistant plasterboard on a layer of 12.5 mm wallboard, with staggered joints, on each face of a steel stud wall.
- For separating walls, 60 minutes fire resistance is generally achieved by two layers of 15 mm fire resistant plasterboard, with staggered joints, on each face of a steel stud wall.

- For floors, 30 minutes fire resistance is achieved with 18 mm T&G boarding on light steel joists and 12.5 mm fire resistant plasterboard beneath the joists. The joints are taped and filled.
- For floors, 60 minutes fire resistance is achieved with one layer of 12.5 mm fire resistant plasterboard on a layer of 12.5 mm standard plasterboard with staggered joints beneath the joists and at least 18 mm T&G board on top.

For separating walls and floors, it is often necessary to increase the thickness of fire protection to 2 × 15 mm fire resisting plasterboard (type F to BS EN 520 [18]) to satisfy the acoustic insulation requirements. Lining materials are constantly developing and individual manufacturers may use alternative, more economic materials and configurations to achieve the above levels of fire protection. Fire tests on walls with acoustically resilient bars have shown that the resilient bars have no adverse effect on the fire resistance of a load bearing wall.

For further information, see SCI publication ED016 [19].

Cement-particle boards can also be used and they are very effective in providing integrity in fire conditions. When multiple layers of board are used, their joints should be staggered to maximise integrity in fire. The boards, which may be 12.5 mm or



Fixings of boards to wall studs:
For single layer of plasterboard, screws at 300 mm centres (maximum)

For two layers of plasterboard:
- First layer of fixings at 600 mm centres (max.)
- Second layer fixings at 300 mm centres (max.)
- Joints staggered by half a board

Plasterboard should always be laid with long side vertical
Plasterboard plank, always placed as the first layer, with long side horizontal

Figure 2.4
Fire protection to members in a wall

15 mm thick, should be attached to framing members with fixing screws spaced at not more than 150 mm centres at the edges of the boards and at maximum 300 mm centres internally for walls and 230 mm internally for ceilings.

Compartment walls and floors

In residential construction, each dwelling forms a separate fire compartment. A fire resistance of 60 minutes is required for all walls and floors that separate compartments. In hotels and similar multi-occupancy residences, only the floors have to be compartmented.

Compartment walls and floors will usually also act as acoustic separating constructions. The measures for fire protection will also help achieve enhanced acoustic performance.

Cavity barriers or fire stops must be provided around any penetrations through fire resisting walls, in accordance with Building Regulations. Usually 50 mm thick wire reinforced (or polyethylene sleeved) mineral wool fire stops are used, installed in any cavities around compartment floors and walls to prevent spread of smoke between compartments.

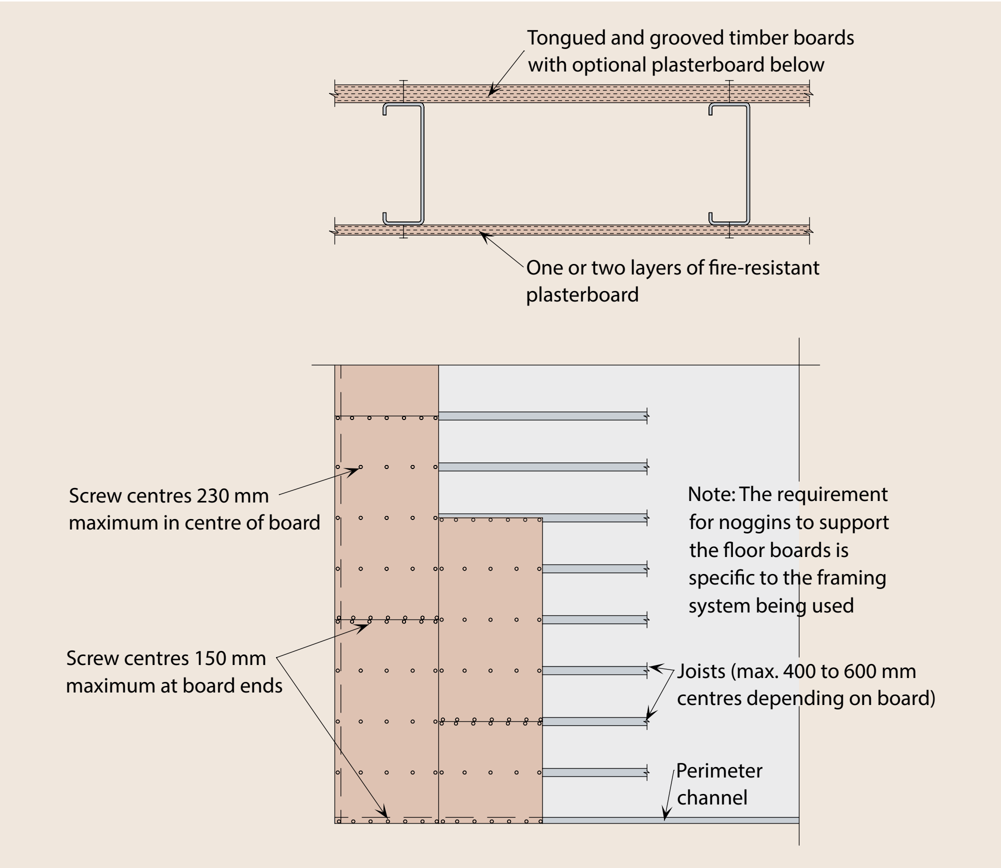


Figure 2.5 Fire protection to members in a floor

Surface flame spread

External claddings, with limited combustibility and national Class 0 (or European Class B) flame spread, are required for external walls within 1 m of a site boundary and for buildings over 20 m tall. There are also limitations on opening areas.

Surface spread of flame ratings can be met by achieving specific fire ratings to either British test standard BS 476-7 [20] or European test standard BS EN 13501-1 [21]. Table 2.3 shows typical surface flame spread classifications for cladding and lining materials.

Table 2.3 Surface flame spread classification to BS 476-7

CLASSIFICATION	MATERIAL
Class 0 (European Class B)	Brickwork Cement render Tile and slate hanging Cement bonded particle board Cement fibre board Wood based materials treated with flame retardant finish to class 0
Class 1	Wood based materials treated with flame retardant finish to class 1

2.2.3 Fire safety during construction

Fire safety during construction is an important consideration for some forms of construction. However, light steel framing possesses the following beneficial attributes in terms of fire safety during construction:

- Steel is non-combustible and does not add to the fire load of the building.
- Plasterboard is non-combustible and provides fire resistance by virtue of its insulating properties and inherent chemically-bonded water content.
- Mineral wool or glass wool may be used as both acoustic and thermal insulation. They are non-combustible and do not add to the fire load.
- Modular units are lined with plasterboard or similar material and fitted with external sheathing board off site. If a fire were to start within a module, it would be fully contained.
- When fire protected by plasterboard, tests have shown that the temperature of light steel remains below 100 °C in a real fire with a duration up to 80% of its specified fire resistance period, and thus the light steel can be re-used after a fire.
- Steel connections are very robust in fire and do not fail before the connected members.

Light steel frames and floor cassettes may be delivered as large pre-fabricated elements and are lifted into position from the lorry by crane. They are non-combustible, except for the timber floor boarding, which possesses only a low fire load. The wastage rates for light steel construction are extremely low; so there is almost no combustible waste material stored on-site. Generally, the bundles or pallets of insulation are stored externally, as they will be installed on the outside of the light steel walls and roof. Carpentry is generally carried out after the ceiling and wall boards have been fixed, at which point the light steel framework is fully fire protected to its design resistance period. Therefore, light steel structures possess little risk of fire during construction, thanks to the non-combustibility of the materials used, and the ‘just in time’ nature of the construction process.

It is not necessary to phase the construction programme of a light steel structure in order to reduce the risk of fire, because of the low fire load, nor is there any fire risk to adjacent buildings.

2.3 Acoustic performance

2.3.1 Building Regulations Part E: Resistance to the passage of sound

The requirements of Part E of the Building Regulations apply to floors and walls that separate one dwelling from another, internal walls and floors and walls and floors that separate a dwelling from a communal space. There are no statutory requirements for acoustic insulation of the external envelope.

Approved Document E describes two methods of demonstrating compliance with Part E of the Building Regulations; pre-completion testing (PCT) and by use of Robust Details (RDs).

PCT is carried out on-site and the onus is on the builder to demonstrate compliance. PCT only applies to separating walls and floors and is not necessary for internal walls and floors. PCT should be carried out when the rooms either side of the separating element are essentially complete, except for decoration.

Robust Details were developed as an alternative to PCT. A range of details has been developed which have been proved through testing to consistently satisfy (and exceed +5 dB) the acoustic performance requirements specified in Approved Document E. The available RDs and their specification requirements are given in Robust Details Handbook [22] published by Robust Details Limited. Robust Details are available for light steel walls and floors, however, it is more usual for PCT to be used to demonstrate compliance with the Building regulations for light steel framing.

The acoustic performance of a floor or wall will be acceptable if the values given in Table 2.4 are demonstrated in tests. These tests should be carried out in accordance with BS EN ISO 10848-2 [23] (and the performance calculated in accordance with BS EN ISO 717 [24]).

Table 2.4 Sound insulation values for separating floors and walls in purpose built dwelling houses and flats

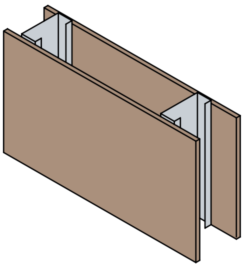
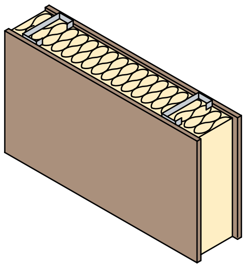
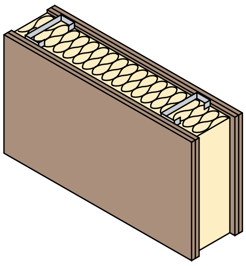
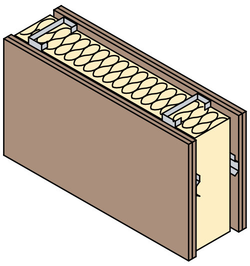
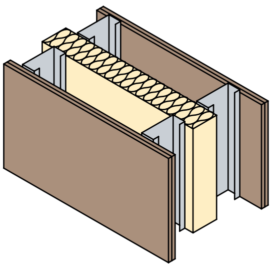
SEPARATING ELEMENT	PERFORMANCE (dB)
Separating wall - airborne sound insulation ($D_{nT,w} + C_{tr}$)	≥ 45
Separating floor - airborne sound insulation ($D_{nT,w} + C_{tr}$)	≥ 45
Separating floor - impact sound transmission ($L'_{nT,w}$)	< 62

Most light steel framing manufacturers have had their typical constructions tested to demonstrate compliance with the Regulations.

2.3.2 Acoustic insulation in lightweight construction

Framed construction relies on the presence of a cavity between the various layers and a degree of structural isolation to achieve good acoustic performance. In separating walls, double skin construction is used with minimal inter-connections. Table 2.5 illustrates a range of wall constructions with their respective acoustic insulation. Table 2.6 compares measured acoustic performance of residential buildings using light steel framing with the current requirements, as given in Table 2.5.

Table 2.5 Light steel wall constructions giving indicative acoustic insulation and fire separation

	MATERIAL SPECIFICATIONS	ACOUSTIC INSULATION $D_{nTw} + C_{tr}$ or R_w	FIRE RESISTANCE
	12.5 mm plasterboard Light steel studs 12.5 mm plasterboard	R_w 36 – 43 dB	30 min
	12.5 mm plasterboard Light steel studs with mineral wool between 12.5 mm plasterboard	R_w 40 – 50 dB	30 min
	2 layers of 12.5 mm plasterboard Light steel studs with mineral wool between 2 layers of 12.5 mm plasterboard	R_w 45 – 52 dB	60 min
	2 layers of 12.5 mm plasterboard Resilient bars Light steel studs with mineral wool between Resilient bars 2 layers of 12.5 mm plasterboard	$D_{nTw} + C_{tr}$ 47 – 51 dB	60 min
	2 layers of 12.5 mm plasterboard Light steel studs Mineral wool between stud walls Light steel joists 2 layers of 12.5 mm plasterboard	$D_{nTw} + C_{tr}$ 45 – 56 dB	60 min

Floor constructions achieve good acoustic insulation by multiple layers rather than by the use of heavyweight components. Resilient bars, in the form of small Z sections or 'top hat' sections attached to the floors or walls, add to the insulation by reducing direct transfer of sound.

Further guidance on acoustic detailing and sound insulation is provided in SCI publication *Acoustic Detailing for Steel Construction* (P372) [25] and SCI publication ED015 [26].

The acoustic insulation properties of walls or floors vary with the frequency of the noise. Certain frequencies are likely to be attenuated (reduced) more effectively than others by any given construction. Low pitched sounds are usually attenuated less than high pitched sound. BS EN ISO 140 [27] enables field tests to be performed to measure airborne sound insulation between rooms and the impact sound insulation of floors in buildings.

Lightweight construction uses dry assembly processes. Wet plastering will tend to seal cracks and joints. When using dry lining board, it is important to ensure efficient sealing of air paths that can lead to local sound transfer. Furthermore, flanking at the floor-wall junctions should be minimised by good detailing at these positions. General guidance on acoustic insulation in light steel construction is given in SCI publication *Acoustic Performance – Case studies* (P371) [28] and SCI publication P372 [25].

Table 2.6 Comparison of the acoustic performance of separating floors and walls in light steel framed dwellings

	ACOUSTIC PERFORMANCE		
	FLOOR $D_{nT,w} + C_{tr}$ (dB)	FLOOR $L'_{nT,w}$ (dB)	WALL $D_{nT,w} + C_{tr}$ (dB)
2010 Building Regulations Part E	≥ 45	< 62	≥ 45
Measured values in light steel framed dwellings			
Oxford Brookes University demonstration building	57	54	65
Modular residential building, West London	52	49	48
The Paragon Project, London	48	54	47
King Edward Court, Windsor	51	54	–
Care home, West London	52	52	54
Houndsmill, Basingstoke	53	52	51

2.3.3 Separating walls

In separating walls using light steel framing, two generic forms of construction exist.

- Double leaf walls in which each leaf of the wall is structurally and physically independent of the other.
- Single leaf walls with acoustically resilient bars on both sides of the wall.

In a double leaf wall, the sound insulation of individual components combines together in a cumulative relationship, provided that the two leafs remain largely structurally separate.

In single leaf walls the resilient bars are designed to absorb acoustic vibrations and therefore to increase the attenuation of the single leaf wall.

The essential requirements for good acoustic insulation of separating walls in lightweight dry construction are:

- A minimum weight of 25 kg/m^2 in each leaf (two layers of 12.5 mm plasterboard, or equivalent).
- For double leaf walls a minimum spacing of 200 mm between plasterboard layers is recommended.
- Good sealing of all joints.
- A mineral fibre quilt within one or both of the leafs or in the cavity between the leafs.

2.3.4 Separating floors

For a separating floor construction between dwellings, both airborne and impact sound transmission must be addressed. High levels of acoustic insulation are achieved in lightweight floors by using a similar approach to that described in Section 2.3.3 for walls. It is important to separate (as far as possible) the top surface layer from the ceiling dry lining layer. This is usually done by the use of a resilient layer between the top floor finish and the structure below, and by resilient bars used to isolate the ceiling. A series of typical floor constructions is presented in Table 2.7.

Impact sound transmission in lightweight floors is reduced by:

- Specifying an appropriate floor treatment consisting of a resilient layer with correct dynamic stiffness under imposed loading.
- Ensuring that the resilient layer has adequate durability and resonance.
- Isolating the floating floor surface from the surrounding structure at the floor edges. This can be achieved by returning the resilient layer up the edges of the walking surface.

Airborne sound insulation in lightweight floors is achieved by:

- Structural separation between layers.
- Appropriate mass in each layer.
- Sound absorbent quilt.
- Minimising flanking transmission at floor-wall junctions.

Further improvements in the design of lightweight floors can be achieved by complete separation of the floor structure from the ceiling structure, in a similar way to the double leaf walls described above.

The resilient layer may be in the form of a battened floor system or a dense mineral wool which contributes to insulation against both airborne and impact sound. Generally, mineral fibre with a density between 70 and 100 kg/m^3, provides sufficient stiffness to prevent local deflection but is soft enough to function as a vibration insulator. At the underside of the steel joists, resilient bars partially isolate the dry lining layer from the structure. A mineral wool quilt in the cavity between the steel joists provides sound absorption.

The precise specification of each layer needs to be considered to optimise the floor performance. Increasing the mass of the top (floating) layer can have a significant improvement on the airborne sound insulation. Floor joists at 600 mm centres have slightly better sound insulation than joists at 400 mm centres and thicker plasterboard layers and gypsum fibreboard will have a higher mass, thus reducing sound transmission.

2.3.5 Flanking transmission

Flanking transmission occurs when airborne sound travels around the separating element of structure through adjacent building elements. Flanking transmission is difficult to predict, because it depends on the details of the floor and wall junction and the quality of construction on site. It is possible for a building to have separating walls and floors built to a high specification, but for sound to be transmitted through side walls which are continuous across the separating elements.

Flanking transmission is dependent on:

- The properties of the surrounding structure, and whether it allows for indirect passage of sound.
- The size of the wall or floor and, therefore, the proportionate effect of flanking losses.
- The details of the floor/wall connections.

Flanking transmissions can add 3 to 7 dB to the sound transfer of real constructions in comparison to those tested acoustically in the laboratory.

To reduce flanking transmission, it is important to prevent the floor boarding from touching the wall studs by including a resilient strip between the wall and floor boarding (see Figure 2.6). Furthermore, the air space between the wall studs should be filled with mineral wool insulation to a height of 300 mm above the floor level in separating and external walls.

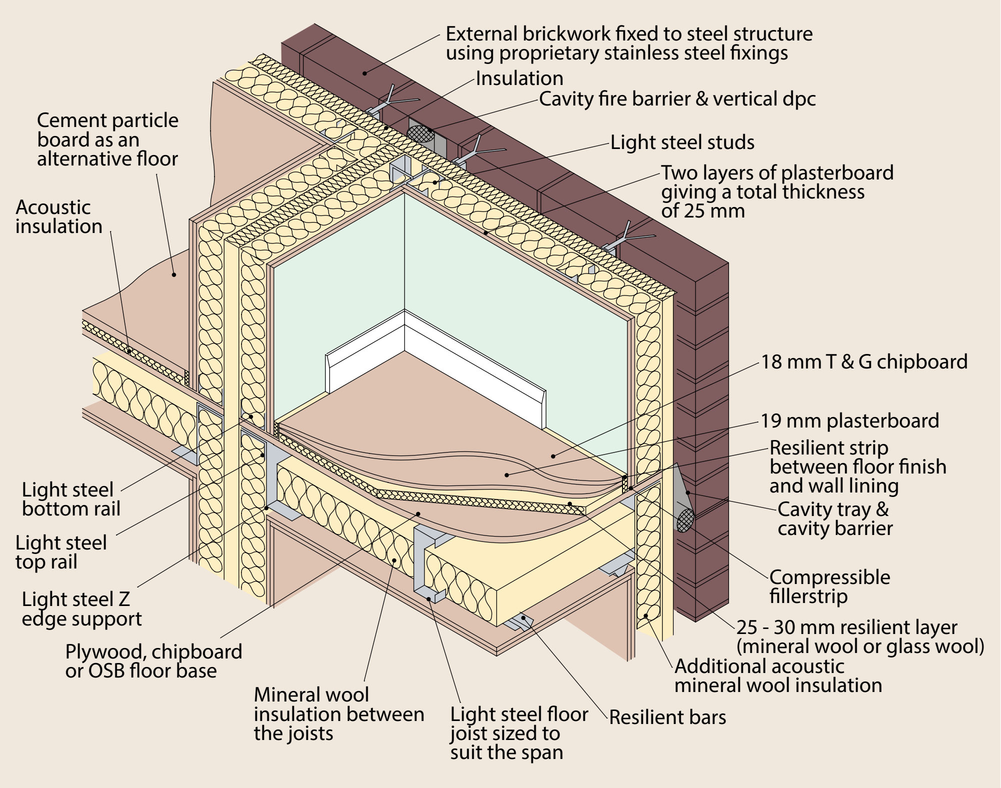


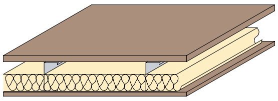
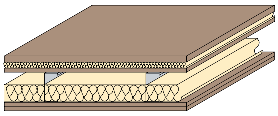
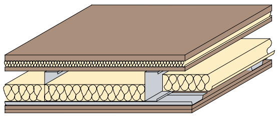
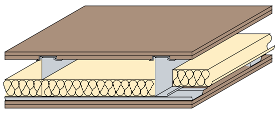
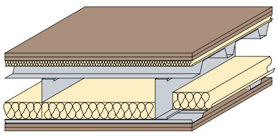
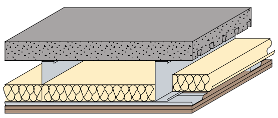
Figure 2.6 Details of compartment floor at junction with external wall and separating wall

2.3.6 Penetration of linings

Since sound attenuation can be particularly affected by air paths between spaces, special care should be taken around openings for service pipes and other penetrations. Electrical sockets penetrate the plasterboard layer and should be carefully insulated by quilt at their rear. Back to back electrical fittings should be avoided (see Section 9).
In panelised and modular construction, electric wiring can be pre-installed in the factory,

which facilitates commissioning on site and allows additional precautions to be made to ensure that it does not compromise acoustic performance.

Table 2.7 Sound insulation (indicative) and fire resistance characteristics of lightweight steel floors

	SPECIFICATION	ACOUSTIC INSULATION dB $D_{nTw} + C_{tr}$	ACOUSTIC INSULATION dB L_{nTw}	FIRE RESISTANCE
	18 mm chipboard Light steel joists 100 mm mineral wool between joists 12.5 mm Plasterboard	26 – 35	70 – 80	30 min
	19 mm cement particle board 10 mm resilient layer (min) Chipboard, OSB or plywood Light steel joists 100 mm mineral wool 2 layers of Plasterboard (total thickness 30 mm)	45 – 50	45 – 58	60 min
	18 mm T&G chipboard 19 mm plasterboard 25 – 30 mm mineral wool or glass wool Chipboard, OSB or plywood base Light steel joists 100 mm mineral wool between joists Resilient bars 2 layers of Plasterboard (total thickness 30 mm)	46 – 52	45 – 55	60 min
	18 mm T&G chipboard Proprietary top hat isolating section Plasterboard between the top hat section Light steel joists Mineral wool between joists Resilient bars 2 layers of Plasterboard (total thickness 30 mm)	45 – 52	45 – 59	60 min
	18 mm T&G chipboard 19 mm plasterboard 25 – 30 mm mineral wool or glass wool 30 mm profiled steel decking Light steel joists Mineral wool between joists Resilient bars 2 layers of Plasterboard (total thickness 30 mm)	47 – 55	45 – 55	60 min
	Composite steel decking and concrete slab Light steel joists Mineral wool between joists Resilient bars 2 layers of Plasterboard (total thickness 30 mm)	46 – 56	48 – 60	60 min

2.4 Thermal performance

2.4.1 Building Regulations Part L: Conservation of fuel and power

The housing and residential sector increasingly demands more energy-efficient and higher quality buildings. In 2014, the latest revision to Part L of the Building Regulations was published. The objective of this and planned future improvements, is to reduce CO_2 emissions to meet the Government's 'zero carbon' target in 2016.

In England, Approved Document L (Conservation of fuel and power) provides practical guidance on ways of complying with the energy efficiency requirements of the Building Regulations. Similar guidance documents are published in Wales, Scotland and Northern Ireland.

For dwellings, the approved documents are, for England:

- Part L1A 2013 – Conservation of fuel and power in new dwellings
- Part L1B 2013 – Conservation of fuel and power in existing dwellings

The main change in Approved Document L1A 2013 is the introduction of a requirement that requires new dwellings to achieve, or better, a fabric energy efficiency target in addition to the existing carbon dioxide target.

Approved Document L1A 2013 includes five performance criteria:

Criterion 1: Achieving the target CO_2 emission rate

The calculated CO_2 operational emissions rate from the building as built, should be less than or equal to the Target CO_2 Emissions Rate (TER) as set out in the Approved Documents.

The calculated emission rate of CO_2 is based on the annual energy requirements for space heating, water heating and lighting, less the emissions saved by renewable energy generation technologies. It makes use of standard sets of data for different activity areas, and calls on common databases of construction and service elements.

For residential buildings, the Dwelling CO_2 Emissions Rate (DER) is calculated using the Standard Assessment Procedure (SAP) [29].

In addition, for new dwellings only, the 2013 Part L Approved Document includes Fabric Energy Efficiency Standards (FEES) alongside the existing CO_2 emissions targets. It is a requirement that the calculated Dwelling Fabric Energy Efficiency (DFEE) rate must not be greater than the Target Fabric Energy Efficiency (TFEE) rate.

Criterion 2: Limits on design flexibility

While the approach to complying with Criterion 1 allows flexibility, the Approved Documents provide limiting fabric and services system efficiencies. In terms of the fabric, limiting U-value and air permeability parameters are given.

Criterion 2 is intended to limit design flexibility and to discourage excessive and inappropriate trade-offs e.g. individual building fabric elements with poor insulation standards being offset by renewable energy systems with uncertain service lives.

Criterion 3: Limiting the effects of heat gains in summer

The effects of summer heat gains must be limited by considering window size, orientation, shading and solar control measures, ventilation, thermal capacity and heat losses from pipes.

Criterion 4: Building performance consistent with the calculated emission rate

This criterion is to ensure that the building fabric is constructed so that its performance is consistent with the calculated CO_2 emission rate. Construction and commissioning issues considered include:

- Continuity of insulation over the whole building envelope
- Heat loss through cavity party walls
- Avoidance and minimization of thermal bridging – The avoidance of thermal bridging in steel construction is discussed in SCI publication *Avoidance of thermal bridging in steel construction* (P380) [30].
- Air permeability and pressure testing
- Commissioning of the building services systems.

Criterion 5: Provision of information for energy efficient operation of the building

Operating and maintenance instructions must be provided to ensure that owners/ occupants can operate and maintain the building in an energy efficient manner.

2.4.2 Code for Sustainable Homes

The Code for Sustainable Homes, launched in 2006 and revised in 2010, includes energy efficiency as a key element in its 'star' rating of sustainability. Buildings are rated on a scale from Level 1 to Level 6, where Level 6 is the highest. Since May 2008, it is mandatory for all new homes to be rated against the Code. Buildings that are not assessed under the Code are awarded a 'nil-rated' certificate. Code level 4 represents a 25% reduction in Target Emissions Rating (TER) relative to the 2010 Building Regulations, and is a higher standard than the 2013 amendment to the Building Regulations. An addendum to the Code Technical Guidance was published in 2014 to align the Code requirements with the latest (2013) version of Part L1A. Refer to www.communities.gov.uk.

One of the recommendations of the Government's *Housing Standards Review* [31] undertaken in 2013, was to 'wind down' the Code for Sustainable Homes. However, the precise timeframe for this is uncertain but Government's intention is to consolidate some of the Code requirements into the Building Regulations.

For further information relating to steel construction see SCI publications *Code for Sustainable Homes – How to satisfy the code using steel technologies* (P386) [32] and *Sustainability of steel in housing and residential buildings* (P370) [33].

High levels of insulation and lower air leakage rates in light steel framing satisfy modern comfort standards and energy efficiency targets economically. Also the 'warm' frame concept using light steel framing maintains the light steel components within the heated envelope, avoiding condensation and durability problems. Information on the thermal performance of light steel construction is given in SCI publication ED019 [34].

Architects and developers can hence exploit the benefits of light steel framing and modular construction as an economic and versatile alternative to traditional construction systems. See SCI publication *Energy efficient housing using light steel framing* (P367) [35].

2.4.3 Energy rating methods for buildings

SAP rating

The Standard Assessment Procedure (SAP) [29] is the methodology used in the UK to assess the energy performance of dwellings. The current version of SAP (SAP 2012) is used for building regulation compliance (Part L). SAP 2012 is also used to produce Energy Performance Certificates.

SAP indicators of energy performance are Fabric Energy Efficiency (FEE), energy consumption per unit floor area, energy cost rating (the SAP rating), Environmental Impact rating based on CO_2 emissions (the EI rating) and Dwelling CO_2 Emission Rate (DER).

The SAP rating is based on the energy costs associated with space heating, water heating, ventilation and lighting, less cost savings from energy generation technologies. It is adjusted for floor area so that it is essentially independent of dwelling size for a given built form. The SAP rating is expressed on a scale of 1 to 100, the higher the number the lower the running costs.

The Dwelling CO_2 Emission Rate (DER) is used for the purposes of compliance with building regulations. It is equal to the annual CO_2 emissions per unit floor area for space heating, water heating, ventilation and lighting, less the emissions saved by energy generation technologies, expressed in kg/m^2/year.

National Home Energy Rating

The National Home Energy Rating (NHER) [36] is a method of assessing the energy performance and fuel cost of a dwelling. It uses a similar data set to SAP but includes more detail on occupancy, location and appliance use to give a more accurate calculation of CO_2 emissions and running costs for a specific dwelling. The NHER rating is not a statutory requirement. It is often used by affordable housing providers to give a good indication of potential running costs of new properties.

Elemental Method

This is the simplest approach for designing the insulation envelope of a dwelling or a building consisting of dwellings. The Elemental Method specifies U-values of the elements of the building fabric which should be met.

Energy Performance Certificates

A requirement of the EU Directive on the Energy Performance of Buildings [37], EPCs were first introduced in the UK in 2007. Domestic EPCs are mandatory for new dwellings and for existing dwellings whenever the property is sold or let. EPCs are valid for 10 years and must be produced by an accredited energy assessor.

The EPC provides an energy efficiency rating (the Asset Rating) on a scale of A to G. The EPC indicates the current rating of the property and the potential rating that could be achieved if certain recommendations, included in the EPC, are implemented. Domestic EPCs are calculated using SAP [29]. All EPCs are recorded on a National Register.

2.4.4 Location of insulation

The thermal insulation of the building envelope is characterised by its U-value (in W/m^{2}K). Lower U-values lead to higher levels of insulation.

The U-value calculation takes account of the position of the light steel framework within the building envelope.

In light steel framing, thermal insulation is placed outside the steel studs together with supplementary insulation placed between the steel studs to create a 'warm frame' construction (see Figure 2.7). The amount of thermal insulation on the outside of the steel studs should provide at least two thirds of the insulating properties and the supplementary insulation is to be placed in contact with the studs to minimise air gaps and to prevent local condensation. A typical example of the insulation to light steel framing is shown in Figure 2.8.

The perimeters of openings should be detailed to minimise cold bridging. In traditional construction, thermal bridges are most common around window and door openings and at the junction of walls with floors and roofs, and can significantly increase heat loss. The 'warm frame' principle ensures that the full thickness of insulation is continuous right up to the window or door frame. This avoids the cooler wall surfaces that can occur around openings.

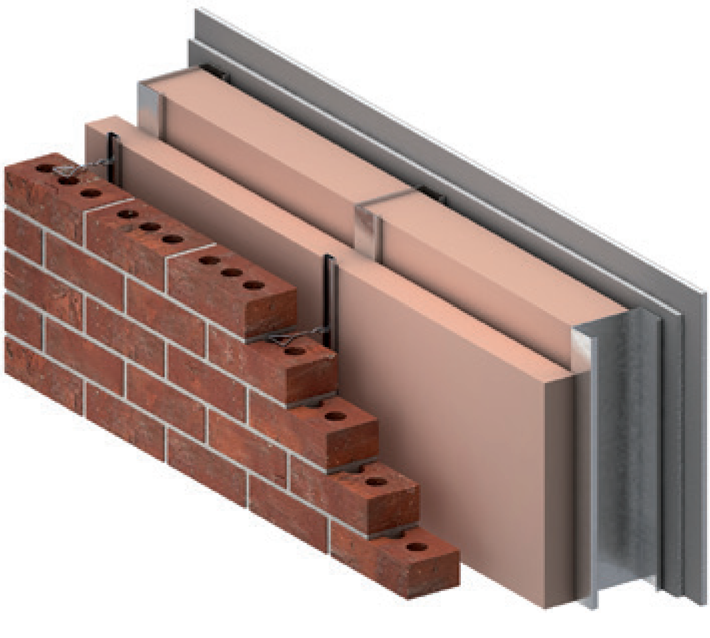


Figure 2.7 External wall supporting brickwork without and with sheathing boards

(a) Light steel wall without sheathing board

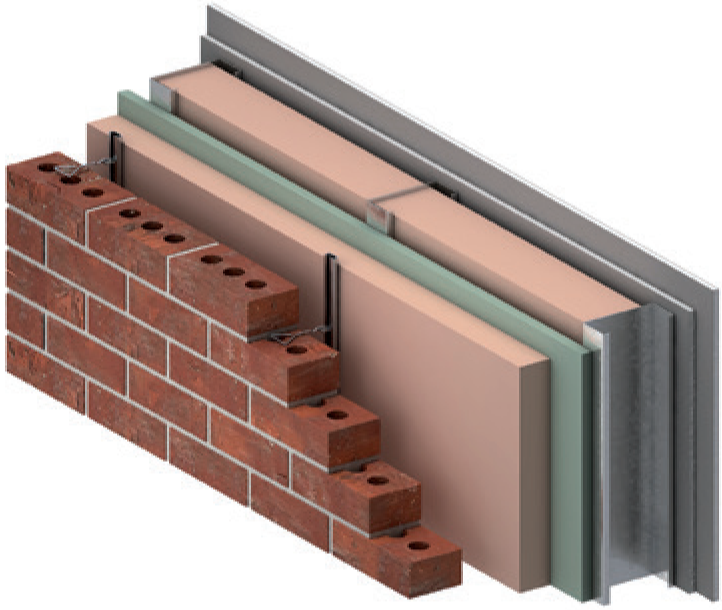


Figure 2.7 (continued) External wall supporting brickwork without and with sheathing boards

(b) Light steel wall with sheathing board

The minimum thicknesses of closed cell insulation placed outside of the light steel framework as shown in Table 2.8 for brick-clad buildings and in Table 2.9 for insulated render cladding. These tables take account of thermal effect of the C sections that are within the thickness of the mineral wool. Guidance on linear thermal bridging is presented in Section 2.5.

Accredited Construction Details (ACDs) have been developed to assist the construction industry achieve the performance standards required to demonstrate compliance with the energy efficiency requirements (Part L) of the Building Regulations. The details focus on the issues of insulation continuity (minimising cold bridging) and airtightness.

Table 2.8 Insulation thickness for light steel framing (100mm C section) with inter-stud insulation and a brick façade

INSULATION THICKNESS (mm)	U-VALUE W/m²K - CLOSED CELL PIR INSULATION IN CAVITY	OVERALL WALL THICKNESS (mm)
60	0.20	337
80	0.18	357
100	0.15	377

Mineral wool is placed between the C sections in all cases.
PIR = Polyisocyanurate closed cell insulation board with aluminium foil facing

Table 2.9 Insulation thickness for insulated render cladding (100mm C section) with inter-stud insulation

INSULATION THICKNESS (mm)	EXPANDED POLYSTYRENE (λ = 0.035 W/mK)	CLOSED CELL INSULATION (λ = 0.025 W/mK)	OVERALL WALL THICKNESS (mm)
80	0.23	0.19	220
100	0.20	0.16	240
120	0.18	0.14	260

Mineral wool is placed between the C sections in all cases and sheathing board is generally used in insulated render systems.

Figure 2.8 Insulated board attached to light steel framework

2.4.5 Control of condensation

Condensation in buildings can occur on a cold internal surface, or as interstitial condensation within the thickness of the wall. The latter can be more serious as it can go unnoticed, leading to damage of the fabric of the building.

Water vapour will pass between spaces or across envelope elements wherever there is a vapour pressure difference. Where vapour-laden air percolates into a wall, floor or roof construction, it will lead to interstitial condensation if it is cooled to its dew point temperature. In light steel construction, interstitial condensation on the steel is avoided by keeping the steel frame fully within the insulated cavity, or ensuring that there is an effective vapour barrier to prevent water vapour reaching the cold part of the envelope. The increased thermal conductivity of steel studs means that the temperature of the steel along the web and at the outer flange is greater than in the insulation alongside, which reduces the likelihood of condensation on the wall studs.

In the worst case, 'thermal bridging' through the studs can cause local cool spots in the vicinity of the stud, leading to 'ghosting' where local condensation causes staining of the wall surface along the lines of the studs. 'Warm frame' construction ensures that the internal surface temperatures along the steel framing elements do not fall to below the dew point temperature. Alternatively, insulated sheathing boards can be used with some insulation between the studs. In this case, a vapour control layer should be used. To avoid surface condensation and 'ghosting', the BRE suggests that internal surface temperatures should not fall below 15.5°C when the internal air temperature is 21°C. Particular attention must be paid to:

- Detailing to ensure continuous insulation at window and door openings.
- Detailing at wall junctions with floor and roof.
- Penetration by services.
- Mechanical venting of spaces subject to high humidity, e.g. bathrooms.

2.4.6 Ventilation of roof space

Part F2 of the Building Regulations defines the requirements for the avoidance of condensation in the roof of buildings. This requires that adequate provision should be made to prevent condensation in the roof or roof void. This requirement can be satisfied by providing sufficient cross-ventilation into the roof space, or placing the insulation above the roof structure. The following options are available as illustrated in Figure 2.9:

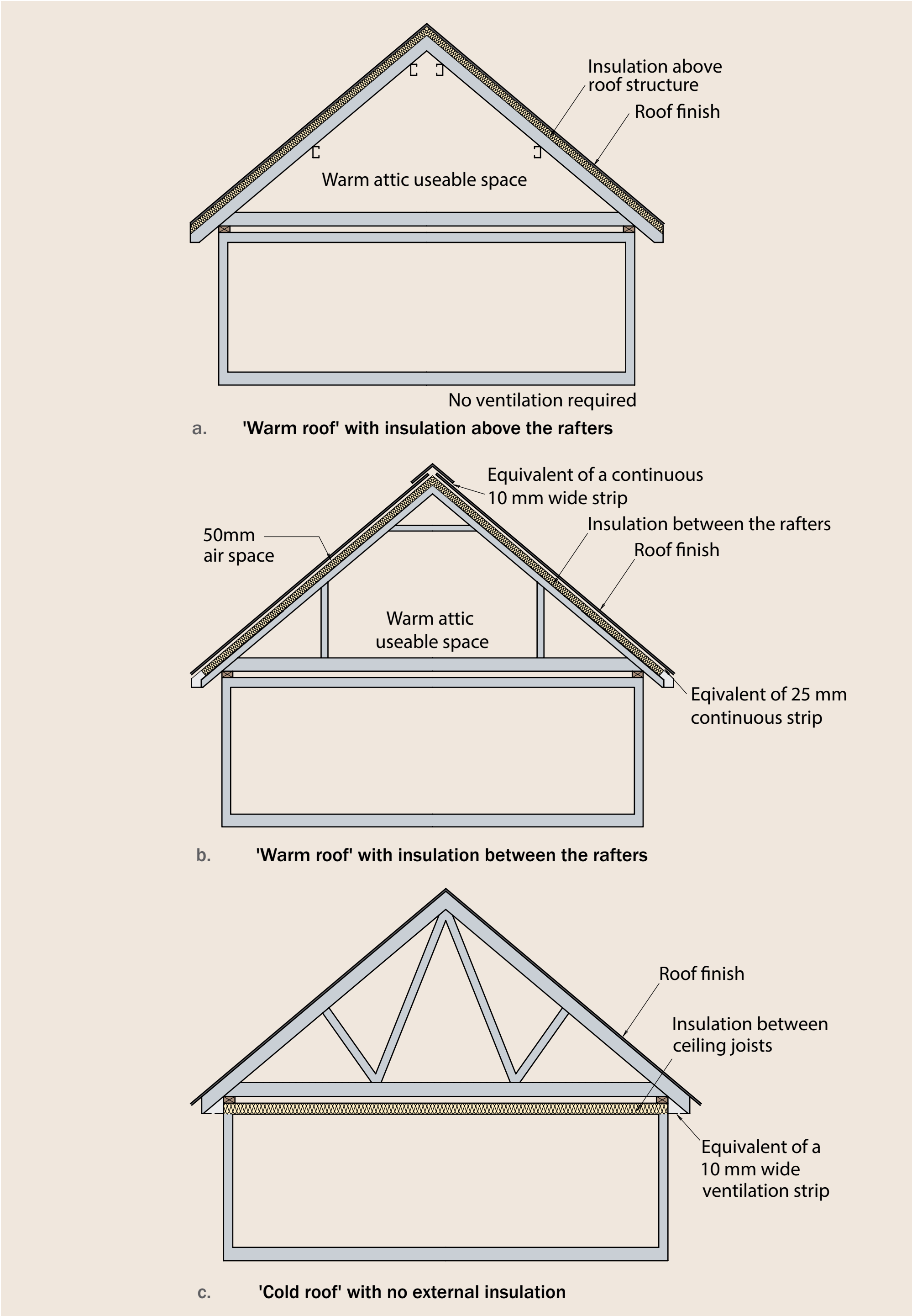


Figure 2.9 Roof space ventilation measures

(Note: The wall insulation has been omitted for clarity. In all cases the insulation at the head of the wall should be continuous with the roof insulation)

- For a pitched roof with a ventilated cold roof space, a ventilation gap equivalent of a 10 mm continuous open strip should be provided along each of the eaves. This requirement is illustrated in Figure 2.9 (c).
- Where insulation follows the pitch of the rafters and is between or below the rafters, a 50 mm air gap must be left between the top of the insulation and the underside of the roof covering, with the equivalent of a 25 mm ventilation grill at the eaves and the equivalent of 5 mm of continuous ventilation at the ridge.
- No ventilation is required for flat and pitched roofs where the insulation is placed above the roof structure.

2.4.7 Air-tightness

Air-tightness signifies the extent to which the building fabric enables either inward or outward air movement. Air-tightness is important as unwanted air leakage can add up to 30% to the heat loss from a building. Specific levels of air tightness for new buildings are verified via air-tightness testing in accordance with ATTMA TS1 [38].

Air-tightness is measured in units of m^3/m^2/hour (or sometimes air changes per hour) which refer to the volume of air passing through a unit area of the building fabric at a test pressure difference of 50 Pa from the inside to the outside. Typical air-tightness rates of light steel and modular construction are presented in Table 2.10, which are lower than envisaged by the Building Regulations. A test air-tightness of less than 5 m^3/m^3/hr is generally achieved by light steel framing and much lower values can be achieved with suitable sheathing boards. In practice, with nominal pressure difference between inside and outside, the actual air infiltration is only about 5% of the test value, so the test is used only to demonstrate compliance with Regulations.

Table 2.10 Air-tightness values for typical forms of construction

BUILDING TYPE	AIR-TIGHTNESS RATE AT 50 Pa ($m^3/m^2/hr$)
Typical on-site construction implied by the Building Regulations	10
Prefabricated light steel framed houses (terraced house)	2 to 5
Residential building using additional sheathing layers or modular construction	1 to 3

Heating demand is significantly affected by infiltration of cooler outside air through cracks and gaps in the building envelope. Furthermore, air flows within the structure can increase the risk of interstitial condensation. Air infiltration is best dealt with by creating an air barrier on the warm side of the insulation, which is well sealed at all joints. Higher levels of air-tightness may be provided by a vapour barrier or some other element of the construction, such as foil backed plasterboard. It must be well sealed, and penetrations should be avoided or appropriately detailed.

Airflows through the structure can be prevented or reduced by means of an air barrier, which can be the vapour barrier or some other layer in the envelope. The air barrier should be continuous, as far as is practical, with seals at overlaps and edges around openings such as windows and doors. Details should prevent penetrations of the air barrier for services or other reasons or, alternatively, there should be an effective seal around all penetrations.

2.5 Thermal bridging

Thermal bridges result in heat transfer from the building that is in addition to the heat loss that occurs within the body of the external walls, roof and ground floor, as defined by the U-value of the individual elements. Thermal bridging can add significantly to the overall heat loss of the building, but it can be minimised by careful detailing. There are two generic forms of thermal bridge in the building envelope: linear thermal bridges occur at the junction of two elements of the construction or change of geometry; and point thermal bridges occur, for example, where an element is penetrated.

The linear thermal bridging parameter is generally given by a ψ (psi)-value, which is in units of W/mK, and its value is dependent on the level of insulation that makes up the U-values of the adjacent elements of construction. The effect of the C sections within the wall is included in the U-value calculation for the wall. The ψ-value is also dependent on the precise detailing that is used and the use of thermal 'breaks', such as cavity closures around windows.

The sum of all the linear thermal bridges times their length and divided by the total enclosed area of the building (including the ground floor) is known as the y-value. The default y-value is often taken as 0.15 W/m^{2}K for typical modern construction practice, which may contribute to about 20% additional heat loss in comparison to the heat transmission through the body of the building envelope.

However, through the use of Accredited Construction Details (ACDs) that are independently verified, the ψ-values of the ACDs may be input into whole building energy models to predict the overall yearly heat loss for the particular building shape and materials used. When summed over the building envelope, these ψ-values generally lead to much lower y-values. The Regulations permit the use of a y-value of 0.04 W/m^{2}K, only when ACDs exist for all the key junctions.

For light steel framing systems, the typical ψ-values of a wide range of typical details in housing have been determined and are presented in Table 2.11. The ψ-values are consistent with U-values of 0.2 W/m^{2}K for the external walls and ground floor and 0.15 W/m^{2}K for the roof. The critical areas for thermal bridging tend to be the ground floor and external wall junction, and where the internal separating wall (or party wall) passes through a 'cold' roof space. The actual ψ-values may differ from the values in Table 2.11, as they depend on the particular details adopted.

For a two storey semi-detached house of 100 m^2 floor area, it may be shown that the aggregated y-value is in the range of 0.04 to 0.06 W/m^{2}K when using these details. The precise value depends on the building shape and number of windows.

The avoidance of thermal bridging in steel construction is discussed in more detail in SCI publication *Avoidance of thermal bridging in steel construction* (P380) [30].

LOCATION OF LINEAR THERMAL BRIDGE IN LIGHT STEEL FRAMING IN A TYPICAL HOUSE	TYPICAL Ψ-VALUES (W/mK)
Junction of separating wall and façade wall	0.06
Junction of separating wall (party wall) and 'cold' roof	0.18
Junction of intermediate floor and façade wall	0.09
Junction of eaves at roof and façade wall	0.05
Junction of gable wall and roof	0.05
Outward corner of external wall	0.06
Lintel above window with cavity closure	0.05
Sill and jamb of window with cavity closure	0.04
Concrete ground bearing floor slab with insulation over the slab	0.12
Suspended ground floor with insulation above or below the floor and between the joists	0.09

Table 2.11 Typical ψ-values for light steel framing (also achieving the U-values in the Building Regulations 2010 amendment 2013)

2.6 Radon gas infiltration

The requirement in Part C of the Building Regulations that precautions shall be taken to avoid changes to health and safety caused by substances in the ground covers the precautions to prevent radioactive radon gas from entering the building from seepage from the ground. In the UK, the degree of exposure varies with location.

Two methods of protecting dwellings from radon gas infiltration include:

- The passive system which consists of an airtight barrier that runs across the whole building including the ground floor and walls. This barrier is usually a polyethylene membrane placed above the floor structure and lapped under the cavity tray at the wall intersections. Where a suspended floor is used, secondary protection is also provided with the introduction of air bricks to provide ventilation of the void beneath the floor. Openings of at least 1500 mm^2 per metre run of wall on two opposite sides are required.
- An active approach which requires the installation of a powered radon extraction system that needs to be maintained throughout its life.

A composite suspended ground floor using steel decking and in-situ concrete provides an impermeable barrier to these gases.

Good design should ensure that service pipe and cable entry points do not permit leaks in the radon-impermeable membrane. Airtight seals should be provided, where necessary.

The guidance in Approved Document C refers to *Radon: Guidance on protective measures for new buildings*, published by BRE [39].

OTHER PERFORMANCE REQUIREMENTS FOR LIGHT STEEL FRAMING

3.1 Durability and design life

The hot dip galvanizing coating ensures durability of light steel frame construction in internal applications not directly exposed to moisture for long periods. The standard coating is G275 (275 grams/m^2 summed over both surfaces).

As for traditional construction, attention to design and construction details is essential. Control of moisture ingress and condensation, including the correct positioning of thermal insulation and use of damp proof courses, membranes and flashings will ensure good performance, and long design life.

When using galvanized steel, damaged areas of corrosion protection, e.g. at weld zones, must be reinstated by treatment with an appropriate zinc-rich paint. For this treatment to be fully effective, these areas must be thoroughly cleaned by wire brushing, primed and coated with two coats of a zinc-rich paint having a zinc content of at least 96%, or an equally effective alternative protection system.

In the following situations, sacrificial loss of zinc coating in local areas occurs and this protects the exposed edges of steel against corrosion. No further attention is required for:

- member ends, which have been cut in the factory
- holes for bolts or services, which have been punched in the factory
- penetrations made by self-drilling self-tapping screws.

A number of buildings, using standard galvanized steel components, have been monitored to assess the loss of zinc, leading to predictions of their design life (to major maintenance). A design life of over 200 years can be achieved in 'warm frame' construction (see SCI publication *Durability of light steel framing in residential buildings* (P262) [40]). In 'cold frame' construction, such as in un-insulated lofts, a design life of over 60 years can be achieved. In all cases, the building envelope should be properly maintained.

3.2 Dimensional discipline

3.2.1 Structural grid

For the effective use of materials, regular spacing of studs, floor joists and trusses is desirable. The spacing of these components should be compatible with standard floor, ceiling and wall boards. A structural grid of 400, 600 or 1200 mm is usually adopted to suit the use of 1200 mm wide plasterboard.

3.2.2 As-built tolerances for light steel framed structures

Light steel framing is very accurate and dimensional variations are largely due to the inaccuracy of the other components, particularly the foundations. Light steel framing may be used with all foundation types but care must be taken to ensure that target line and level tolerances are achieved, in order to assemble the wall panels accurately (see Section 4).

Compliance with normal accuracy of construction can be achieved easily, but the actual location of external brickwork in cavity walls, compared to the theoretical location, is a common practical problem. Here, the courses of brickwork below the DPC are laid before the DPC is in place. Any deviations in the brickwork at this level clearly affect the cavity space between the brickwork and the frame.

It is essential that the main contractor and the light steel framing supplier agree a hand-over procedure and ascertain the accurate position of the brickwork **before** the steel frame is erected.

The nominal cavity between the insulation and the brickwork is 50 mm, although the Approved Documents illustrate cases where the ‘actual’ cavity when using partial-fill insulation between two masonry skins can be reduced. NHBC recommend that the **minimum** cavity width that is achieved on site is 50 mm between the insulation and the internal face of the brickwork.

The construction tolerances for light steel frames are as shown in the following figures. The verticality (plumb) of the frame may deviate by up to 5 mm per storey, as shown in Figure 3.1 (+ indicates outward movement of the frame).

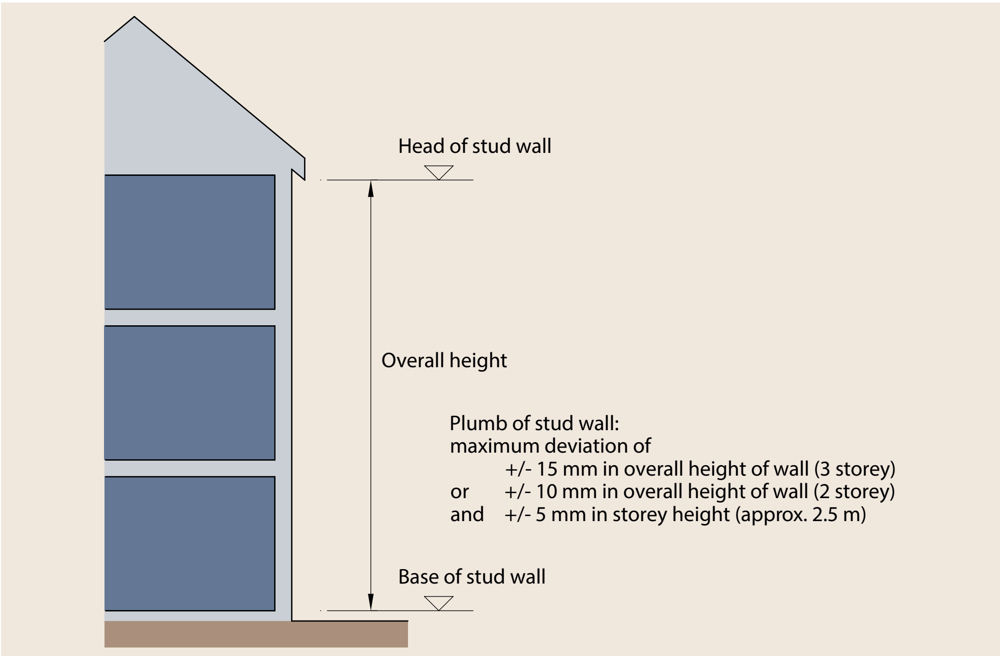


Figure 3.1 Verticality of frame (relative to base)

There are additional requirements for masonry clad walls. In determining the nominal cavity width, the following construction tolerances should be considered:

Out of verticality of brickwork +/– 10 mm total or +/– 5 mm per floor

Deviation in the surface of the insulation +/– 5 mm

It is unreasonable to consider that the 'worst' tolerances of all the components occur together at the same position. The normal method of considering a sensible probability of occurrence is either:

Expected maximum deviation = 2/3 × sum of individual maximum deviations

or = SQRT (Sum of squares of individual max deviations)

Tolerances in foundation levels are presented in Section 4.1.

Frames are manufactured as flat components to tight tolerances (< 3 mm) but, when installed, may be forced to align with other irregular components. Figure 3.2 shows a method of checking straightness on plan. A maximum deviation of 5 mm in a length of up to 10 m is reasonable.

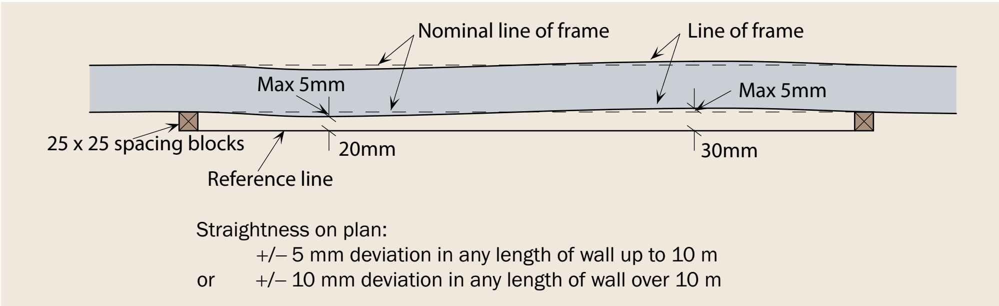


Figure 3.2 Horizontal position of frame (at base)

The level of floors is dependent on the level of the end supports. In this case, a deviation in level of ± 5 mm is acceptable, as shown in Figure 3.3.

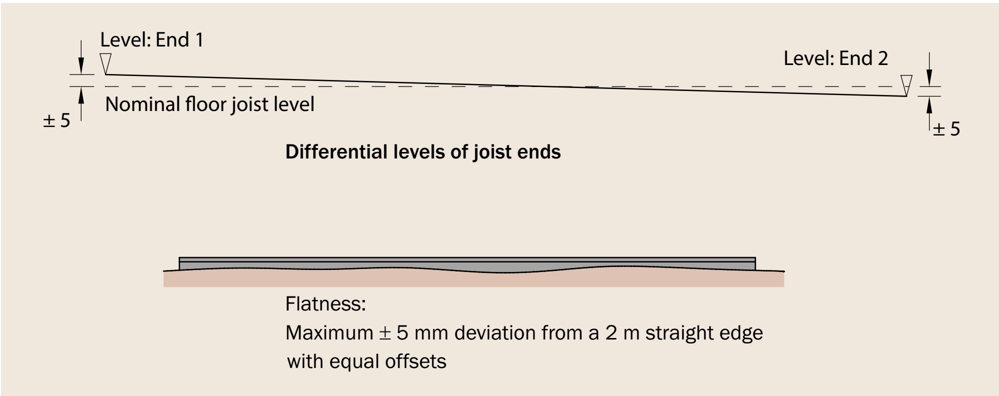


Figure 3.3 Level of floors

EN 1090-4 [41] defines the requirements for the manufacture of thin-gauge cold-formed steel elements, the execution of structures made from such elements (e.g. roofs, coverings, walls, floors, ceilings and purlins) under predominately static loading conditions and documentation. It is currently (2014) under development and covers products of construction class I and II, according to EN 1993-1-3.

3.3 Health and safety requirements

A risk assessment and method statement are required to satisfy the requirements of the Construction Health and Safety Plan. These are site and design specific and therefore need to be dealt with on a project by project basis.

3.3.1 Welding of galvanized steel

Welding of galvanized steel is a hazardous activity, because of the harmful gases that are given off and which should be mechanically extracted. Consequently, welding on site should be avoided, unless the zinc coating is removed locally beforehand and work is carried out in accordance with an H&S/COSHH method statement. Weld affected areas should be 'made-good' with a zinc rich paint or similar corrosion inhibiting material.

3.3.2 Erection procedure

The erection procedure for a light steel frame used in housing is illustrated in Figure 3.4. In Stage 1, the slab dimensions are checked because an accurate starting point is essential to minimise geometrical inaccuracy and alignment problems.

At Stage 2, the panels at ground floor are aligned and levelled, temporarily braced or propped, and fixed to the foundations.

At Stage 3, the individual floor joists or prefabricated cassettes are supported on the wall beneath. In platform construction, the floor boarding provides a working platform for the erection of the upper wall panels, as in Stage 4.

At Stage 4, the first floor panels are erected, plumbed and braced. Wind girders are also erected.

At Stage 5, the roof trusses are lifted individually and positioned on the upper walls. Roof bracing is installed and the structure is stable.

Storey-high panels and roof trusses can be man-handled into place, or by the use of a crane (particularly for lifting of larger panels). In some cases, roofs can be prefabricated, sheathed and lifted into place to provide a rapid weather-tight envelope.

3.3.3 Temporary bracing

Wall frames are unstable until floor members are fixed in position. As with any type of building, it is unsafe practice to leave a partially erected structure in an unstable state. Therefore, temporary side props or bracing may be required, particularly when the structure is left overnight in a partially erected condition. The requirements of every individual case should be separately considered but it may be appropriate to use a scaffold 'cage' for extra restraint.

The addition of other loads, such as stacking of plasterboard on suspended floors, is not acceptable until the framework has been completed and fully braced. These loads should be agreed with the designer.

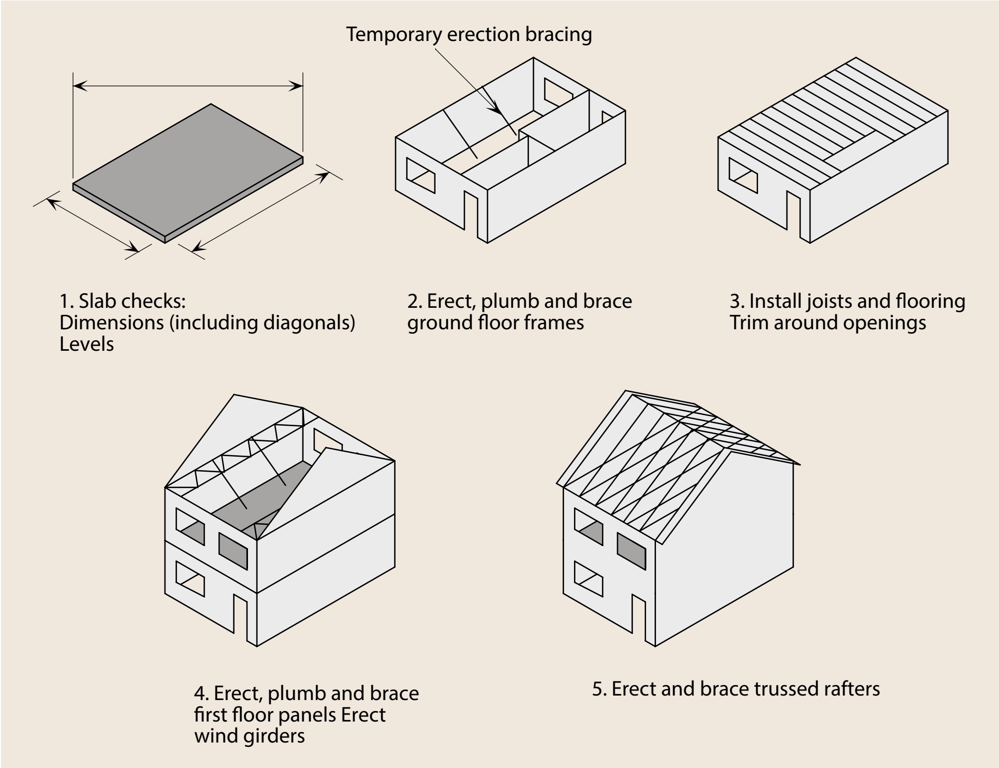


Figure 3.4
Erection procedure for light steel frames

FOUNDATIONS

Foundations to light steel framing are essentially the same as for any other form of construction, although the permanent loads applied by the light steel frame will be much lower than in concrete or masonry construction.

The foundation size will be determined either by the vertical load or by the requirement to resist wind uplift.

4.1 Site tolerances

All forms of frame construction require an accurate 'starting point'. Therefore, the foundations or ground beams must be finished accurately in order to be acceptable for 'hand-over' to the frame erector. For accurate erection of the frame, the following tolerances are required at the level of the base of the wall frames.

- Length of wall frame +/– 10 mm in 10 m.
- Line of wall frame +/– 5 mm from outer face of plate.
- Level of base of wall frame +/– 5 mm over complete wall line.

As a simple check on squareness, if the walls are of the correct length and location, the diagonals of a rectangular plan form will be equal.

A special steel member may be incorporated into the foundations to facilitate accurate later attachment of the steel sub-frames or panels, see Section 5.

If the specified tolerances are not achieved, a number of problems may arise affecting the quality of the finished structure:

- Insufficient bearing for sole plate.
- Variations in cavity width.
- Cavity 'ledge' at sole plate.
- Insufficient fixity of superstructure to foundations.

In practice, the foundation or ground beam will have local deviations in level along its length and some packing will be required to achieve the required tolerances on frame position and to provide for effective load transfer.

It is suggested that the following packing methods should be used, although individual systems may vary from this:

< 10 mm	pack under each stud with thin pre-galvanized steel shims
10 – 20 mm	pack under each stud with pre-galvanised steel shims and grout over the length of the sole plate
> 20 mm	obtain advice from the frame designer / manufacturer. In this situation it is likely that the steel frame erector will not accept the sub-base and remedial work will be required.

4.2 Foundation types

Light steel frames may be designed to suit a range of foundation types, depending on the ground conditions that are encountered. Strip or trench fill foundations are currently the most common but raft, pile or pre-cast pile foundations may be suitable in some instances.

An SCI publication *Mini-piles and composite ground floors for housing* (P299)[42] presents guidance on the design of composite ground floors and mini-piles for housing.

Installation of a steel frame on a typical trench fill foundation is illustrated in Figure 4.1. The over-site damp proof membrane (DPM) should be attached to the side of the slab and returned under the damp proof course (DPC) on which the frame is placed. To comply with Part M of the Building Regulations, Approved Document M suggests

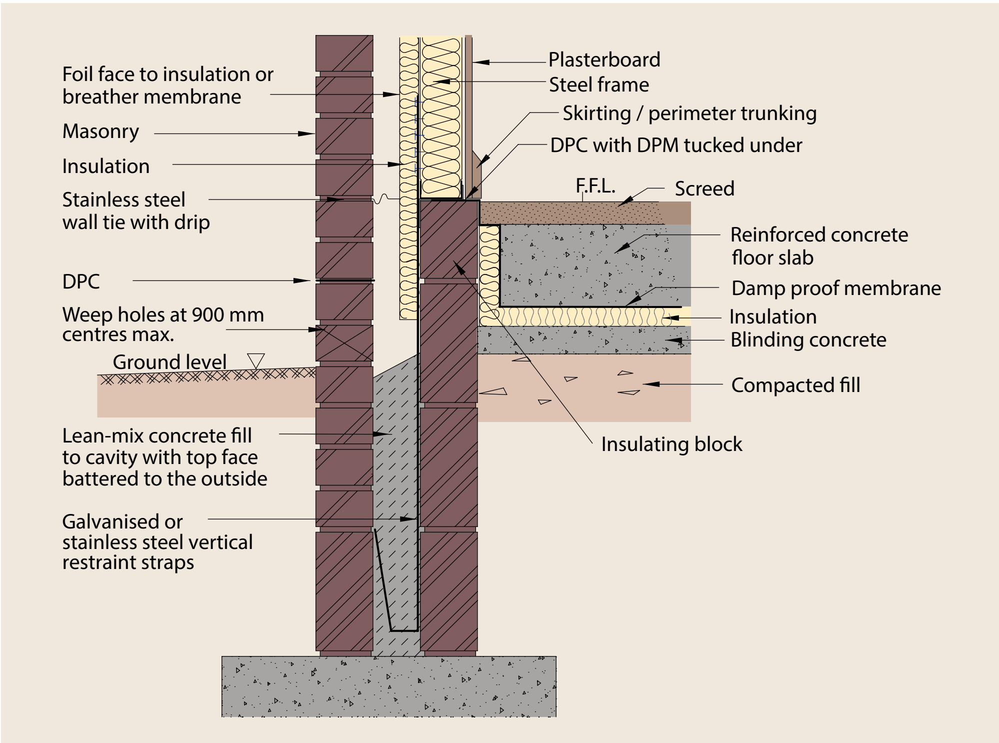


Figure 4.1 Foundation – generic interface detail for ground-floor slab

Note: The insulation may be positioned above the ground slab with a floating timber floor boarding over, as shown in Figure 5.1.

level threshold details, shown in Figure 4.2. In this case, the external leaf DPC may be placed two courses above the internal DPC. The DPC/DPM detail requires careful execution, as in practice the DPM often billows out and may bridge the cavity, providing a ledge for mortar droppings to rest upon. The external wall at this position is below the DPC and will increase the risk of dampness crossing the cavity to the sole plate.

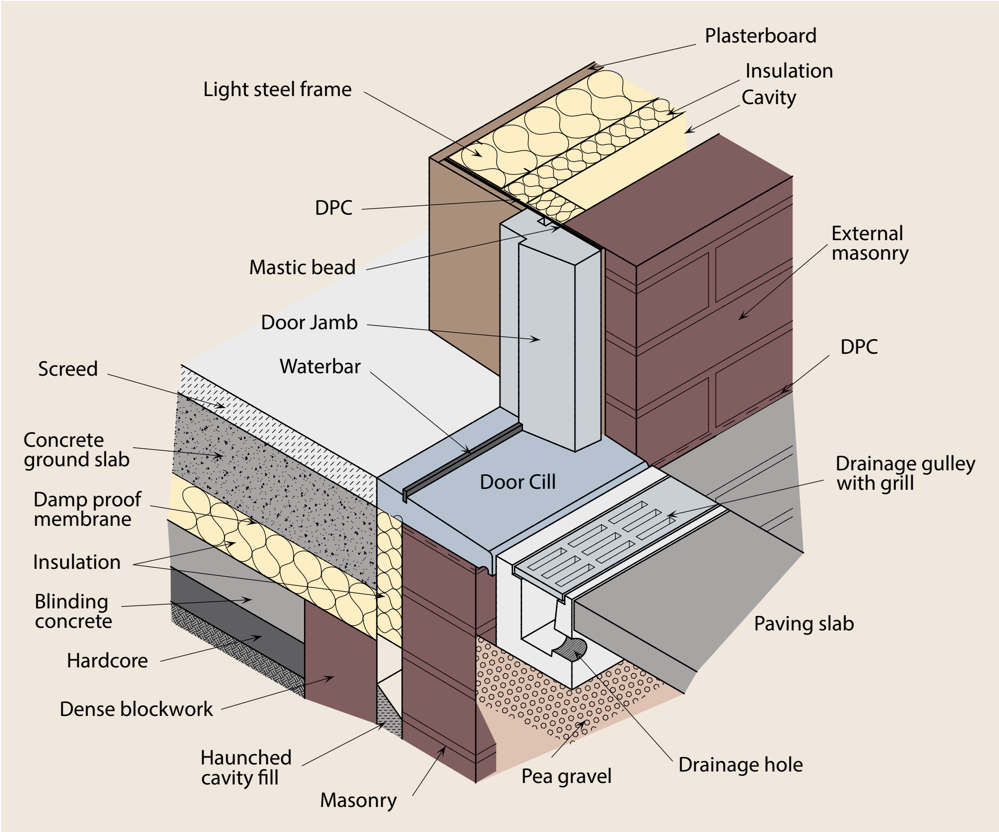


Figure 4.2 Accessible threshold to meet Part M of the Building Regulations

4.3 Holding down requirements

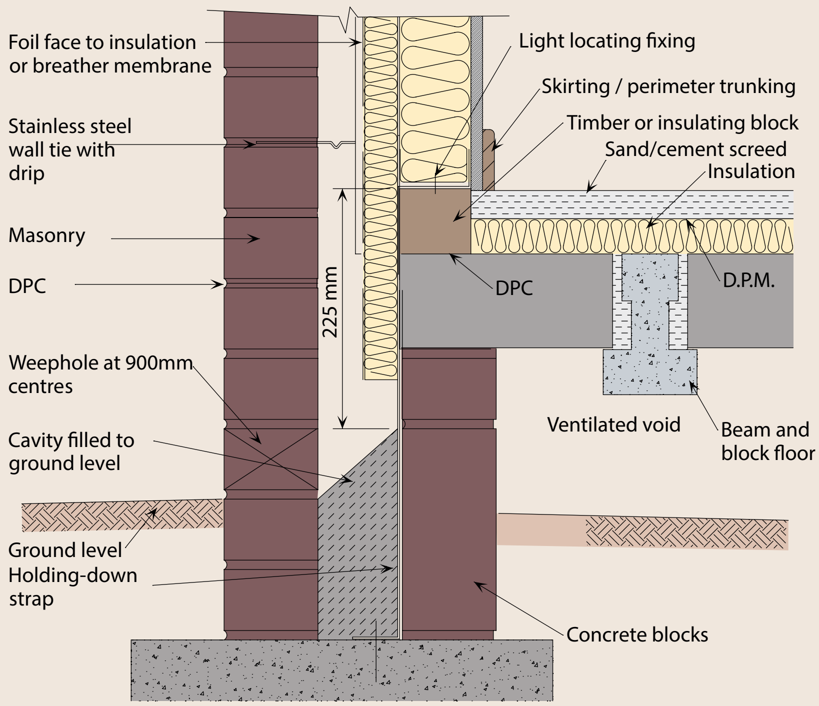
For lightweight structures, a combination of actions (wind and permanent loads) may lead theoretically to uplift on the foundation. In such cases, it is necessary to provide holding down anchorages at various positions, for example, at braced bays. Holding down anchorages may take various forms;

- Steels straps fixed to the stud wall and attached to the masonry supports or to the concrete foundations.
- Chemical anchors fixed to the concrete ground slab or suitable proprietary floor system with a structural screed over.
- For relatively low loads, screw fix connectors may be used to attach the frame to the slab.

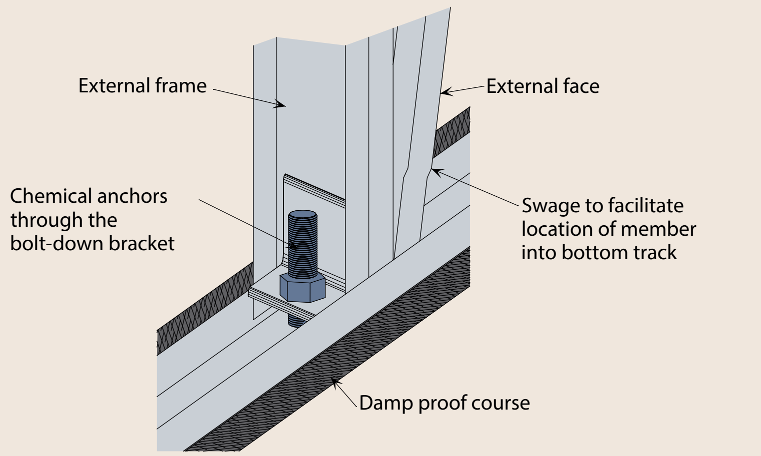
Where stainless steel holding down straps are used, as shown for the suspended beam and block floor in Figure 4.3(a), they should be in Grade 1.4301 steel to BS EN 10088 [43]. They should also be isolated from the studs by use of neoprene gaskets, or similar attachments, in order to minimise the risk of galvanic action.

Non-stainless connectors should also be isolated from the straps by the use of suitable grommets and washers.

In concrete raft construction, walls may be bolted to the concrete slab using chemical or expanding anchor fixings. Chemical or expanding anchors are suitable for use in an in-situ concrete raft of minimum C20/GEN 3 grade concrete to BS 8500-2:2006+A1:2012 *Specification for constituent materials and concrete*[44]. In the example shown in Figure 4.3 (b), the connection to the light steel frame is made by a steel angle that is welded to the C section so that the uplift force can be



a. **Holding-down detail for light steel frame on a suspended ground floor**



b. **Bolt-down bracket detail for light steel frame on insitu concrete slab/edge beam**

Figure 4.3 Different forms of anchorage of light steel frames to foundations transferred by bending of the leg of the angle. In this detail, care should be taken to ensure minimum edge distances to the slab are complied with.

Particular attention must be paid to the details at the interface between the super-structure and the foundation to minimise the risk of corrosion. The light steel frame should be located entirely above the DPC level of the brickwork. In circumstances where this cannot be achieved, particularly at openings providing wheelchair access, a thickness of corrosion protection equivalent to Z460 galvanizing, or a suitable bituminous coating, should be applied to all components below DPC level.

GROUND FLOORS

Ground floors may be of two generic types: ground bearing (i.e. raft), or suspended. Suspended ground floors are the most common choice, particularly when the ground conditions are poor.

Suspended ground floors may comprise light steel floor joists, as shown in Figure 5.1, or steel decking and in-situ concrete, or a more traditional beam and block floor. Light steel frames can be readily used with both light steel joists and concrete floor slabs. The beam and block floor can be adapted to light steel frame construction, provided the steel elements are properly protected from moisture.

The ground below a suspended ground slab must be covered by a layer of blinding concrete or a damp proof membrane, to prevent plant growth. A ventilated air space is required beneath the floor; this must be at least 150 mm from the top of the ground cover to the underside of the floor boards and at least 75 mm below the underside of any wall plate. The external walls should have ventilation equivalent to openings of 1500 mm^2 per metre run of wall.

For lightweight construction, it may be necessary to provide additional holding down anchorages or straps but it is not sufficient to tie them only to the ground floor (see Section 4.3).

5.1 Steel joist floor

A suspended ground floor may be constructed using light steel joists as shown in Figure 5.1. In this figure, the floor is embedded in a masonry stub wall. The galvanizing layer on the joists provides sufficient protection against corrosion due to the ambient air, provided a membrane is placed over the ground, or the floor joists are insulated from below. The first layer of floor boarding is attached directly to the floor joists and provides lateral restraint to the joists and diaphragm action. The preferred location of the insulation is under the joists, so that a ‘warm frame’ can be maintained but, alternatively, insulation may be placed on the floor and a final layer of boarding placed on the insulation.

The joists must be laid on a damp proof course at the support points. Where the joists are built into masonry, additional corrosion protection will be required in the form of bitumen paint or a pre-formed closure. Where loads are transferred from the wall through the joists to the foundation, additional strengthening sections or web stiffeners may be required to support the loads from above.

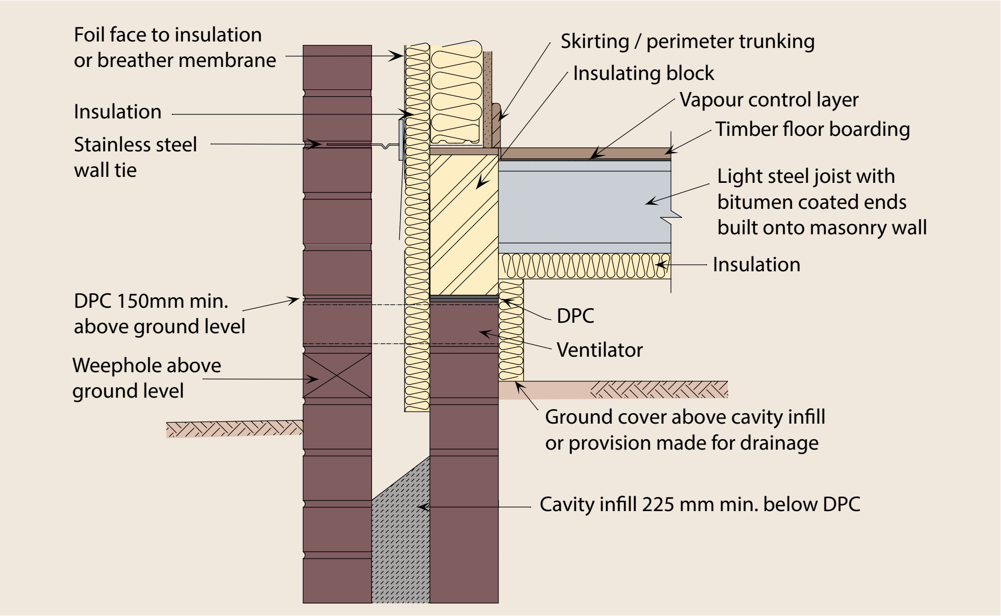


Figure 5.1 Ventilation and insulation detail for suspended ground floors using steel joists

5.2 Beam and block floors

Precast concrete beam and block floors are commonly used in domestic-scale construction. Figure 5.2 and Figure 5.3 show details suitable for this form of construction when used with light steel framing.

The holding down straps, as shown in Figure 5.2, are plugged and screwed to the face of the foundation masonry. This work must be carried out before the frame is erected and the straps should be properly installed within tolerance, in the correct position,

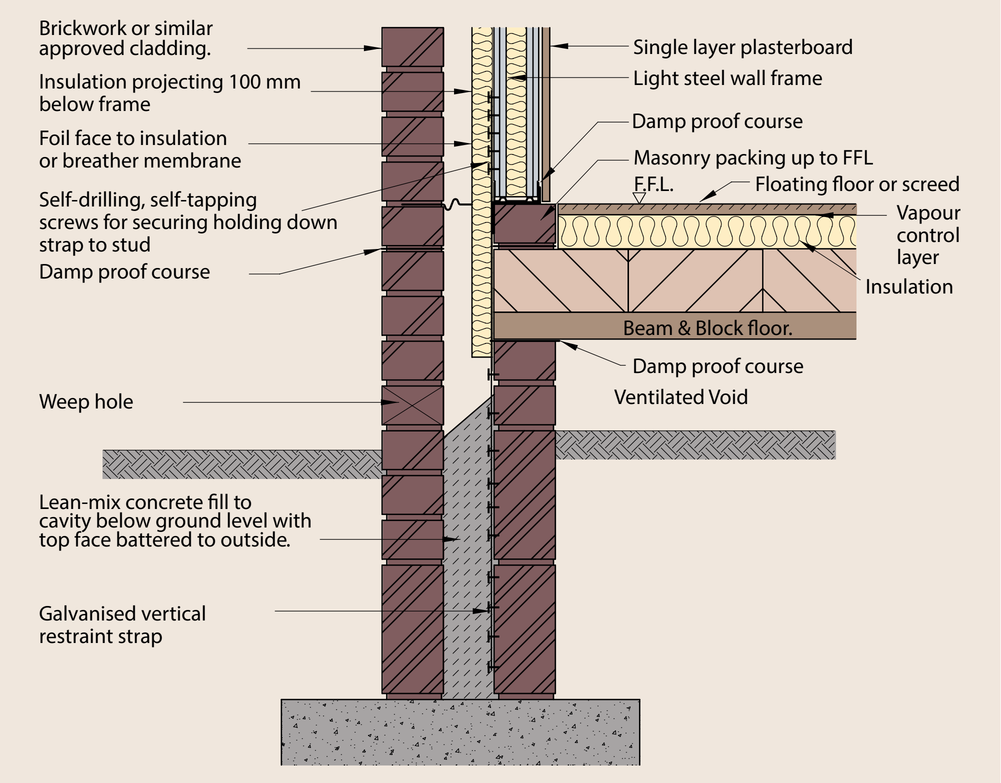


Figure 5.2 Fixing down details for the light steel walls on beam and block ground floors using steel straps

since the flexibility for further adjustment is very limited. The protruding section of the strap is screw-fixed to the face of the wall studs.

As an alternative, the hook detail shown in Figure 5.3, may be used and is installed by the frame erector. Communication with the ground worker is essential to ensure that the cavity fill is not placed before the hooks are installed. To resist high uplift forces, a reinforcement hoop can be embedded in the mass concrete footing and the restraint strap can be hooked through it. This system overcomes the problems of the horizontal alignment with the wall studs associated with the previous system.

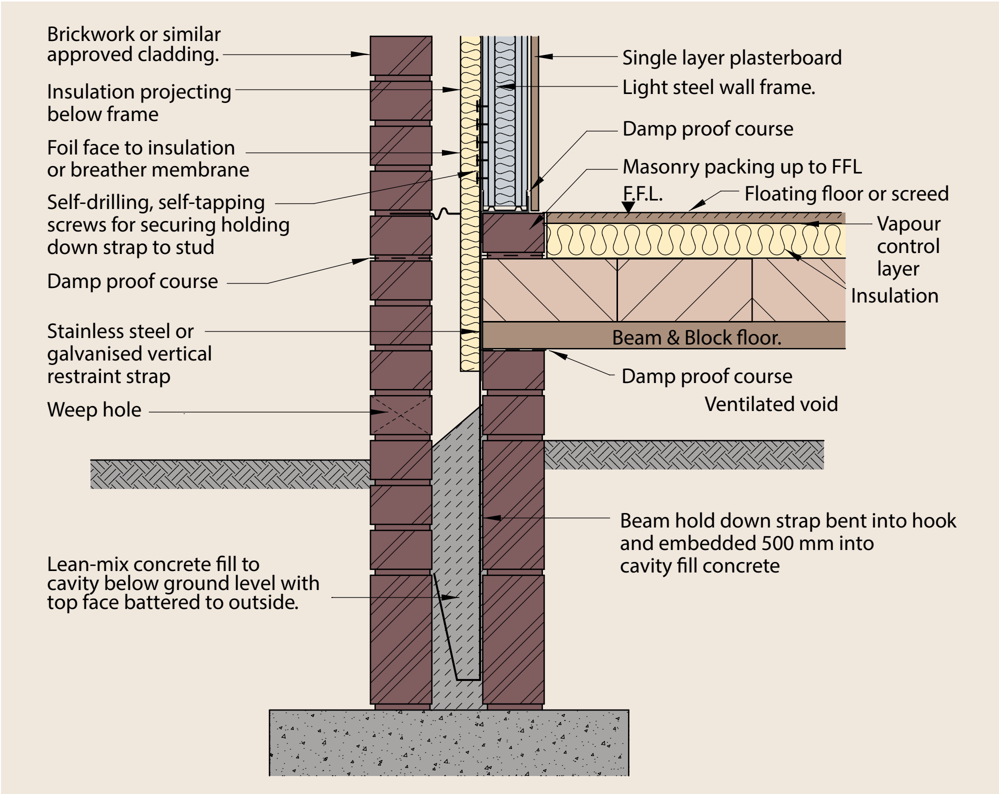


Figure 5.3 Fixing down details for the light steel walls on beam and block ground floors using steel "hooks"

5.3 Composite ground floor slab

A composite suspended ground floor slab may be constructed using steel decking acting compositely with the in-situ concrete slab placed on it. In this case, the clear span during construction is limited to about 3.5 m for steel decking thicknesses up to 1.2 mm. Spans of up to 4.5 m can be readily achieved for composite slabs in residential applications if an internal temporary support is provided to support the decking during construction. This may take the form of a sleeper wall on a modest foundation. Subsequently, the composite slab is able to resist imposed loads on the floor without requiring this intermediate support. Light mesh reinforcement is required in the slab topping to prevent cracking. A DPC is required to protect the ends of the decking where it sits on the foundation. The decking and slab may rest directly on the masonry foundation or a galvanized steel perimeter beam may be used to facilitate the erection of the wall frames and to evenly distribute the loads to the foundations.

INTERMEDIATE FLOORS

The construction of a suspended floor comprising cold formed steel floor joists is similar to that for a floor using timber joists. Figure 6.1 shows a suspended floor arrangement using C section joists. The strength to weight ratio of light steel joists is higher than that of timber joists of similar size. Steel joists are dry, stable and do not suffer the long term problems of drying out, creep or shrinkage. Joists are generally positioned at 400 or 600 mm centres, depending on the spanning capabilities of the floor boarding.

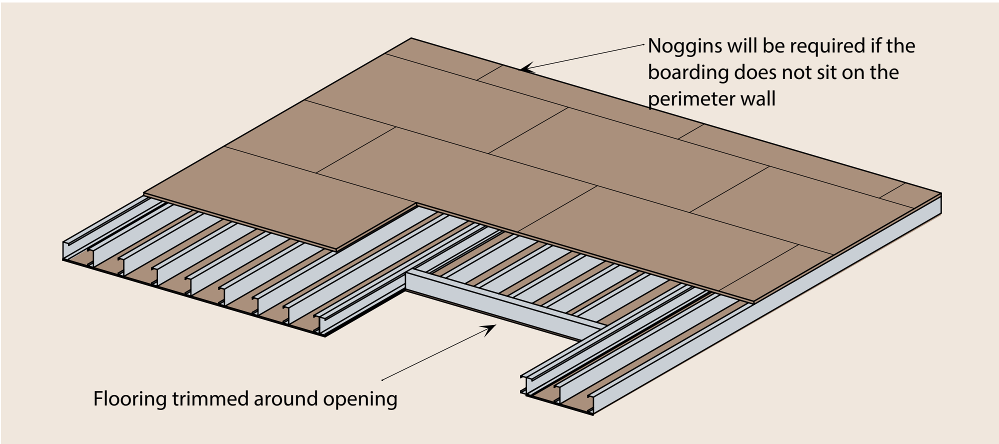


Figure 6.1 Typical suspended floor using C section joists

Figure 6.2 and Figure 6.3 show typical floor/wall junctions for floor joists orientated parallel and perpendicular to the wall. If the positions of joists perpendicular to the wall do not coincide with wall studs, special components, such as the Z section shown in Figure 6.3, may be required in order to transfer the vertical loads. When using this type of section, the joists are fixed by web cleats to the perimeter Z section.

6.1 Floor finishes

6.1.1 Flooring materials

For floors in domestic-scale buildings, moisture resistant, type P5 chipboard to BS EN 312 [45] should be used. OSB3 is used for floating floors and in moisture resistant load-bearing panels designed for use in humid conditions and is therefore ideal for many structural and non-structural applications in both internal and protected external environments. OSB3 is manufactured in accordance with BS EN 300 [46]. When improved moisture resistance is required, WBP grade plywood to BS EN 1072 [47], or cement particle board to BS EN 634-1 [48], should be specified. Installation should comply with the appropriate clauses of BS EN 1995-1-1 [15], BS 8000-5 [49] and BS 8201 [50].

To prevent squeaking due to small movements of the flooring, tongue and grooved joints should be glued, using adhesives complying with BS 4071 [51]. Square edge board should be supported on all sides on joists or noggins.

6.1.2 Ceilings

Plasterboard or other ceiling linings may be fixed directly to the bottom flange of joists and perimeter Z sections, provided they are spaced at not greater than 600 mm centres. When the joist centres exceed 600 mm, or where a high level of acoustic insulation is important, resilient bars or furrings are fixed to the joists and the ceiling is fixed directly to them. These resilient bars improve the acoustic insulation of the floor significantly (see Section 2.3.4). Noggins are required when plasterboards of up to 12.5 mm are attached to joists or trusses at 600 mm centres.

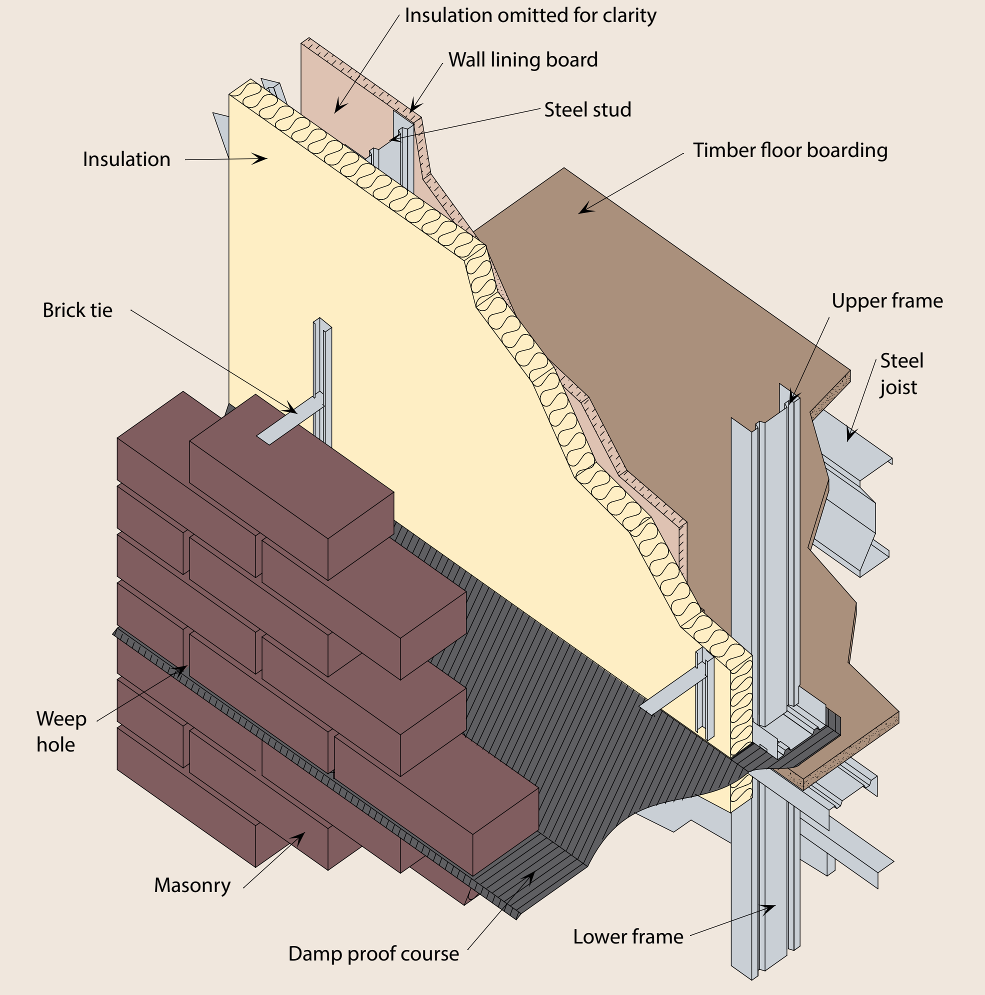


Figure 6.2 Junction of walls to first floors – single family dwelling (joists parallel to walls)

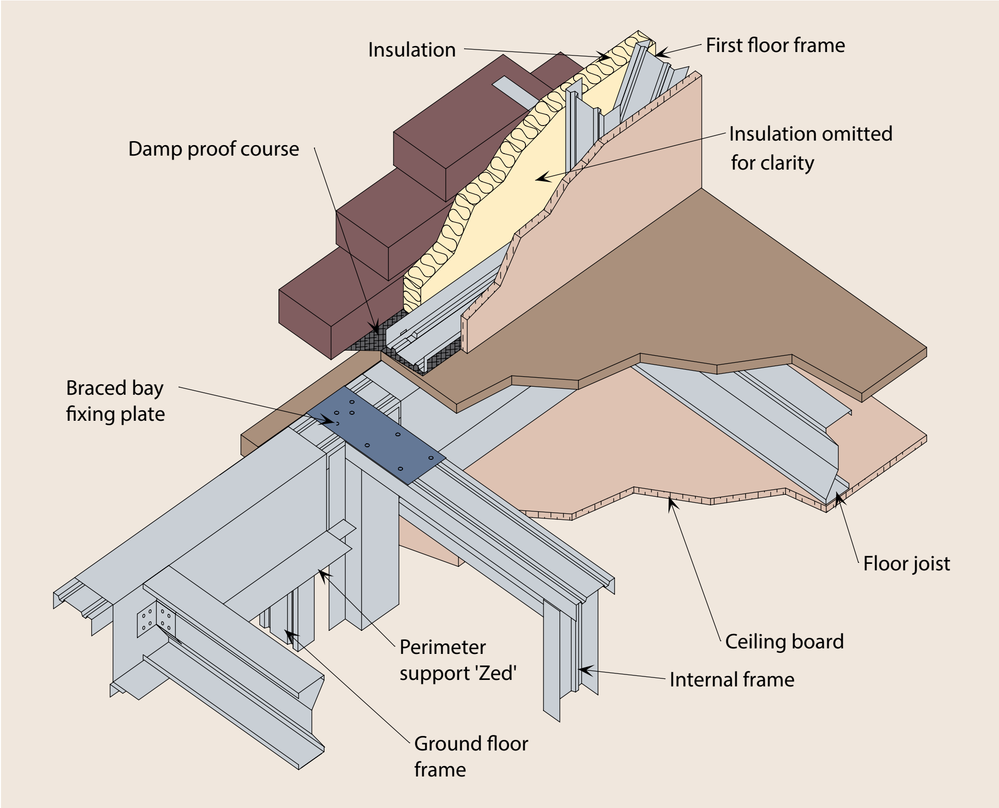


Figure 6.3 Junction of walls to first floor – single family dwelling (joists perpendicular to walls)

6.2 Design of light steel floor joists

6.2.1 Serviceability performance of light steel floor joists

For user comfort, floors should be sufficiently stiff that vibration due to normal activities does not cause annoyance. The recommendations for the serviceability performance of light steel floor joists supporting a boarded floor are:

Static criteria:

a. The maximum deflection of a single joist subject to dead and imposed loads is limited to the smaller of span/350, or 15 mm.
b. The maximum deflection of a single joist subject only to imposed load is limited to span/450.

Dynamic criteria:

c. The natural frequency of the floor should not be less than 8 Hz for the uniformly distributed load case of dead load plus 20% of the imposed load, which represents the nominal load on a lightly loaded floor. This is achieved by limiting the deflection of a single joist to less than 5 mm for this loading condition.
d. For public spaces and corridors, the natural frequency of the floor should not be less than 10 Hz for the uniformly distributed load case of dead load plus 20% of the imposed load. This is achieved by limiting the deflection of a single joist to 3 mm for this loading condition.

e. The deflection of the complete floor (i.e. series of joists plus the flooring material) when subject to a 1 kN point load, should be limited to the values presented in Table 6.2 (Virginia Polytechnic [52] criterion).

For domestic floors with a characteristic imposed load of 1.5 kN/m², the governing criterion is most likely to be b. (span/450) for spans to 3.5 m, or e. (1 kN point load) for longer spans.

For other floors subjected to imposed loads in excess of 1.5 kN/m², the governing criterion is most likely to be a. (span/350 or a maximum of 15 mm).

For separating floors and other floors with high dead load, criterion c., (8 Hz limit), may become critical. For public spaces, it is likely that criterion d. will control.

For floors constructed using floor boarding (timber boards, chipboard, plywood or cement particle board) that are screw fixed to the top flange of light steel joists, criterion e. may be applied as follows to determine the required second moment of area of the individual floor joists.

$$I_{\text{required}} = \frac{L^3 \times 10.16}{N_{\text{eff}} \times \delta_j} \quad \text{in cm}^4$$

where:

L is the joist span (m)

N_{eff} is the number of effective joists acting with single point load, or may be taken as in Table 6.1

δ_j is the limiting deflection (mm) obtained from Table 6.2.

Table 6.1
Value of N_{eff} (kN) for different flooring configurations

FLOOR CONFIGURATION	**JOIST CENTRES**	
	400 mm	**600 mm**
Chipboard	2.5	2.35
Cement particle board	3	2.75
Built-up acoustic floor	4	3.5

Table 6.2
Limiting deflection of floors δ_j subject to a 1 kN point load at mid-span

SPAN (m)	3.5	3.8	4.2	4.6	5.3	6.2
DEFLECTION δ_j (mm)	1.7	1.6	1.5	1.4	1.3	1.2

Note: Table 6.2 to Table 6.5 are provided as an aid to assessing the floor joist properties required for estimating purposes. The tables are for joists at 400 or 600 mm centres and for imposed loads of 1.5 kN/m² or 2.5 kN/m². Although a heavier dead load has been used for the 2.5 kN/m² situation, the criterion e. has not been assessed for an 'acoustic' floor. The limiting spans listed under this criterion have been calculated from the full formula, not the simplified formula which appears in this publication.

Table 6.3
Maximum span (m) for joists at 400 mm centres for $G_k = 0.32$ kN/m², $Q_k = 1.5$ kN/m²

I OF INDIVIDUAL JOIST (cm⁴)	MAXIMUM SPAN (m) FOR LIMITING CRITERION				
	L/450 UNDER IMPOSED LOAD	*L*/350 UNDER TOTAL LOAD (OR 15 mm)	8Hz UNDER SELF-WEIGHT + 0.3 kN/m²	δ_j + 10% UNDER 1 kN	
				18 mm CHIPBOARD	22 mm CHIPBOARD
50	3.08	3.14	3.56	**3.04**	3.08
100	3.88	3.95	4.24	**3.57**	3.61
150	4.44	4.53	4.69	**3.97**	4.03
200	4.89	4.98	5.04	**4.30**	4.36
300	5.59	5.59	5.57	**4.82**	4.89
400	6.15	6.00	5.99	**5.23**	5.30
500	6.63	6.35	6.33	**5.57**	5.65
600	7.04	6.64	6.63	**5.87**	5.95
700	7.42	6.90	6.89	**6.13**	6.22
800		7.14	7.12	**6.37**	6.46
900		7.35	7.34	**6.59**	6.68
1000		7.55	7.53	**6.80**	6.89
1100				**6.98**	7.08
1200				**7.16**	7.26
1300				**7.33**	7.43
1400				**7.49**	7.59

Note: The limiting span is shown in bold. Slight increases in the limiting span result from using 22 mm rather than 18 mm chipboard. A 10% increase in δ_j is permitted for residential buildings in Reference 52.

Table 6.4
Maximum span (m) for joists at 400 mm centres for $G_k = 0.72$ kN/m², $Q_k = 2.5$ kN/m²

I OF INDIVIDUAL JOIST (cm⁴)	MAXIMUM SPAN (m) FOR LIMITING CRITERION				
	L/450 UNDER IMPOSED LOAD	*L*/350 UNDER TOTAL LOAD (OR 15 mm)	8Hz UNDER SELF-WEIGHT + 0.5 kN/m²	δ_j + 10% UNDER 1 kN	
				18 mm CHIPBOARD	22 mm CHIPBOARD
100	3.27	**3.27**	3.59	3.57	3.61
150	3.74	**3.74**	3.97	3.97	4.03
200	4.12	**4.12**	4.26	4.30	4.36
300	4.72	**4.71**	4.72	4.82	4.89
400	5.19	5.19	**5.07**	5.23	5.3
500	5.39	5.50	**5.36**	5.57	5.65
600	5.94	5.76	**5.61**	5.87	5.95
700	6.26	5.99	**5.83**	6.13	6.22
800	6.54	6.19	**6.03**	6.37	6.46
900	6.80	6.37	**6.21**	6.59	6.68
1000	7.05	6.54	**6.38**	6.80	6.89
1100	7.27	6.70	**6.53**	6.98	7.08
1200	7.49	6.85	**6.67**	7.16	7.26
1300	7.69	6.99	**6.81**	7.33	7.43
1400		7.12	**6.94**	7.49	7.59
1500		7.24	**7.06**		
1600		7.36	**7.17**		
1700		7.47	**7.28**		

Note: The limiting span is shown in bold text.
See notes under Table 6.3.

I OF INDIVIDUAL JOIST (cm⁴)	MAXIMUM SPAN (m) FOR LIMITING CRITERION				
	L/450 UNDER IMPOSED LOAD	*L*/350 UNDER TOTAL LOAD (OR 15 mm)	8Hz UNDER SELF-WEIGHT + 0.3 kN/m²	δ_j + 10% UNDER 1 kN	
				18 mm CHIPBOARD	22 mm CHIPBOARD
100	**3.39**	3.45	3.83	3.50	3.63
150	3.88	3.95	4.24	**3.88**	4.06
200	4.27	4.35	4.55	**4.20**	4.40
300	4.89	4.98	5.04	**4.71**	4.93
400	5.38	5.42	5.41	**5.12**	5.34
500	5.79	5.73	5.72	**5.45**	5.69
600	6.16	6.00	5.99	**5.75**	5.99
700	6.48	6.24	6.22	**6.01**	6.26
800	6.78	6.45	6.44	**6.24**	6.50
900	7.05	6.64	6.63	**6.46**	6.73
1000	7.30	6.82	6.8	**6.66**	6.93
1100	7.53	6.98	6.97	**6.84**	7.12
1200		7.14	7.12	**7.02**	7.31
1300		7.28	7.27	**7.19**	7.48
1400		7.42	7.40	**7.34**	
1500		7.55	7.53	**7.49**	

Table 6.5 Maximum span (m) for joists at 600 mm centres for $G_k = 0.32$ kN/m², $Q_k = 1.5$ kN/m²

Note: The limiting spans are shown in bold text.
See notes under Table 6.3.

I OF INDIVIDUAL JOIST (cm⁴)	MAXIMUM SPAN (m) FOR LIMITING CRITERION				
	L/450 UNDER IMPOSED LOAD	*L*/350 UNDER TOTAL LOAD (OR 15 mm)	8Hz UNDER SELF-WEIGHT + 0.5 kN/m²	δ_j + 10% UNDER 1 kN	
				18 mm CHIPBOARD	22 mm CHIPBOARD
100	2.86	**2.86**	3.24	3.50	3.63
150	3.27	**3.27**	3.59	3.88	4.06
200	3.60	**3.60**	3.85	4.20	4.40
300	4.12	**4.12**	4.26	4.71	4.93
400	4.54	**4.53**	4.58	5.12	5.34
500	4.89	4.88	**4.84**	5.45	5.96
600	5.19	5.19	**5.07**	5.75	5.99
700	5.47	5.41	**5.27**	6.01	6.26
800	5.71	5.59	**5.45**	6.24	6.50
900	5.94	5.76	**5.61**	6.46	6.73
1000	6.16	5.91	**5.76**	6.66	6.93
1100	6.35	6.06	**5.90**	6.84	7.12
1200	6.54	6.19	**6.03**	7.02	7.31
1300	6.72	6.31	**6.15**	7.19	7.48
1400	6.89	6.43	**6.27**	7.34	
1500	7.05	6.54	**6.38**	7.49	
1600	7.20	6.65	**6.48**		

Table 6.6 Maximum span (m) for joists at 600 mm centres for $G_k = 0.72$ kN/m², $Q_k = 2.5$ kN/m²

Table 6.6 (continued) Maximum span (m) for joists at 600 mm centres for $G_k = 0.72$ kN/m², $Q_k = 2.5$ kN/m²

I OF INDIVIDUAL JOIST (cm⁴)	MAXIMUM SPAN (m) FOR LIMITING CRITERION				
	$L/450$ UNDER IMPOSED LOAD	$L/350$ UNDER TOTAL LOAD (OR 15 mm)	8Hz UNDER SELF-WEIGHT + 0.5 kN/m²	δ_j + 10% UNDER 1 kN	
				18 mm CHIPBOARD	22 mm CHIPBOARD
1700	7.35	6.75	**6.58**		
1800	7.49	6.85	**6.67**		
1900		6.94	**6.76**		
2000		7.03	**6.85**		
2100		7.12	**6.94**		
2200		7.20	**7.02**		
2300		7.28	**7.09**		
2400		7.36	**7.17**		
2500		7.44	**7.24**		
2600		7.51			

Note: The limiting span is shown in bold text.
See notes under Table 6.3.

6.2.2 Attachment of floors to walls

Joists may be built in to or bolted to walls or supported by joist hangers or cleats. Cleated connections should be made through the web to minimise the risk of local bearing or buckling of the section. For steel joists supported on loadbearing masonry walls, a tight control of masonry tolerances is required on-site to ensure that adequate bearing is provided.

Figure 6.4 (a), (b) and (c) shows alternative support details at an intermediate floor. Figure 6.4 (a) shows platform construction that is often used in housing in which the timber floor decking extends through to the external face of the stud wall. The second wall frame is then fixed directly to the floor and loads are transferred through the boarding. The direct attachment of the boards to the walls provides stability and permits the floor to act as a structural diaphragm.

In platform construction, alignment of the walls is achieved on each floor, so that there is no accumulation of differential vertical deviations. The floor joists are supported by the perimeter light steel Z sections and each joist should be connected by a cleat to the Z section, which is fixed to each C section in the lower wall panel. In general, self-drilling, self-tapping screws are used for all connections, although bolts may be used. In multi-storey buildings, the upper wall panel can be installed directly on the Z section which avoids any potential for longer term movement due to compressibility of the floor boarding. Effective diaphragm action is achieved through the Z section and the connection to the cleats with a minimum of 3 screws per cleat.

Figure 6.4 (b) is similar to Figure 6.4 (a), but the joists continue over the head of the stud wall. In this configuration, the joists should align with the studs, both above and below the joists. Stiffeners in the form of short sections of stud may be required to transfer concentrated loads from the stud walls above.

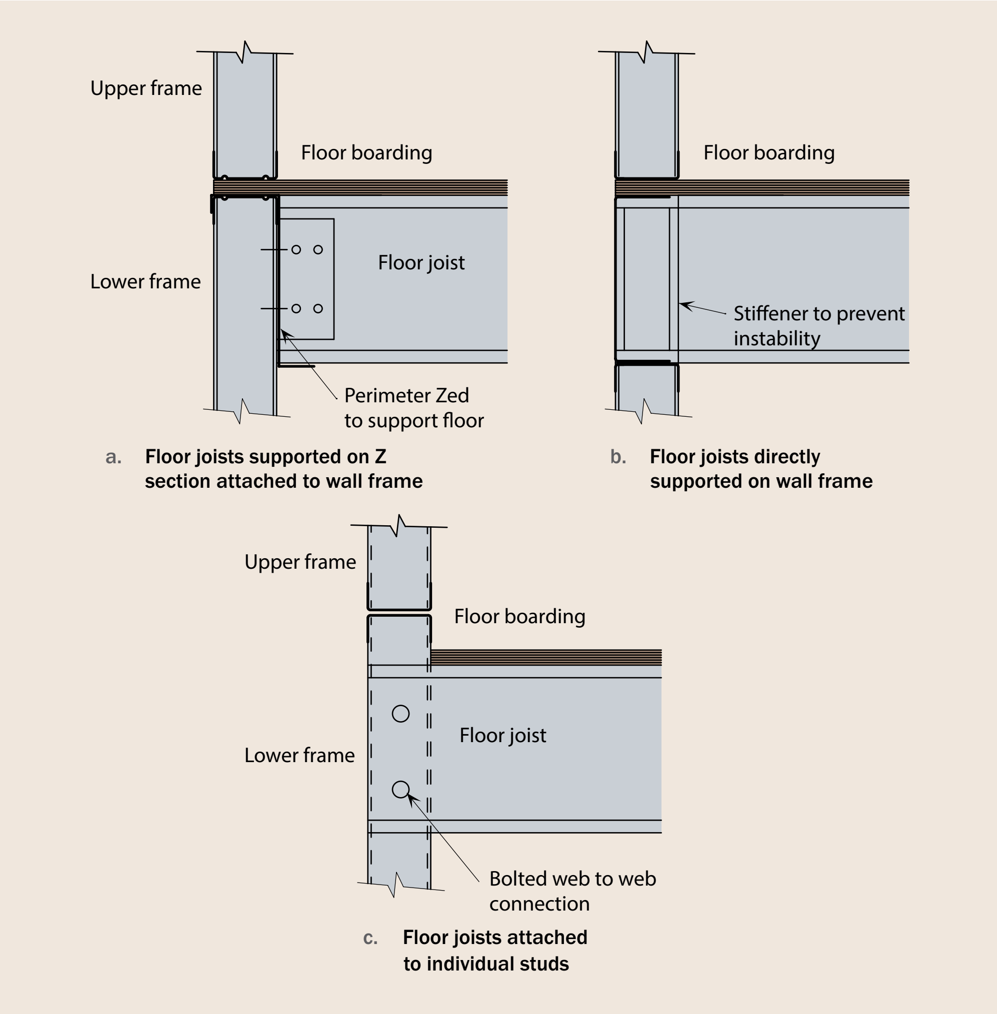


Figure 6.4 Generic connection details between floors and walls

Figure 6.4 (c) shows an alternative arrangement where the studs continue beyond the floor level and the joists connect into the side of each stud. This affords each frame a degree of continuity to resist horizontal loads. In this configuration the floor boarding is attached right up to the inside face of the stud wall. Only two bolts are required for adequate structural connection.

Joists may also be supported by joist hangers or similar brackets attached to hot rolled steel sections used to provide support over large openings. In this case, the hot rolled steel section is generally designed to be accommodated within the floor depth. The hot rolled steel section should be supported by discrete columns, often in the form of boxed C sections or rectangular hollow sections.

6.2.3 Bridging and blocking of joists

In general, C section joists should be 'handed' so that the flanges of adjacent C sections point in opposite directions and torsional effects are minimised. Where the plasterboard or resilient bars are directly fixed to the bottom flange of the C sections, then it may be assumed that torsional effects are small and no bridging or blocking is required for floor spans of residential buildings (up to 5 m typically).

Where a suspended ceiling is used, then no torsional restraint is provided and advice on the use of bridging and blocking should be sought from the manufacturer on the exact requirements for the system being used on a particular contract. Examples of bridging and blocking details are shown in Figure 6.5.

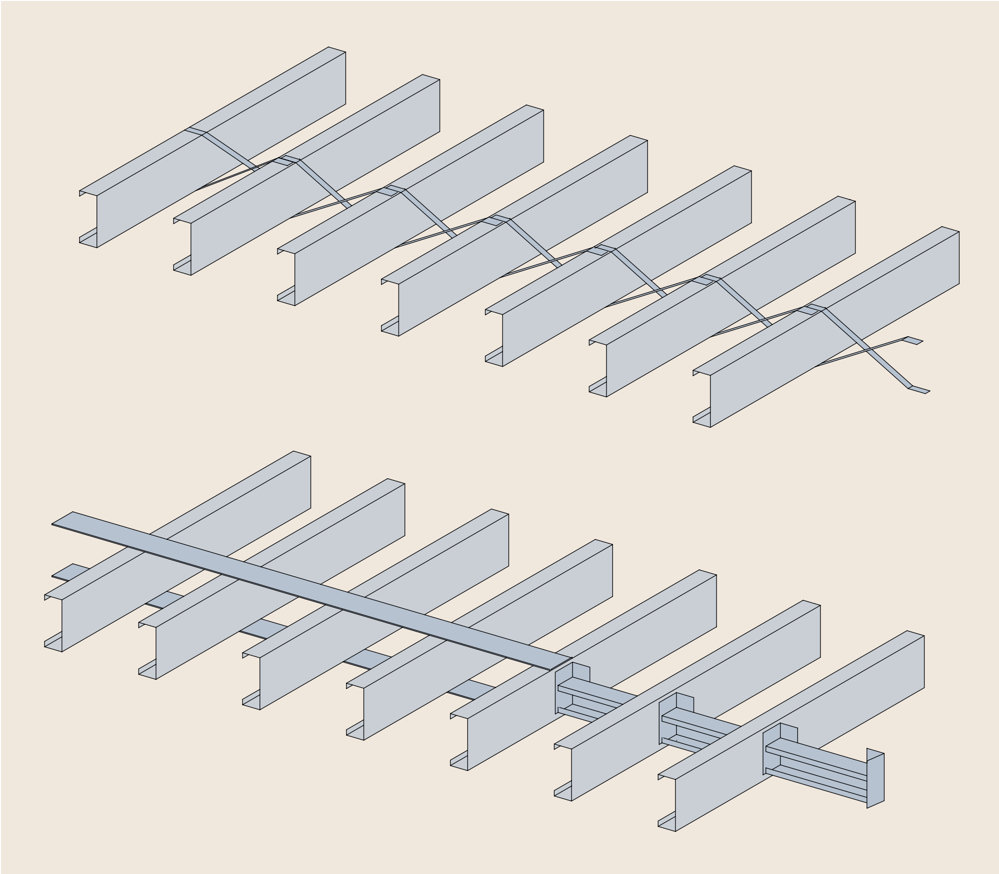


Figure 6.5 Generic bridging and blocking details for joists with a suspended ceiling

6.3 Concrete floors

Concrete floors may be used with light steel framing. Concrete floors may be constructed using either thin pre-cast units or in-situ concrete placed on steel decking. A composite floor may be created by using steel decking with an in-situ concrete floor. The decking also acts as permanent shuttering. Typically, spans of up to 5 m can be achieved if the decking is propped during construction. Otherwise, un-propped spans are limited to 3 to 3.5 m unless deep deck profiles are used. In some situations, due to the weight of the construction, additional hot rolled steel members may be required.

For composite floors with simply supported spans of up to 6 m, the effects of creep and shrinkage on long-term deflections can be significant. NHBC have published guidance [53] for limiting the designed deflection of simply supported composite floors to a value which takes account of the long-term effects of creep and shrinkage.

The NHBC guidance states that composite floor designs using profile steel decking should comply with one of the following approaches:

- Simple approach – based on limiting the span-to-depth ratios for slabs
- Detailed design – which takes the effects of shrinkage and creep into account or applies additional total deflection limits.

In the simple approach, the span/depth ratio of the simply supported slab is limited as follows:

- Where composite action between the steel decking and concrete is assumed and single bar reinforcement is provided in the ribs, the span/depth ratio should be less than 28.
- Where no bar reinforcement is provided, the span/depth ratio should be less than 26.
- If no composite action is assumed, so that the design at the ultimate limit state is based on a reinforced concrete slab, the span/depth ratio should be less than 30. The area of the steel profile decking can be taken into account in the modification factor for the amount of tension reinforcement provided.

In the detailed design approach the following limits should be applied:

- When shrinkage effects are taken into account, the total deflection should be limited to 24 mm or span/250, whichever is less.
- If shrinkage effects are ignored in the design, the total deflection should not exceed 16 mm or span/375.

In both approaches, steel mesh reinforcement (minimum 0.2% of the gross cross-sectional area of concrete above the ribs) should be provided in the topping as crack control reinforcement and to distribute local point loads.

Where fibre reinforcement is used instead of the mesh, the span/depth ratio in the simple approach should be restricted to 26 and where composite action is proposed, third-party accreditation will be required.

Table 6.7 Typical sizes of concrete and composite floors

TYPE OF FLOOR	OVERALL SLAB THICKNESS	SPAN CONDITION	SPAN	WEIGHT kg/m²
Precast concrete units	100 mm	Un-propped	5.0 m	235
	150 mm		7.0 m	250
Composite slab	130 mm	Un-propped	4.0 m	200
	(60 mm deck)	Propped	4.5 m	200
Composite slab	150* mm	Un-propped	3.5 m	230
	(80 mm deck)	Propped	4.5 m	230

Imposed load of 1.5 kN/m^2.

* 180 mm composite slab is also commonly used.

6.4 Separating floors

The Building Regulations require that a separating floor provides acoustic insulation between dwellings or between a dwelling and a communal space (see Section 2.3).

'Built-up' floors, using resilient layers, are particularly effective in reducing impact sound transmission. Steel decking or floor boarding may be laid over light steel joists and heavy density mineral wool slabs, or similar, are fixed to the decking or boarding using beads of mastic adhesive. Plasterboard planks are then laid over the insulation to provide a firm and level base for the final layer of floor boarding (see Section 2.3).

Steel decking may be used to replace one or more layers of boarding. It is relatively shallow (< 30 mm deep) because it is only required to span up to 600 mm between floor joists.

To avoid acoustic flanking transmission at floor to wall connections, the space between the studs should be filled with mineral wool to a height of 300 mm above floor level for separating walls.

A compressible filler strip should be fitted to all perimeters of the floor boarding to avoid the transmission of impact sound from the floor to the light steel frame (see Figure 6.6). The spaces between the floor joists are also filled with a mineral wool sound insulating quilt.

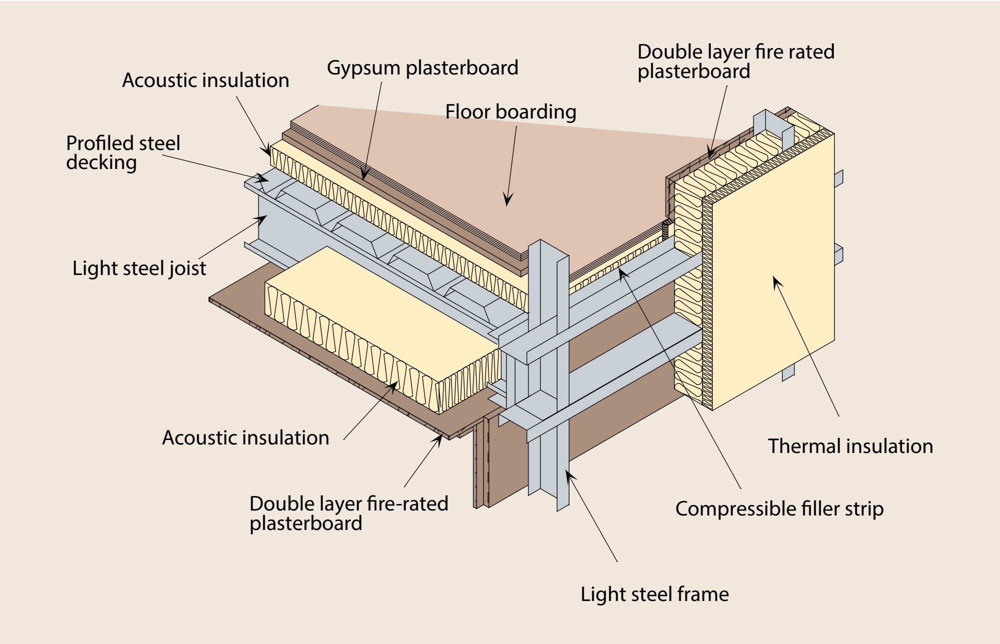


Figure 6.6 Detail of a typical separating wall / floor junction using profiled steel decking

6.5 Compartment floors

For residential construction, the Building Regulations require that a floor between two dwellings acts as a compartment floor, to provide fire separation. In general, a compartment floor will also act as a separating floor and the same measures that achieve the required acoustic performance will provide the necessary fire separation.

Figure 6.7 shows two alternative ‘dry-build’ floor systems which meet the requirements of the current Building Regulations for compartment floors. The detail also shows an adjacent separating wall where insulation placed between the wall studs reduces flanking losses. Steel decking may also be used and provides for integrity to passage of smoke or flame in fire.

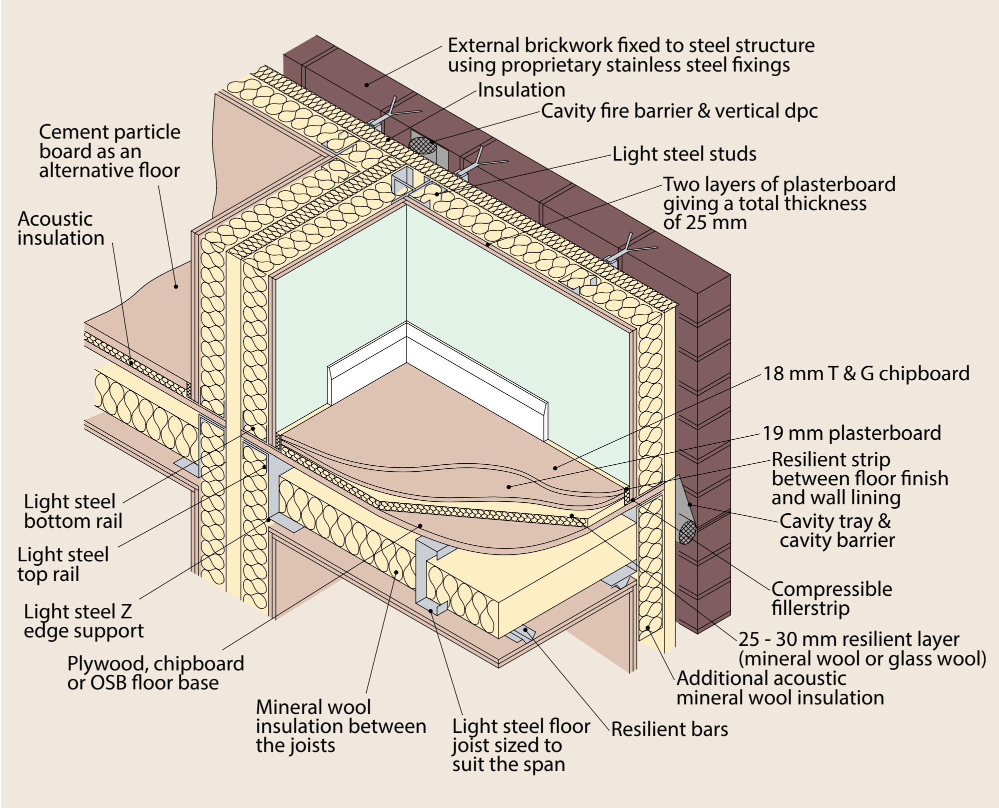


Figure 6.7 Details of compartment floor at junction with external wall and separating wall

EXTERNAL AND LOAD-BEARING WALLS

Walls are generally categorised as load-bearing if they resist significant axial load from floors or the roof. Non-load bearing walls are typically demountable partitions or other internal non-structural walls. However, all walls must be designed to resist the loads due to wind pressure acting perpendicular to the plane of the wall. For external walls, pressures are the sum of external and internal pressures; for internal walls, the maximum differential internal wind pressures are used; suction on one side of the wall, pressure on the other.

7.1 Design for wind forces

7.1.1 Deflection limits

Deflection limits for walls depend on the type of cladding that they support. Cladding may be grouped in the following generic forms.

- Glazing
- Masonry cladding
- Board or rendered materials.
- Sheeting.

For glazing and masonry cladding, control of deflections is important to avoid cracking due to wind loads. The SCI proposes that a horizontal deflection limit of height/350 (including the combined stiffening effect of the brickwork) is used when checking stud walls supporting masonry. Actual deflections may be expected to be 50 to 70% of these deflections.

For board or rendered finishes, it is proposed that a deflection limit of height/250 is used.

Table 7.1 Suggested deflection limits for external walls subject to wind loading

APPLICATION	DEFLECTION LIMIT
Full height glazing	Height/500
Masonry walls	Height/350
Board/rendered finish	Height/250
Steel cladding	Height/200
Other flexible finishes	Height/250

For steel or metallic cladding, a deflection limit of height/200 may be used because of the ability of the cladding to accept greater movement.

Suggested out of plane deflection limits for walls subject to winds loading are summarised in Table 7.1.

7.1.2 Design for stiffness

To meet the relevant limiting deflection criteria, wall studs may be chosen on the basis of their second moment of area, assuming that they deflect as simply supported beams.

Table 7.2 provides guidance on the minimum required second moment of area per metre of wall, since studs may be placed at various centres, typically to suit plasterboard sizes. The tabulated values may be multiplied by the stud spacing (in metres) to obtain the required second moment of area of each stud.

The deflection limit to be considered should be selected on the basis of experience and the type of cladding (see Section 7.1.1).

Table 7.2 Minimum second moment of area, I, in cm⁴ per m width required for C sections in walls to resist wind load only

WALL HEIGHT (m)	CHARACTERISTIC WIND PRESSURE (kN/m²)	$L/200$	$L/250$	$L/350$	$L/500$
2.5	0.5	*10*	*12*	*17*	24
	0.75	*15*	*18*	*25*	36
	1	*19*	*24*	*34*	48
3	0.5	17	21	*29*	42
	0.75	25	31	*44*	63
	1	33	42	*59*	84
3.5	0.5	27	33	*47*	66
	0.75	40	50	*70*	100
	1	53	66	*93*	133
4	0.5	40	50	*69*	99
	0.75	60	74	*104*	149
	1	79	99	*139*	198

Note: It is recommended that the minimum cross section moment of area should not be less than 20 cm⁴/m width of wall for robust behaviour (values in grey area). Values determined on the basis of stiffness, are indicated in italics.

As an example, consider a 2.5 m stud wall resisting an un-factored wind pressure of 0.75 kN/m². If a deflection limit of $L/350$ is specified, this can be achieved with $I_{yy} = 25$ cm^4/m; for studs at 600 mm centres; this equates to $I_{yy} = 15$ cm^4 per stud. This would require use of 75 mm × 1.2 mm lipped C section studs at 600 mm centres. ($I_{yy} = 18$ cm^4 per stud from typical manufacturers' data).

To frame a 1.8 m wide window within this wall, the studs either side of the window would effectively resist load from wind pressure applied to a $(1.8 + 0.6)/2 = 1.2$ m width of wall, hence an $I_{yy} = 30$ cm^4 per stud would be required. A thicker 75 mm deep lipped C section stud would hence be required on either side of the window opening. Otherwise, 75 mm × 1.2 mm lipped C sections in pairs could be used.

7.2 Design for axial load

7.2.1 Axial compression

In housing, lipped and plain C section studs are commonly used in section depths between 75 and 100 mm and in steel thicknesses between 1.2 and 2.4 mm. The axial load resistance is dependent on the stud slenderness. Noggins are often provided within wall frames to provide lateral restraint to the studs. Without these noggins, the minimum radius of gyration dictates the slenderness of plain C sections. When a mid-height noggin is provided, the minor axis slenderness of the studs is reduced by half and the axial resistance increases considerably.

The benefit of mid-height noggins on a lipped C section is less dramatic, since the lips provide more stability to the section and the minimum radius of gyration is much greater than for a plain C section. Table 7.3 presents typical compression loads that may be resisted by 100 mm plain C sections with mid-storey height restraints and 100 mm lipped C sections that are either unrestrained laterally, or restrained laterally at mid-height. Steel with design strength of 390 N/mm^2 has been assumed in these tables.

7.2.2 Bending and compression

In studs subject to combined bending and axial load, the limiting combination of axial load and moment varies with stud length, stud type and restraint conditions. To comply with the requirements of clause 6.2.5(2) of BS EN 1993-1-3 and clause 6.3.3(4) of BS EN 1993-1-1, the ability of a stud to resist moment reduces as the axial load increases. In a typical house, the storey height is 2.5 m and Figure 7.1, Figure 7.2 and Figure 7.3 are presented for walls of this height. These figures are based on the requirements of the above mentioned clauses.

The intercepts on each axis are for pure compression and for pure bending in the major axis direction respectively. A slight improvement can be seen when studs are restrained at mid-height. Figures of this type allow interpolation between tabulated values. These figures should not be used for studs subjected to biaxial bending.

Loads transferred from beams may be assumed to be applied at the face of the column or stud wall, and the moment due to this action is calculated for an eccentricity of half the member depth or width, depending on the orientation of the members.

Table 7.3 Load capacity (in kN) of light steel C section studs resisting axial load only

a. 100 mm plain C section (restrained at mid-height)

WALL HEIGHT (m)	FACTORED LOAD (kN) FOR SECTION THICKNESS		
	1.2 mm	1.5 mm	2.0 mm
2.00	19.4	27.2	41.9
2.25	17.2	24.0	36.9
2.50	15.3	21.2	32.8
2.75	13.6	18.9	29.5
3.00	12.2	17.0	26.8

b. 100 mm lipped C section stud (restrained at mid-height)

WALL HEIGHT (m)	FACTORED LOAD (kN) FOR SECTION THICKNESS		
	1.2 mm	1.5 mm	2 mm
2.00	47.9	67.7	98.6
2.25	45.0	62.8	90.2
2.50	42.0	57.7	81.7
2.75	38.8	52.6	73.6
3.00	35.6	47.7	66.1

c. 100 mm lipped C section stud (unrestrained within height)

WALL HEIGHT (m)	FACTORED LOAD (kN) FOR SECTION THICKNESS		
	1.2 mm	1.5 mm	2 mm
2.00	31.5	41.1	55.4
2.25	26.9	34.6	46.1
2.50	23.0	29.3	38.7
2.75	19.8	25.0	32.9
3.00	17.1	21.5	28.2

Table 7.3 (continued) Load capacity (in kN) of light steel C section studs resisting axial load only

All data is for S390 steel.
Buckling forms considered include Flexural, Torsional and Torsion-Flexural.

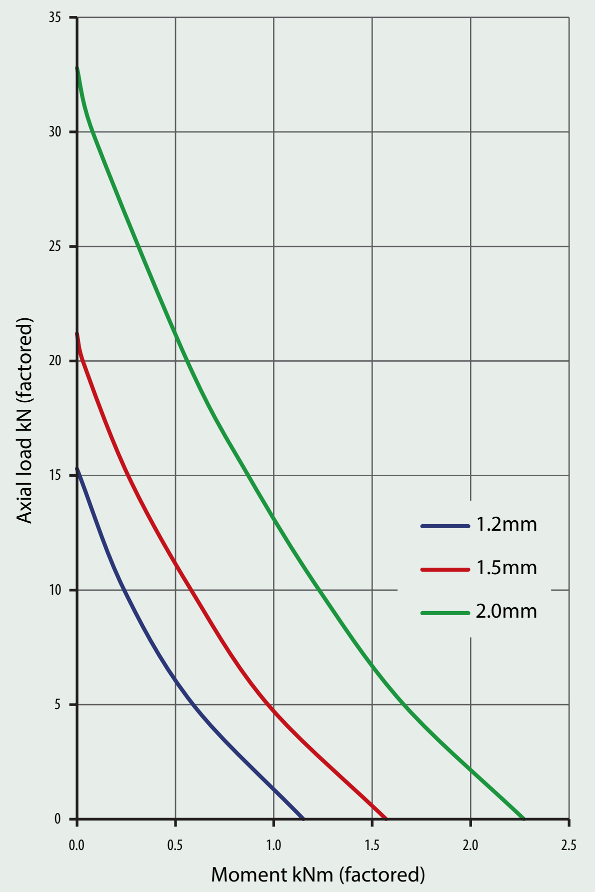


Figure 7.1 Moment / axial load for 2.5 m high, 100 mm plain C stud wall – restrained at mid-height

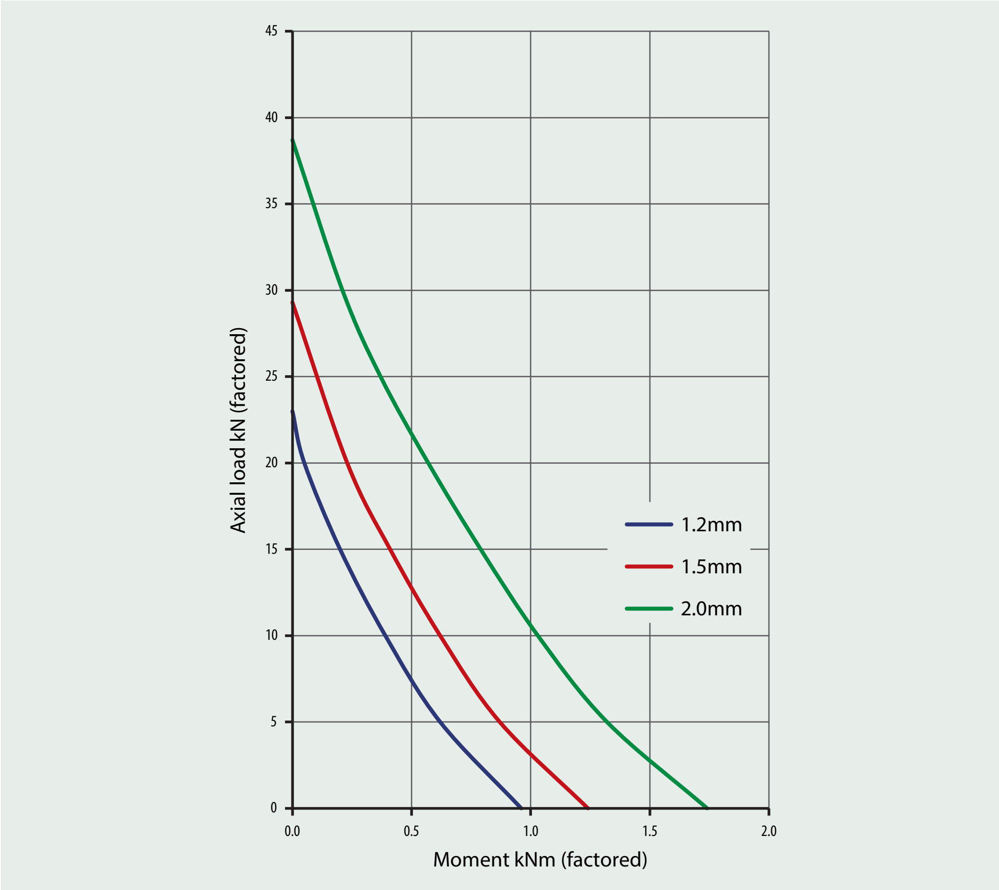


Figure 7.2
Moment / axial load for 2.5 m high, 100 mm lipped C stud wall – unrestrained

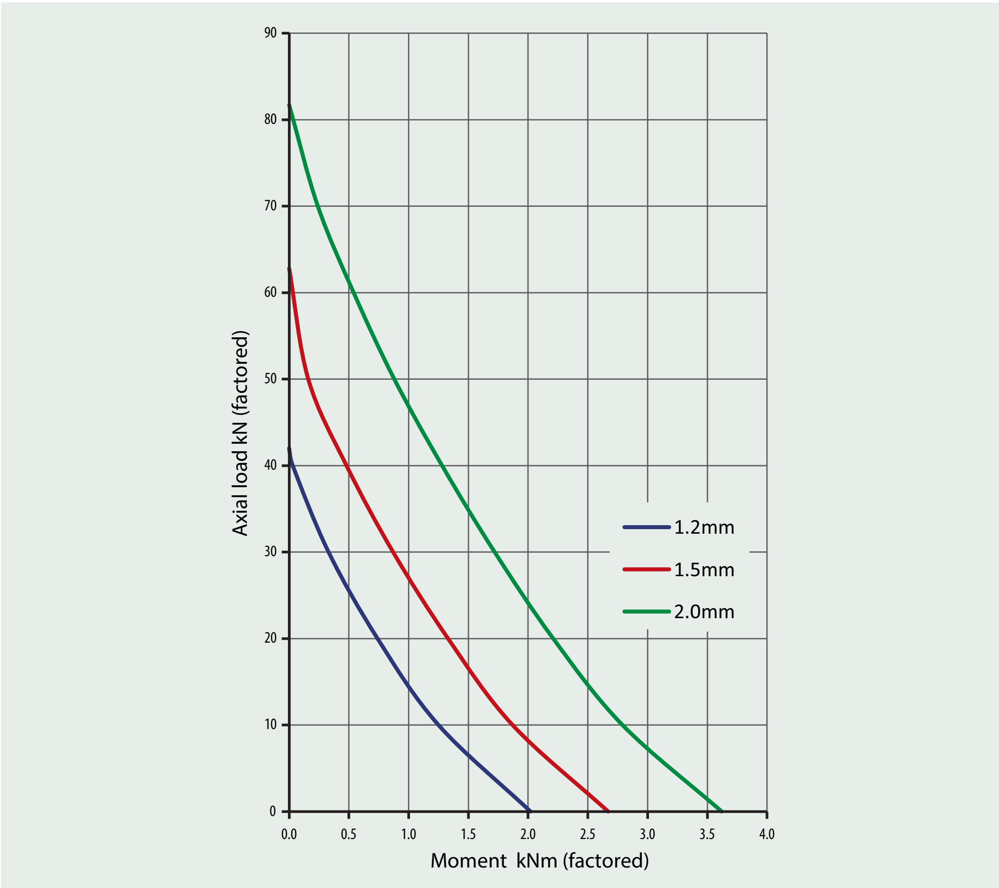
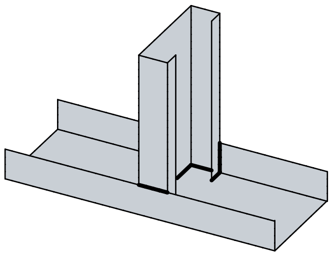
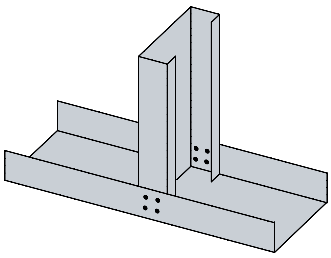
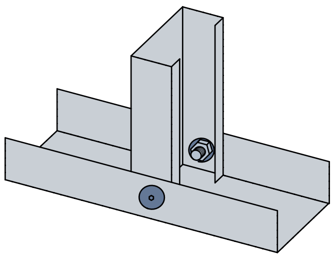
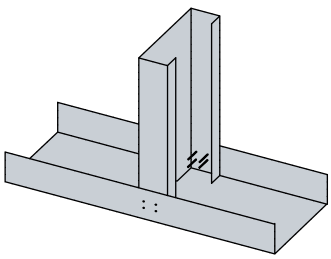


Figure 7.3
Moment / axial load for 2.5 m high, 100 mm lipped C stud wall – restrained at mid-height

7.3 Connections

There are several techniques available for connecting light steel components; some of these are presented in Table 7.4. Guidance on the design and detailing of the most common connection types is given in BS EN 1993-1-3 and BS EN 1993-1-8[54]. Manufacturers use the method which best suits their own framing system, taking into account design, detailing and construction issues and for which appropriate test data are available.

Table 7.4 Typical connections used in light steel construction

WELDED CONNECTIONS	TYPICAL SHEAR CAPACITY: BY TEST (CAN BE AS GREAT AS SHEAR STRENGTH OF SECTION)
	**MIG welding:** Light steel sections may be joined by continuous MIG welding. Care is required to ensure that the welding process does not cause damage to the components being connected, because the parent metal is very thin. The welding of galvanized steel requires special care (see Section 3.3.1). To maintain the durability of the steel, the affected areas should be protected after welding with a zinc rich paint.
	**Spot welding:** Spot welding is primarily used for workshop fabrication. An arc is created between the tips of the welding tool on either side of the steel elements to be joined. It is most appropriate where the welding tool can be supported and easily moved into position to form the weld. A minimum of 3 spot welds should be used for each connection.
BOLTED CONNECTIONS	**TYPICAL SHEAR CAPACITY: 12 mm BOLT: 8 – 12 kN**
	**Bolts** are a common choice for connecting light steel sections because of the ease with which holes in the sections can be punched during the roll forming process. The connections are usually arranged so that the bolts are primarily subject to shear and the capacity of the connection is generally governed by the bearing strength of the thinner material.
SCREWED CONNECTIONS	**TYPICAL SHEAR CAPACITY: 5.5 mm SCREW: 5 kN**
	**Self-drilling, self-tapping screws** are commonly used for connecting light steel components. The drill part of the screw forms a hole in the steel section and the tapping part forms the thread in a single operation. This technique is commonly used to inter-connect either wall panels or stick built frames on site, although care must be taken to ensure that the protruding head of the screw does not interfere with the finishes. Two or more screws should be used for each connection. Self-drilling self-tapping screws are also used extensively to attach finishing materials, such as plasterboard, sheathing, floor boarding, insulation and decking, to light steel structures. Stand-off screws, where the screw thread is discontinuous, may be used to fix cellular insulation boards to light steel components without the risk of crushing the insulation.

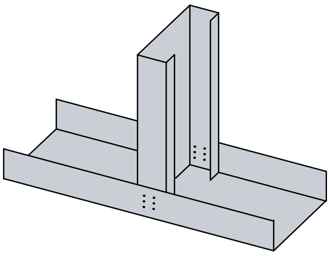
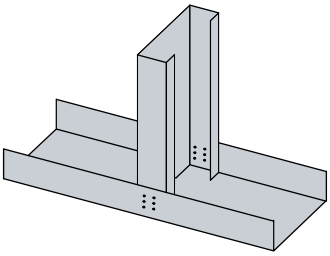
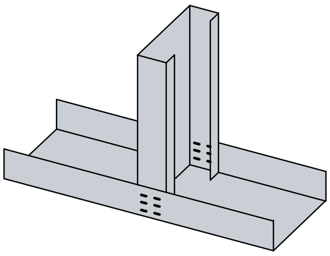
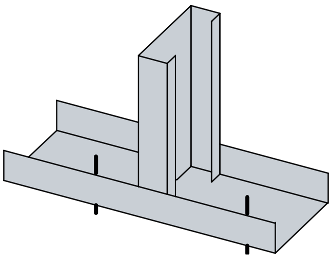
RIVETED CONNECTIONS	TYPICAL SHEAR CAPACITY: BY TEST
	**Blind rivets** are fitted into pre-drilled holes and a mandrel is pulled by a special tool so that the rivet expands into and around the hole. These rivets provide a relatively robust form of attachment with good pull out resistance. They are useful for thin-thin attachments such as the seams of profiled decking and sheeting.
	**Self-piercing rivets** do not require pre-formed holes in the components since the rivet is designed both to pierce and to form a permanent fastening within the materials being joined in one single operation. This requires a hydraulic operated tool with access to both sides of the fixing. The riveted connection is formed in two phases: Piercing: The rivet shank acts as a shearing punch which cuts a hole through the top layer of material and partially through the lower layer until coming under the influence of the reacting die. Flaring: During the final stages of punch travel in the lower sheet, the sheet material is displaced into the die and causes the shank of the rivet to flare out, locking itself into the material.
PRESS JOINING OR CLINCHING	**TYPICAL SHEAR CAPACITY: BY TEST**
	**Clinching** is a combination of drawing and forming that locks two or more layers of thin gauge steel together. Clinching involves a hydraulically operated punch that drives the layers of metal into a die to make an impression. Additional force is then applied to spread the top layer of steel into the bottom layer. This prevents the top layer from being pulled out of the bottom layer. There are two basic clinching methods: a. Cut clinch: This type of clinch is formed by shearing the metal on two sides, drawing the top layer through the slits in the bottom layer and expanding the width to form a lock on both sides. b. Button or round clinch: This type of clinch is characterised by a “button” formed on one side of the metal. The layers of metal are simply formed by drawing them into a circular dovetail; the diameter is then expanded to lock the sheets together.
POWDER ACTUATED FASTENINGS	**TYPICAL SHEAR CAPACITY: RELATED TO BRICK OR CONCRETE STRENGTH IN TYPICAL APPLICATIONS**
	**Powder actuated fasteners** are used to connect light steel members to concrete and masonry or to thick steel members. However, it is not possible to connect thin steel members to each other, because of the flexibility of the connected parts to the driving force.

Table 7.4 (continued) Typical connections used in light steel construction

Site steel-to-steel connections are normally made with either 4.8 mm diameter self-drilling self-tapping screws or 10 – 12 mm diameter, Grade 4.6 bolts. Details of the different types of self-drilling self-tapping screws and their common applications are presented in Appendix D of SCI publication *Construction Detailing and Practice* (P165) [55]. Panel-to-panel connection uses a minimum of three 10 mm bolts, evenly distributed through the storey height, or seven 4.8 mm diameter self-drilling self-tapping screws, one at the base, one at mid-height and five at the head. The grouping at the head of the panel is to enable the sharing of wind loads between adjacent braced panels or to transfer the tie forces required for robustness.

Panels will be attached at the ground level with bolts, at braced panel points, or powder actuated fasteners, along the length of the base track.

Between storeys, the base of the second lift of wall may be attached to the head of the lower storey wall with either self-drilling self-tapping screws or bolts. If self-drilling self-tapping screws are used, it is likely that bolts will be used locally at points of high stress, for example, where braced bays interconnect.

7.4 Details of external wall construction

Typical details for cavity construction of external walls are shown in Figure 7.4 and Figure 7.5. The inner skin, which has a plasterboard lining to the room face, uses C section studs in single lengths between floors, at regular centres of typically 400, 450, or 600 mm. These spacings are chosen, where practical, to ensure the efficient use of plasterboard linings and other cladding materials. Multiple studs are used in heavily loaded applications, such as adjacent to openings or in braced panels.

A wall sub-frame or panel consists of a head rail, a base rail and possibly horizontal noggins at mid-height. Where C sections are used as noggins, their ends are often tapered to fit into the adjacent C section wall studs. These lateral restraints ensure that the design of walls in most applications is governed by major axis rather than minor axis buckling of the studs. For the normal storey heights used in housing, intermediate noggins are not required when using lipped C section studs.

Plasterboard screw fixed on one side of a wall can reduce the slenderness of the C sections. An effective length factor of 0.7 may be used in minor axis buckling. For highly loaded walls, it is necessary to carry out an explicit check on the compression resistance taking account of the stabilising effect of boards attached on one or both sides of the wall. Sheathing boards are beneficial in preventing minor axis buckling.

Where roofs experience high wind loads, vertical straps are required to connect the roof trusses to the wall panels below. These may be in the form of thin galvanised steel strips with 4 to 6 screw fixings at each end. Similarly end gables should be laterally restrained by the roof trusses, which may require use of additional straps.

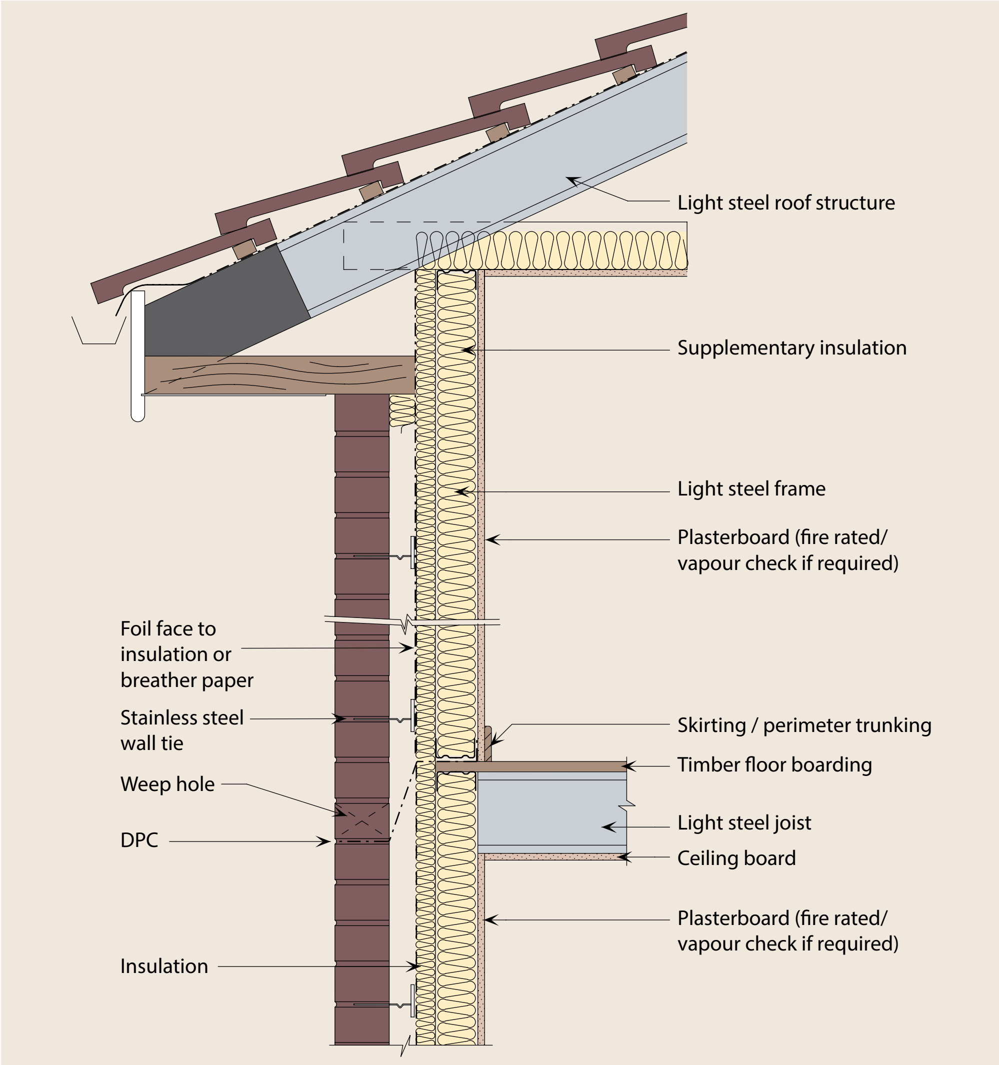


Figure 7.4
Generic detail – external wall connection with eaves and intermediate floor

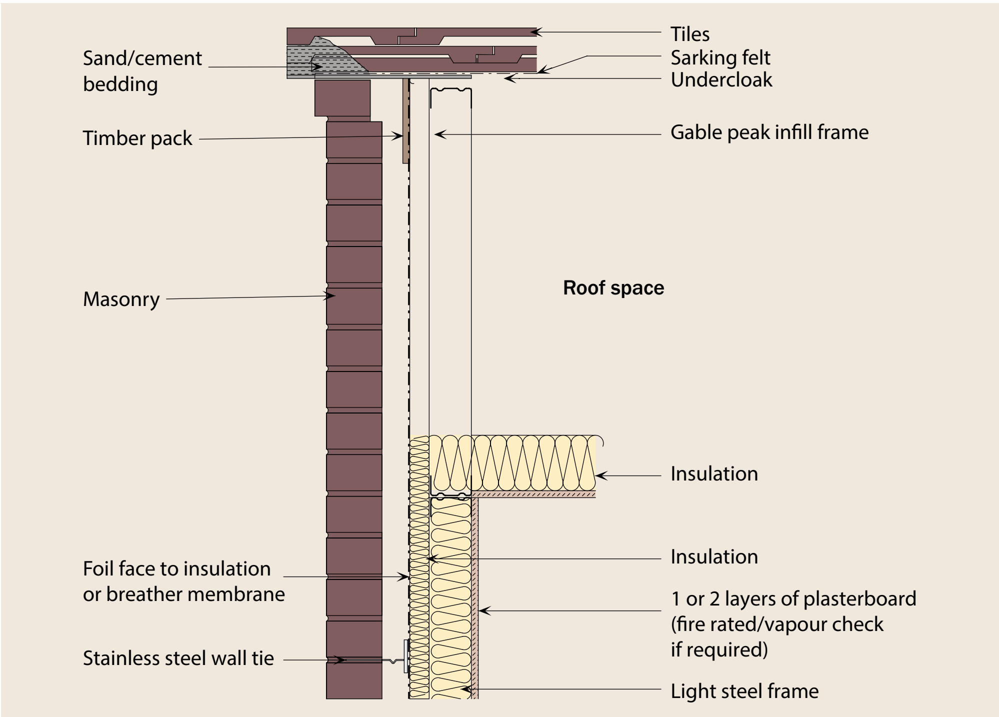


Figure 7.5
Generic detail – Gable wall

7.4.1 Masonry cladding

Masonry cladding supports its own weight on the foundations and transmits only lateral loads to the steel structure. For domestic-scale construction, joints to allow horizontal movement will not normally be required. However, movement joints may be required in structures above four storeys to accommodate differential movement of the brickwork and steel.

The cavity face of the inner skin may be sheathed and should always be insulated with a suitable board material. Some insulation may be placed within the depth of the studs, provided that the risk of interstitial condensation has been assessed and shown to be negligible.

When installing the light steel framing on an in-situ concrete ground slab, the base rail should be placed on a DPC. For heavy load conditions, or an uneven slab, it may be necessary to use a thicker base rail and/or packings.

7.4.2 Lintels

Openings larger than 600 mm wide in external walls will generally require a frame lintel in the plane of the stud wall to transfer loads from above, as illustrated in Figure 7.6. C shaped lintels are recommended at, or just below, floor level where restraint can be properly afforded by the floor joists. Separate lintels are also required within the external brick skin.

Cavity trays should be provided above horizontal cavity barriers and above window and door openings. Attention should be paid to the local details in these areas (see Figure 7.6) to ensure that water is effectively shed to the outer skin of the wall.

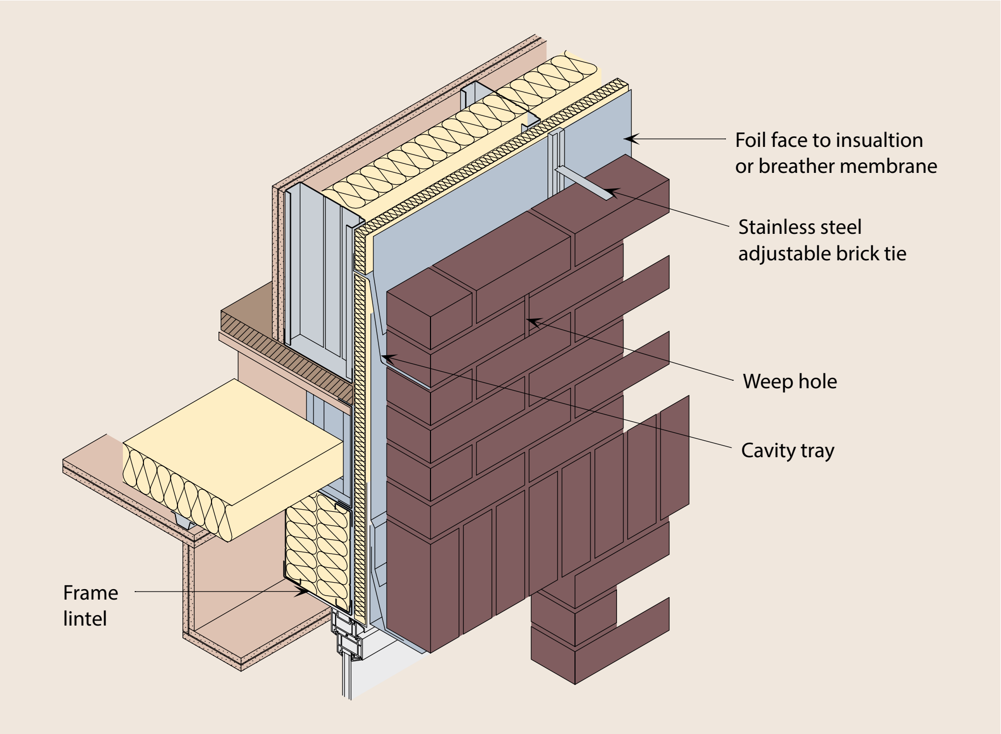


Figure 7.6 Detail of lintel at opening

To ensure that water will not run back and penetrate at the reveal, cavity trays should extend 150 mm either side of a door or window opening and have stopped ends. Damp proof course should be provided around openings, see Figure 7.7.

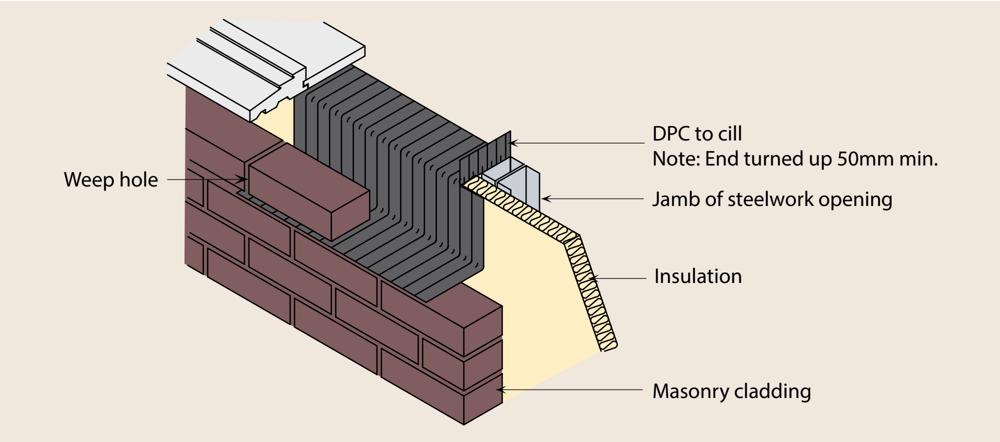


Figure 7.7
Damp proof course (DPC) detail at cill

7.4.3 Wall ties

The majority of details in this publication show how light steel framing interfaces with brickwork. When used with masonry cladding, the external skin should be attached to the light steel frame with either epoxy coated galvanized ties, or austenitic stainless steel ties (to BS EN 845 [56], BS EN 1996 [57], PD 6697 [58], BS 8200 [59] or approved by independent assessment). The ties provide lateral restraint whilst accommodating vertical movement. To accommodate movement and tolerances, brick ties are normally fixed in vertical channels. These channels can be attached directly to sheathing boards or, they may be attached through soft insulation boards using stand-off screws. The stand-off screws should be isolated from the channels with neoprene or similar washers to minimise cold bridging and bi-metallic action.

A minimum distribution of 2.5 wall ties per m^2 of wall is required according to BS EN 1996-1-1 and Building Regulations. NHBC Chapter 6.10 requires a minimum density of wall ties of 3.7 ties/m^2. For areas of high wind suction, the density of ties may need to be increased. Figure 7.8 shows an arrangement of brick ties achieving a

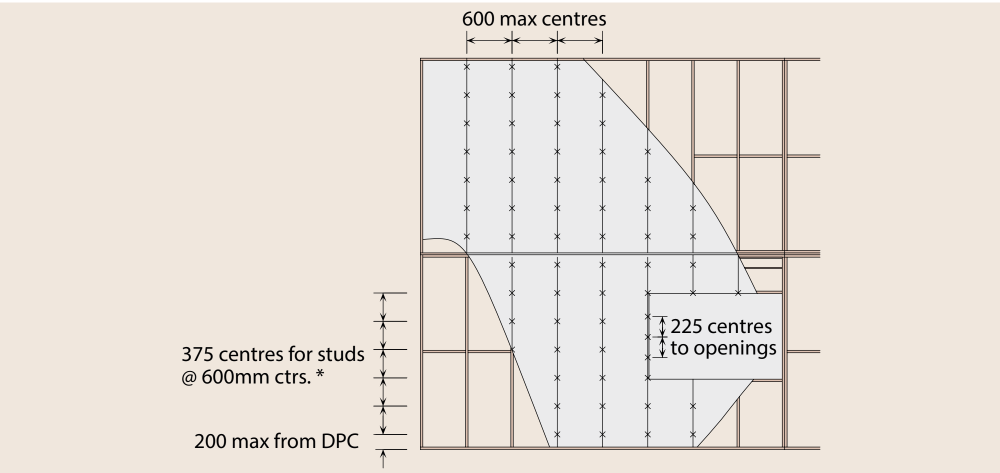


Figure 7.8
Wall tie spacing and fixing

Note: *Centres may increase to 450 mm for studs at 400 mm centres. Ties over windows etc. to be above the lintel and below the cavity tray. Manufacturers have different arrangements which also satisfy building regulations distribution of 4.44 wall ties per m^2 when studs are spaced at 600 mm centres. A vertical spacing of 450 mm and a horizontal spacing of 600 mm is a common solution to achieve the minimum NHBC requirement of 3.7 ties/m^2.

7.4.4 Details at windows

The details at windows and doors depend on the precise masonry detail adopted, such as flush or check reveals.

Figure 7.9 shows typical head, cill and jamb details for insulated and uninsulated cavity closers in flush reveals with masonry cladding (where the window is set into

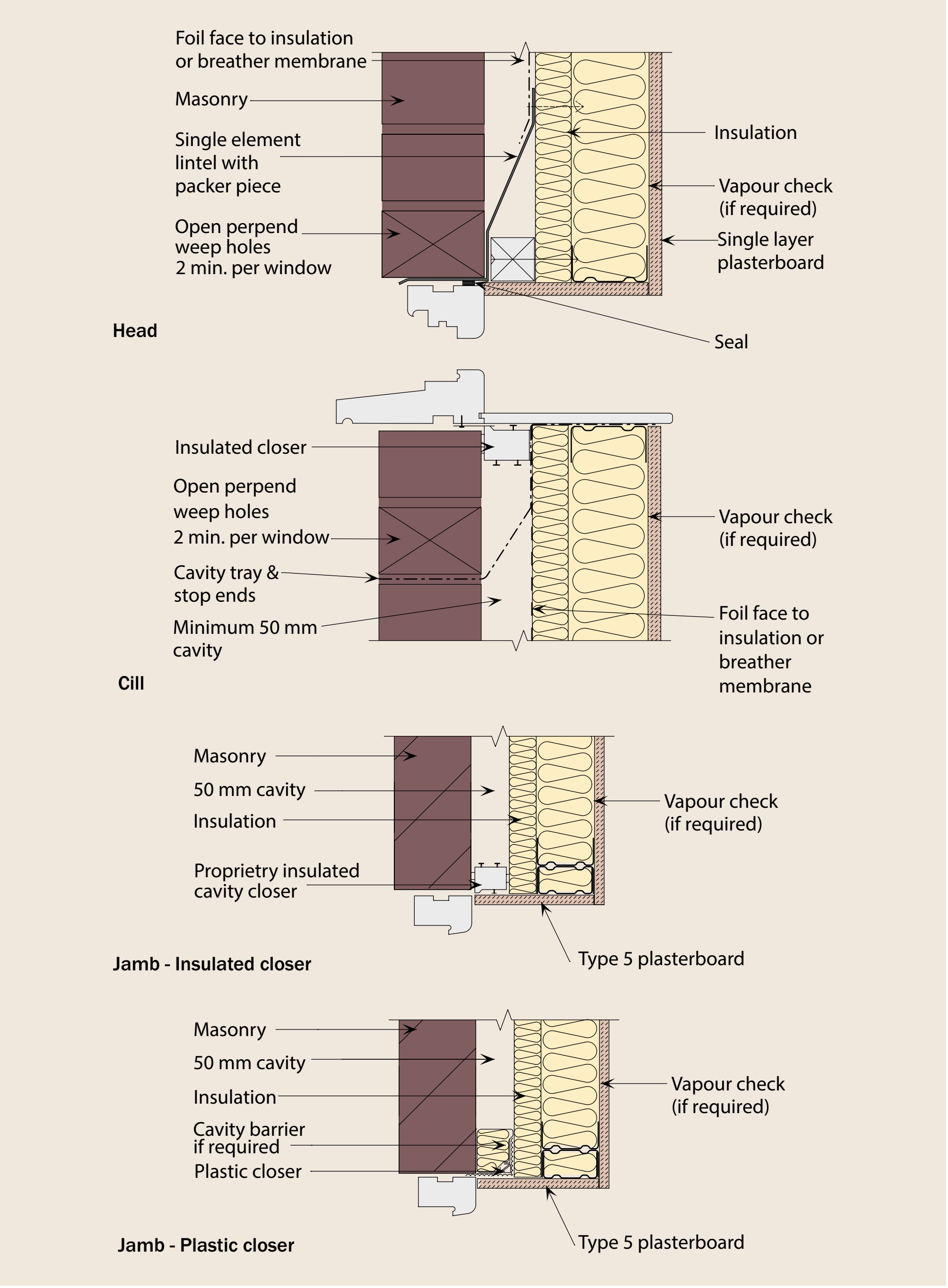


Figure 7.9
Window details: Flush

Note: For severe or very severe exposures a cavity tray with stop ends may be required above the lintel.

the brickwork). Proprietary cavity closures are used around the opening to provide insulation and a barrier to moisture.

Figure 7.10 shows the alternative details for a checked reveal (where the window frame aligns with the cavity).

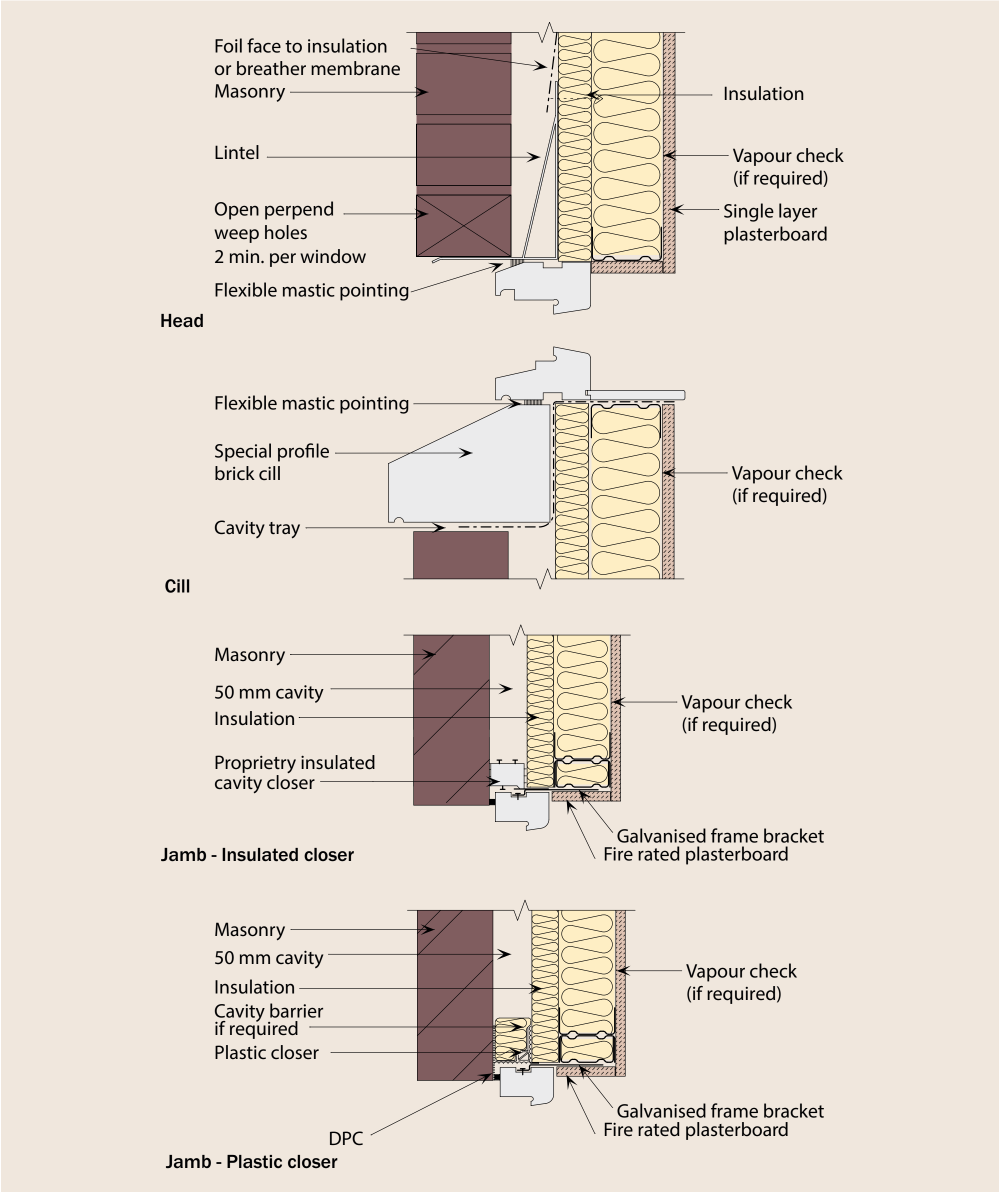


Figure 7.10 Window details: Checked reveal

Note: For severe or very severe exposures a cavity tray with stop ends may be required above the lintel.

7.4.5 Other forms of cladding

Vertical tile hanging

Figure 7.11 shows how vertical tile hanging is fixed in the traditional manner using battens and counter battens. The detail at steps and staggers shown in Figure 7.12 is similar to that used in more traditional forms of construction. Head, cill and jamb configurations are shown in detail in Figure 7.13 (a), (b) and (c). A breather membrane should be fixed between the battens and counter-battens.

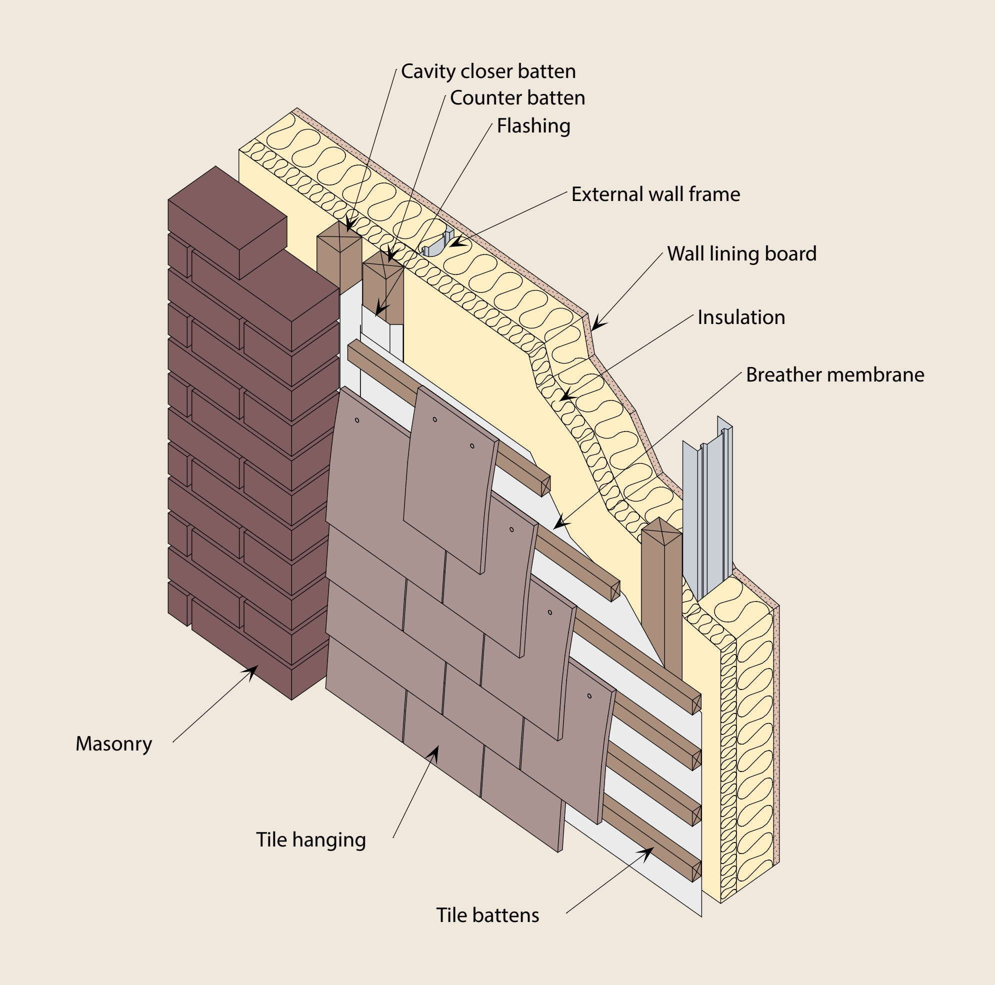


Figure 7.11
Tile hanging detail

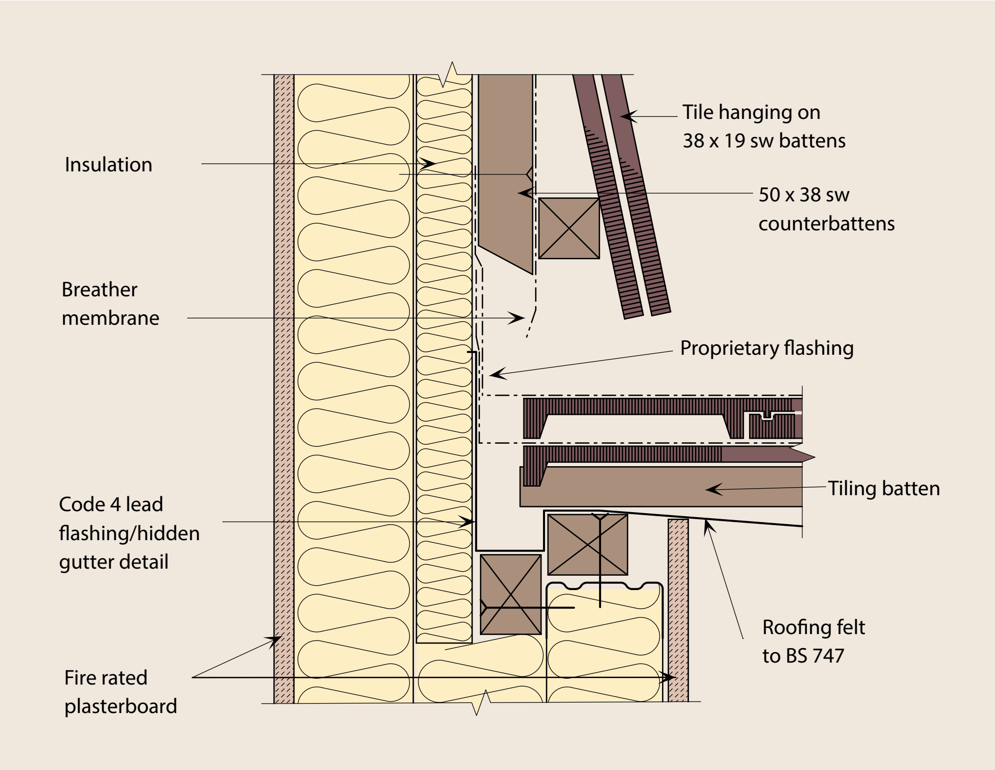


Figure 7.12
Tile hanging – step and stagger detail

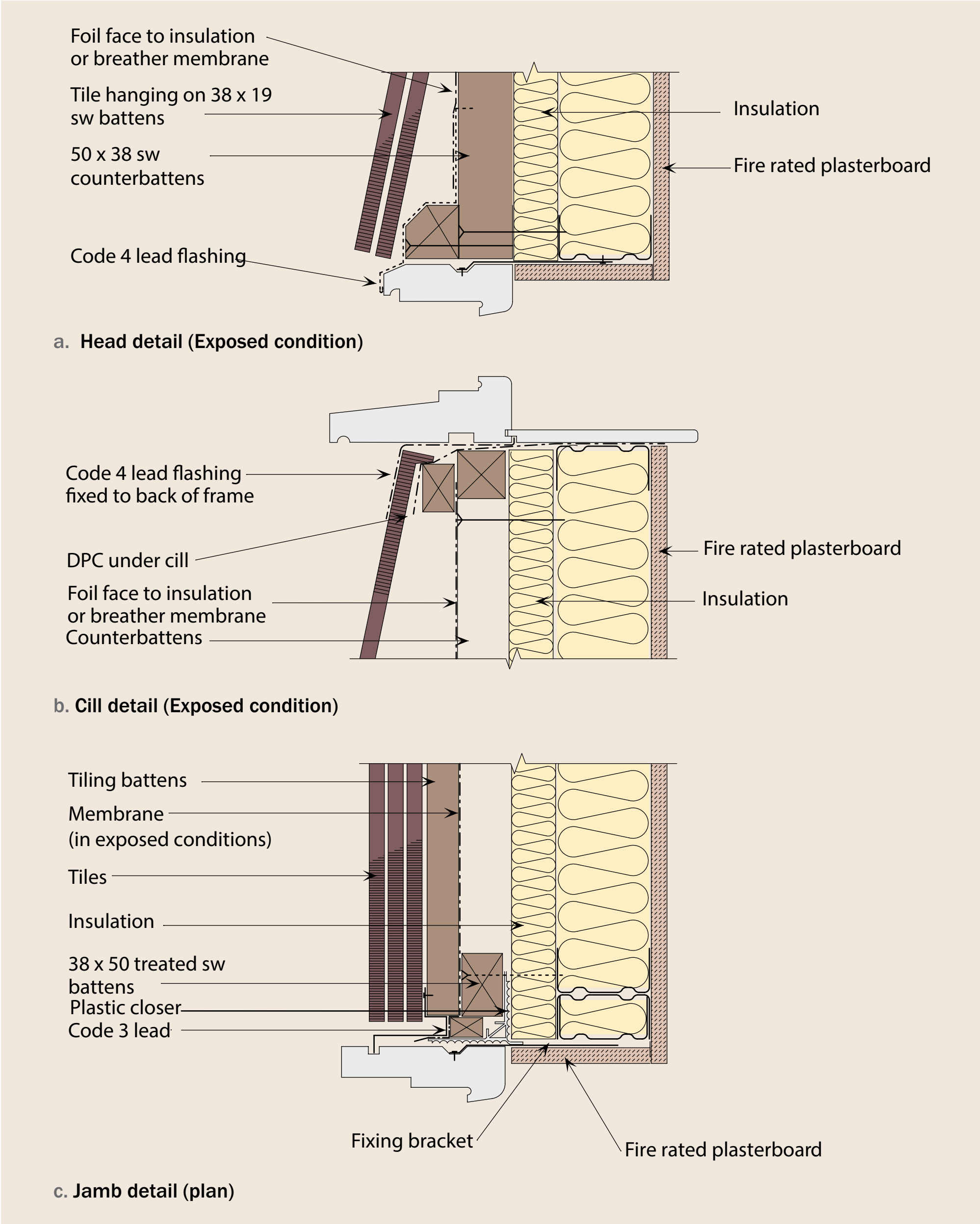


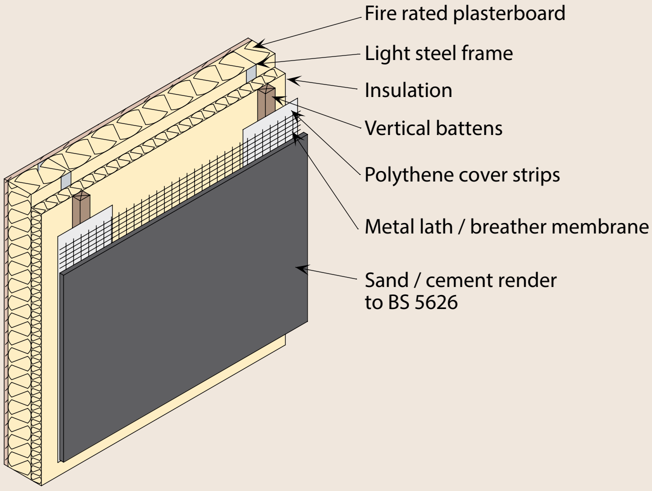
Figure 7.13
Tile hanging details of windows and doors

Render on metal lath

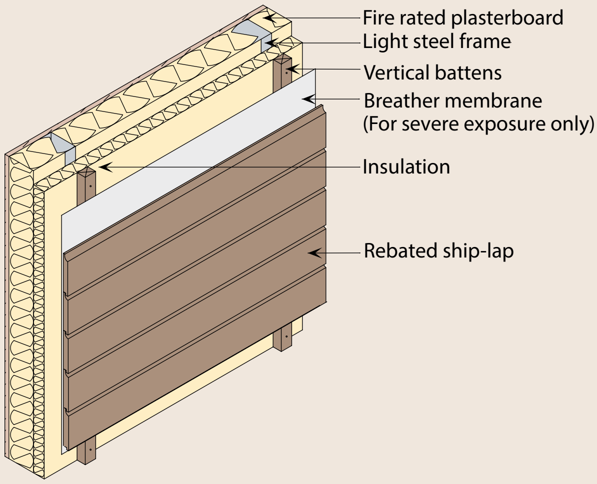
Figure 7.14 (a) shows how vertical battens are fixed in locations to coincide with vertical studs. A combined metal lath / breather membrane is then attached to the battens and the render coat is applied directly to the lath. The finished face can then be sealed with a proprietary sealant and an external paint finish applied.

Timber boarding

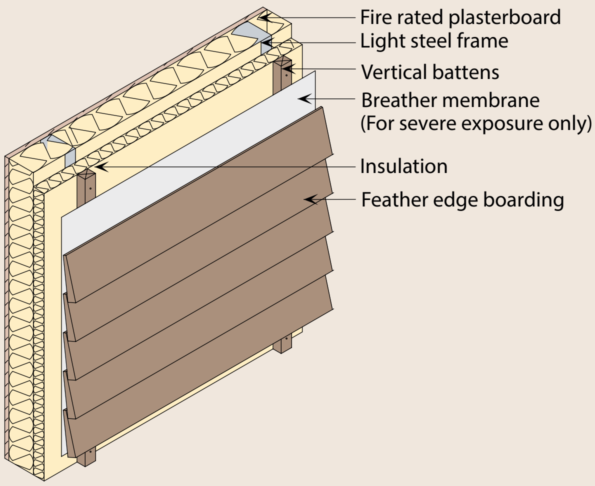
Figure 7.14 (b) and (c) and Figure 7.15 (a) to (c) show how a traditional boarded finish can be achieved with a light steel frame. The arrangement shows vertical battens attached at the stud positions and the boards are attached to these battens. In exposed situations, a breather membrane is required; this should be located between the vertical battens and the boarding.



a. **Render on metal lath**



b. **Ship-lap boarding**



c. **Feather edged boarding**

Figure 7.14
Alternative forms of cladding supported by light steel framing

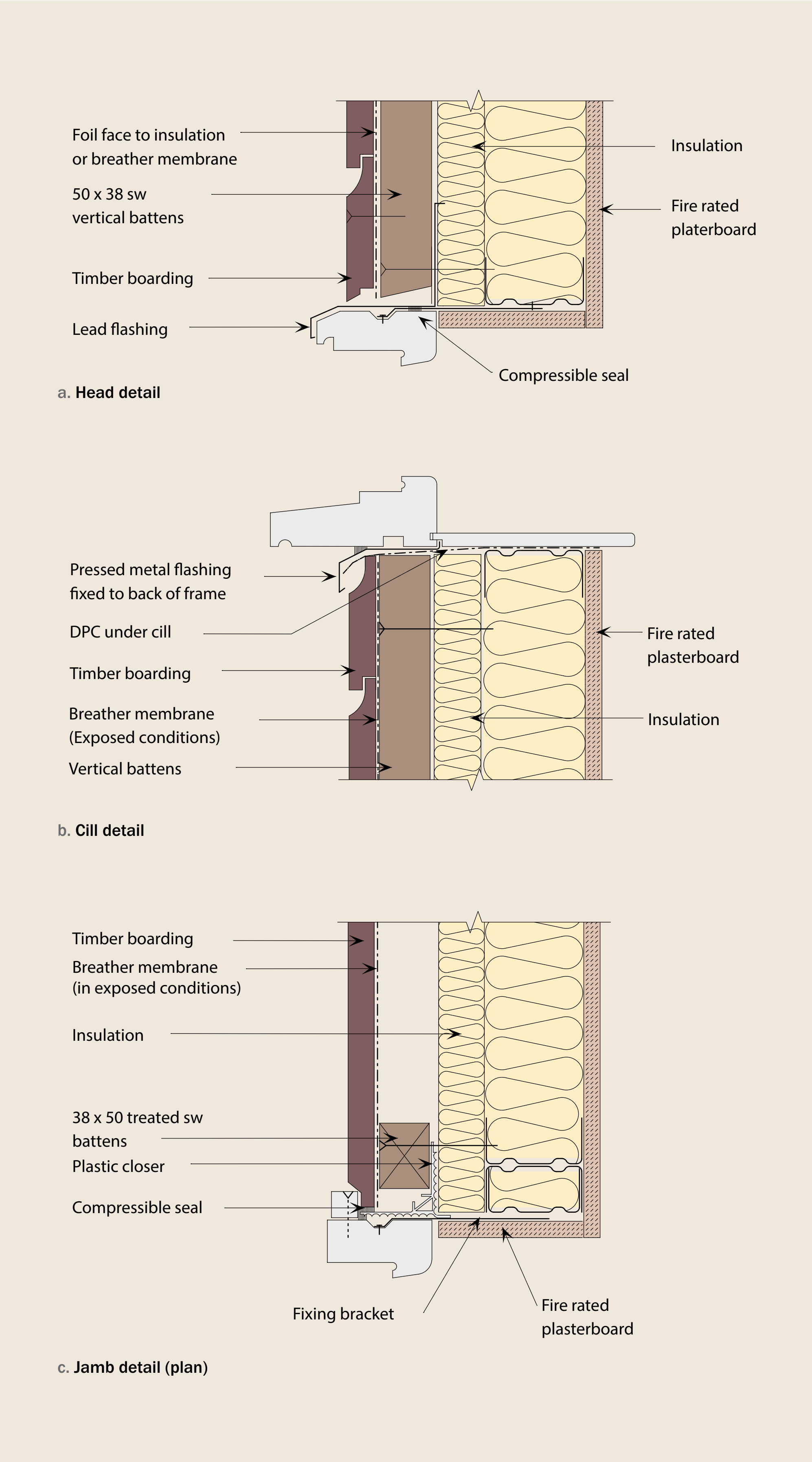


Figure 7.15
Timber boarding details at windows and doors

7.5 Internal wall construction

7.5.1 Loadbearing walls

Loadbearing walls can resist lateral loads when they are suitably braced by integral bracing or by flat straps. Loadbearing internal walls are generally clad on each side with one layer of plasterboard or special fire resistant board. Multiple layers of plasterboard may be used to provide impact resistance, or rigidity for tiling, or where good acoustic insulation or high fire resistance is required.

Attention should be paid to local details at the head and base of the wall to ensure that loads can be adequately transferred without local deformation of the joists or studs. In particular, where joists are continuous over such walls, bearing and buckling of the joists should be checked. The connection can be stiffened by inclusion of a short length of stud, or other measures.

7.5.2 Non-loadbearing walls

The construction of non-loadbearing walls is similar to that of loadbearing walls except that noggins and diagonal bracing are not required to stabilise the studs. As axial loads only arise from the self-weight of the walls, a regular pattern of smaller or thinner studs may be used. Figure 7.16 shows two possible forms of head detail to non-loadbearing walls.

Long-spanning light steel joists reduce the number of load-bearing walls. Consequently, the internal partition walls can be non-loadbearing and this will simplify construction.

7.5.3 Junctions between intersecting walls

Figure 7.17 shows junctions of an external wall and a separating wall. Some of the details use purpose-made light steel sections, whilst others use a particular configuration of C section studs. Special corner studs may be required to ensure that plasterboard can be attached to both walls.

7.5.4 Separating and compartment walls (party walls)

Separating walls generally comprise double skin construction with insulation in the cavity between the skins. Separating walls should continue into the roof space. The requirements for acoustic insulation of separating walls generally satisfy the minimum fire resistance requirements for compartment walls. Therefore, where a separating wall is required also to act as a compartment wall, the acoustic insulation requirements will generally control.

For separating walls, each skin should have at least two layers of plasterboard on the room side, and a minimum thickness of 30 mm. For example, one layer of 19 mm plasterboard plank, and one of 12.5 mm fire rated plasterboard, will achieve 60 minutes fire resistance, provided that the stud wall is continuous into the roof space. In the roof space, the plasterboard may be reduced to a single 19 mm plank with cover strips, or two 12.5 mm plasterboards. Alternative configurations may be adopted with 15 mm plasterboard replacing the 12.5 mm boards.

Cavity barriers or fire stops should be provided around any penetrations through fire resisting walls, in accordance with Approved Document B.

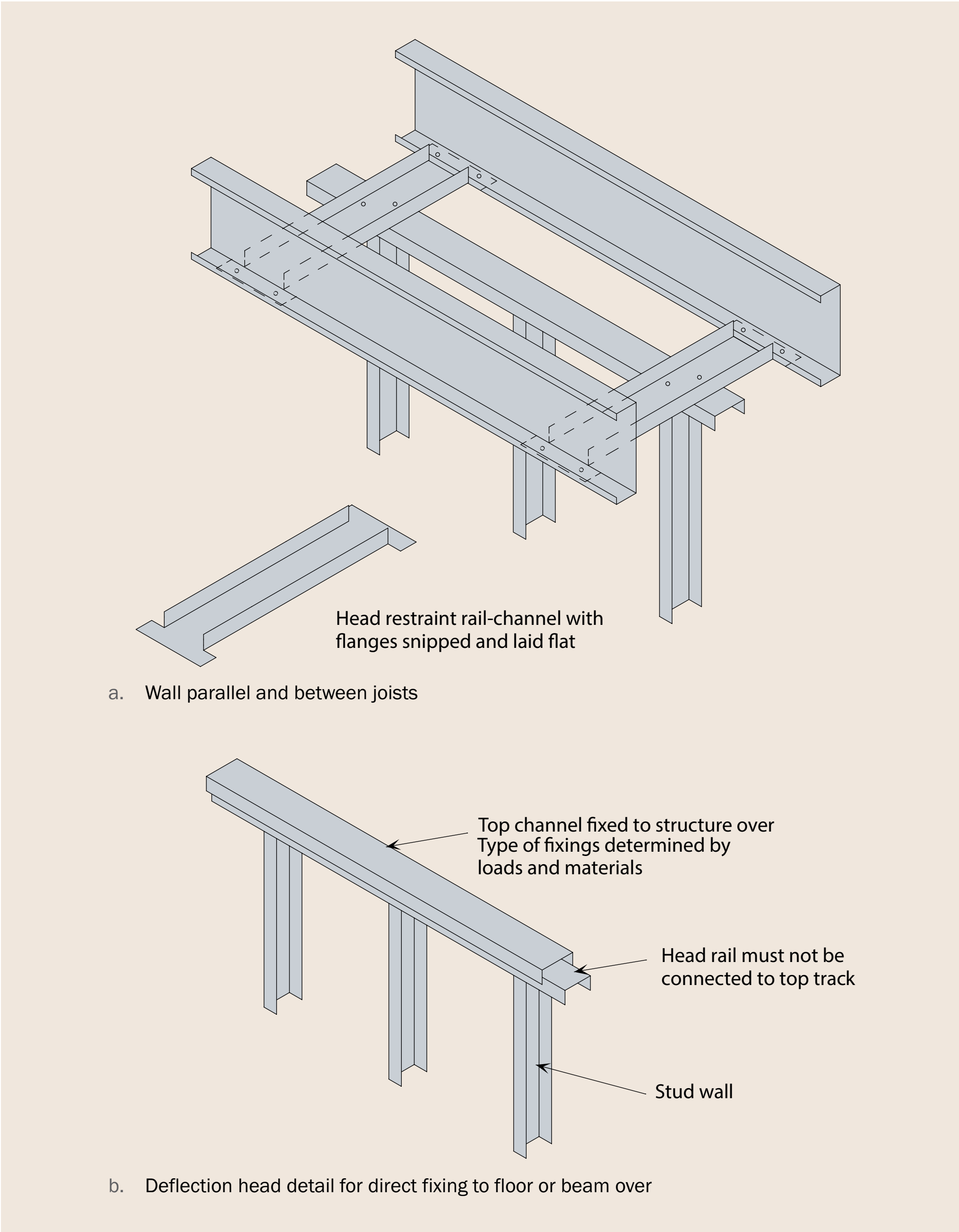


Figure 7.16 Head restraint to interior non-loadbearing wall

Junctions (roof, eaves, external walls, internal, steps and staggers)

Cavity barriers consisting, for example, of 50 mm thick wire-reinforced (or polyethylene sleeved) mineral wool should be provided at the junction of a compartment wall with any external wall void which would otherwise be continuous. These barriers are required in a compartment wall or floor, or any element that is required to be fire resisting. Typical locations would be:

- Horizontally at junctions with floors and roof.
- Vertically at a maximum lateral spacing of 20 m.

Figure 7.17 shows a typical detail at the junction of an external wall and a compartment wall. A 9 mm thick non-combustible board may be used as an alternative and should be fastened to one skin only, in order to reduce sound transmission.

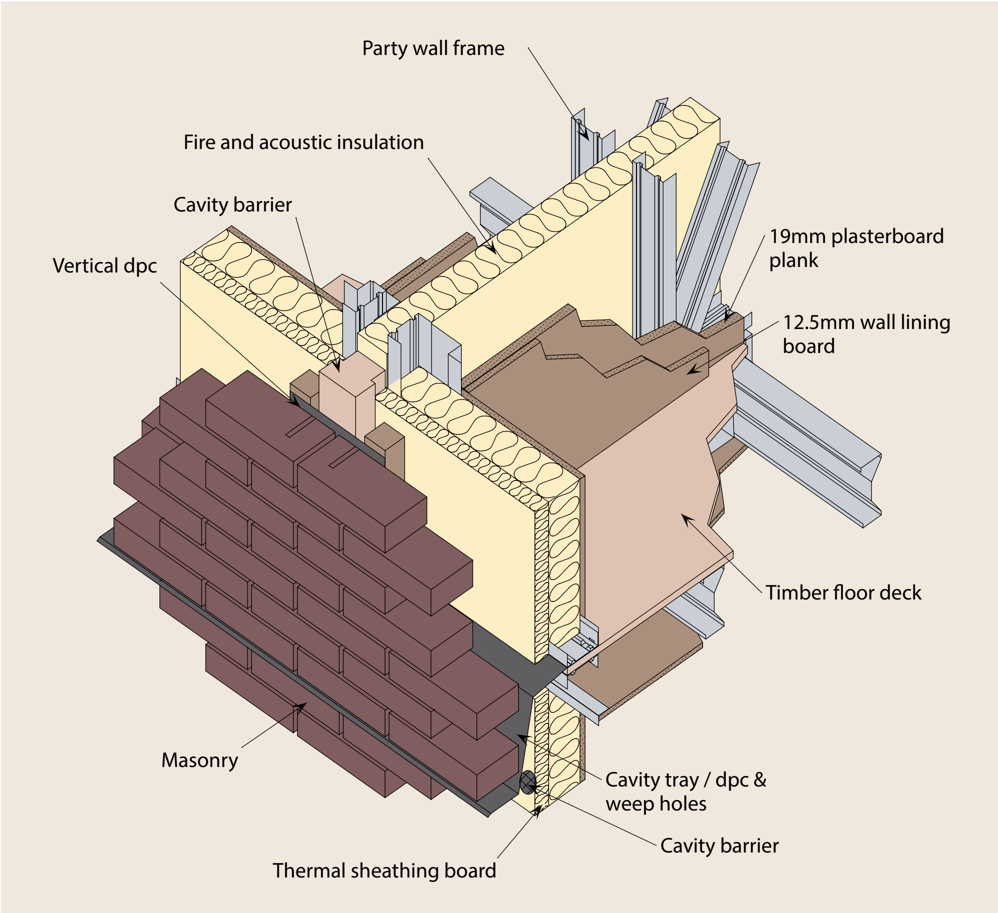


Figure 7.17
Party wall detail at an external wall

A section through a typical separating wall is shown in Figure 7.18. On sloping sites, the roof lines may step, which leads to the step/stagger detail shown in Figure 7.19.

Sound insulation

Provided that the details described in this Section are followed, airborne sound reductions will be achieved which comply with the requirements of the Building Regulations. Particular care should be taken to minimise the physical connection between adjacent properties since this will help to reduce noise transfer.

Further guidance may be noted as follows:

- The location of electric sockets and switches should be carefully considered; back-to-back installations should be avoided between dwellings. Approved Document B allows wall linings to be penetrated so that services pass through the void, provided that the fire and acoustic integrity is maintained. Wherever possible, it is recommended

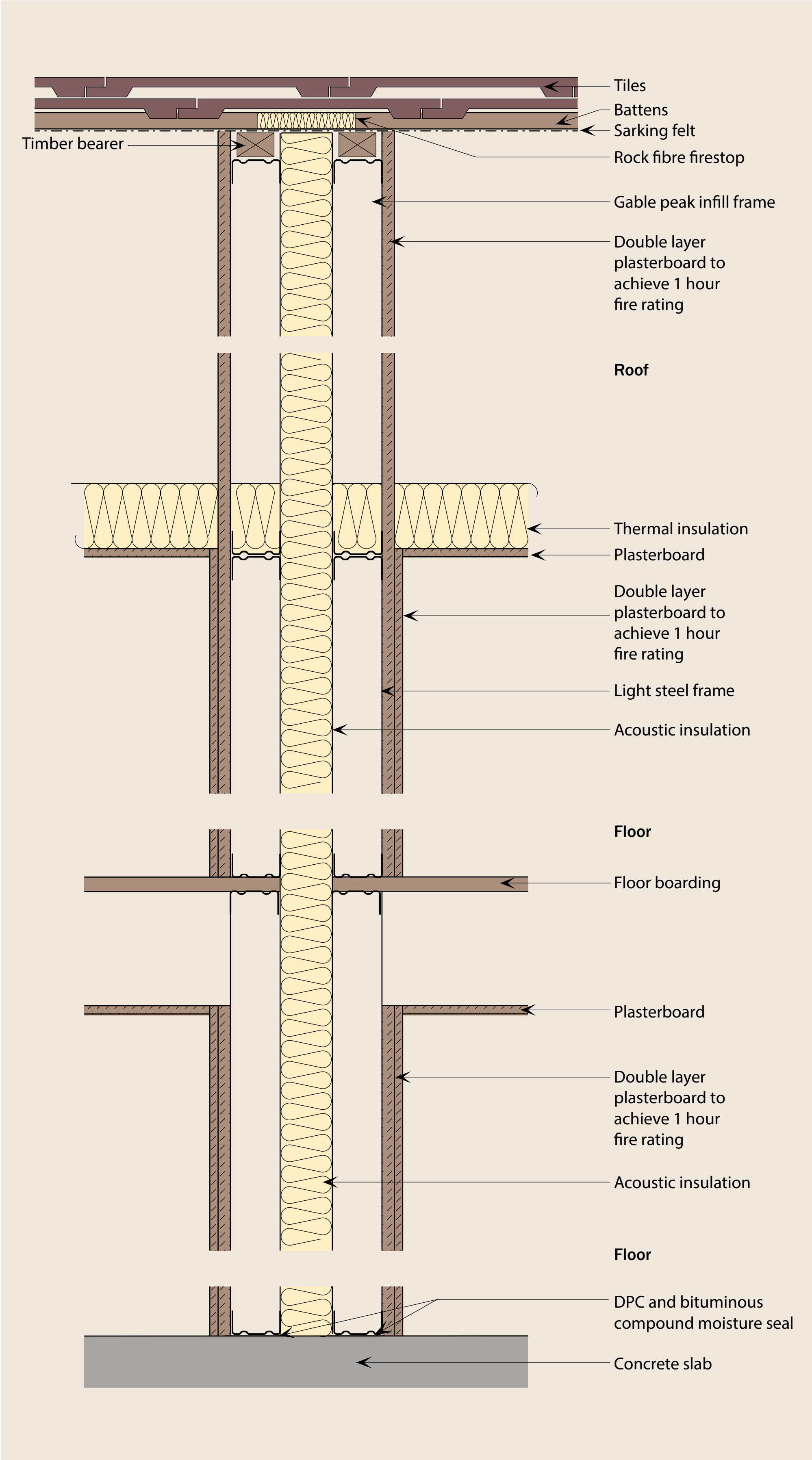


Figure 7.18
Separating wall detail used in conjunction with internal floor

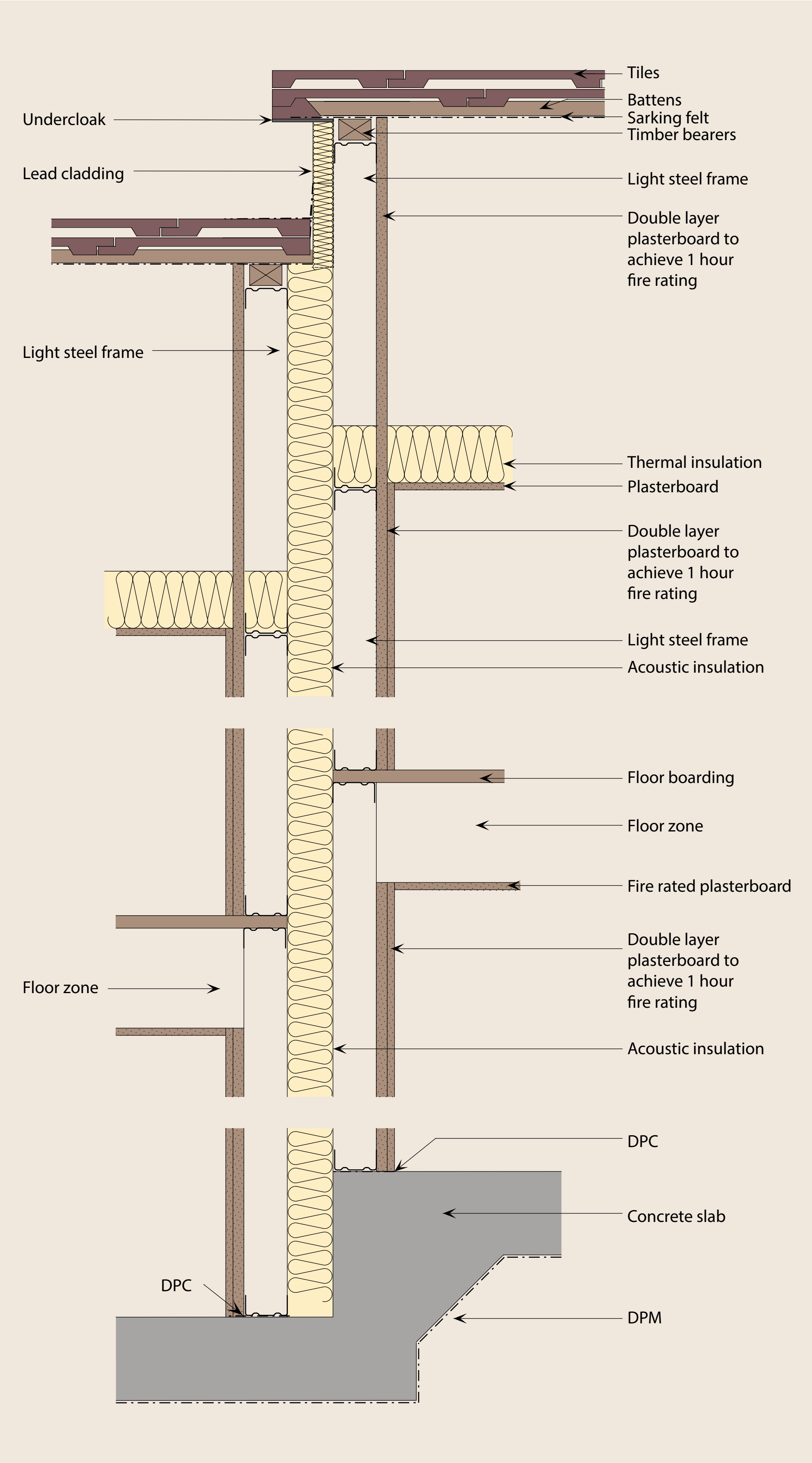


Figure 7.19 Separating wall - step / stagger generic detail used in conjunction with internal floors

that services should be routed away from separating walls. If services and penetrations in separating walls are avoided, then the problem of back-to-back fittings will not arise.

- The joints of successive layers of boarding should not be coincident.
- Acoustic quilt or cavity barriers should be used where appropriate to seal air gaps and to minimise flanking sound transmission, including that from floor to floor.
- There are no restrictions on the proximity of windows for acoustic requirements.
- All air gaps in linings should be avoided or sealed.

In the Building Regulations the airborne sound insulation R_w between rooms within dwellings is stated to be a minimum of 40 dB. For this purpose, insulation is introduced between the studs in walls where improved acoustic insulation is required.

7.6 Fixing wall linings

Plasterboard linings are attached using bugle-headed self-drilling self-tapping screws to minimise the risk of popping of the fixings. In all cases, the vertical edges of the boarding must be supported on studs. The horizontal edges will require secondary supports, unless 15 mm or thicker plasterboards are used on studs at not more than 600 mm centres. Purpose-made components are available for all such junctions. Fixings should be spaced at a maximum of 300 mm.

ROOF CONSTRUCTION

The structure of roofs in housing using light steel framing is generally based on conventional timber fink roof trusses that span between front and rear facades. Where required, timber trusses can be used in conjunction with light steel framing.

Light steel roof trusses using C and Z sections can be used as an alternative, particularly where they are designed for long span applications with greater potential for usable roof space. Flat, pitched and mansard roofs may also be designed using standard steel components. Special roof trusses have been developed which provide an 'attic' or open roof structure with modestly sized components and minimal self-weight. Alternatively, open roofs may be formed by spanning light steel purlins between closely-spaced cross-walls.

Where roof truss/joist centres do not coincide with the light steel studs in the supporting wall frame, a spreader beam of adequate strength and stiffness must be used to transfer the vertical load from the roof into the wall.

8.1 Loading on roofs

Permanent load: Concrete or clay roof tiles weigh approximately 0.5 kN/m^2. Natural slates can be heavier. The permanent (dead) loads on plan should also take account of the slope of the roof. Other finishes, such as battens, felt insulation and plasterboard should be included (allow 0.2 kN/m^2).

Imposed load: This load depends on whether the roof space is occupied. A minimum imposed load of 0.25 kN/m^2, plus any well defined loads, such as water tanks, is used in design. For occupied roof space, an imposed load of 1.5 kN/m^2 is used. On the roof an imposed load of 0.6 kN/m^2 is used.

Snow load: A basic snow load of 0.6 kN/m^2 on the roof is used in England and Wales. This can be reduced for roof slopes greater than 30°. BS EN 1991-1-3 requires a separate check where snow may build up on the roof. The intensity of snow is a function of location and altitude of the building.

Wind load: In the UK National Annex (NA) to BS EN 1991-1-4, wind pressures are based on the fundamental basic wind velocity (the 10 minute mean wind velocity) which depends on the geographical location and is modified for various effects, including altitude and proximity of other buildings. Negative pressures due to wind uplift are applied normal to the plane of the roof slope.

Actions are combined using the partial load factors and load combination relationships as set out in in the UK NA to BS EN 1990. Serviceability limits are not normally critical, except for habitable uses of roofs.

8.2 Pitched roofs

Pitched roofs may be designed in cold or warm construction, depending on whether the enclosed roof space is to be habitable. Typical ridge, eaves and verge details for warm roofs which utilise truss or purlin-based roof constructions are presented in the following sections.

8.2.1 Roof trusses

An 'attic' or open roof truss, as shown in Figure 8.1, creates useable roof space, uses fewer components than a Fink truss and provides an economic solution, since it utilises the high bending strength of the steel members. Additional useable space is provided at a minimal extra cost.

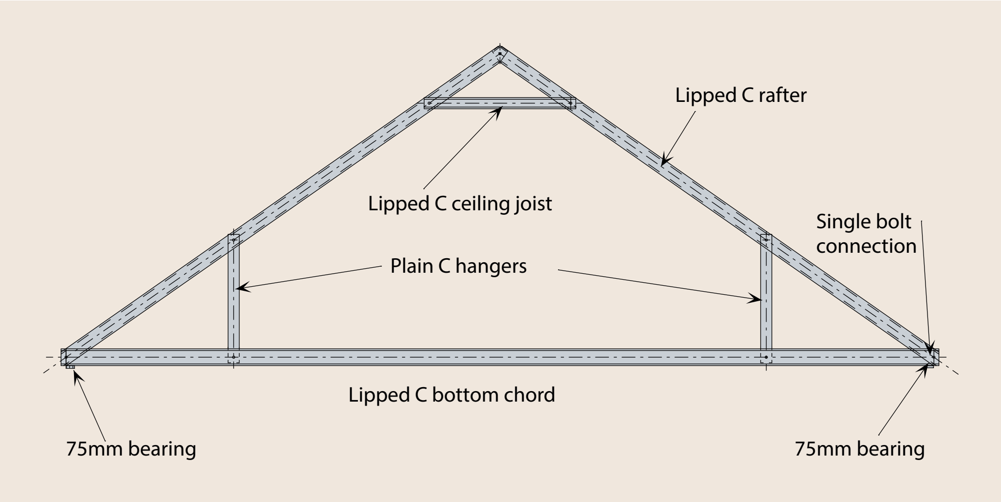


Figure 8.1 Open roof structure using C sections

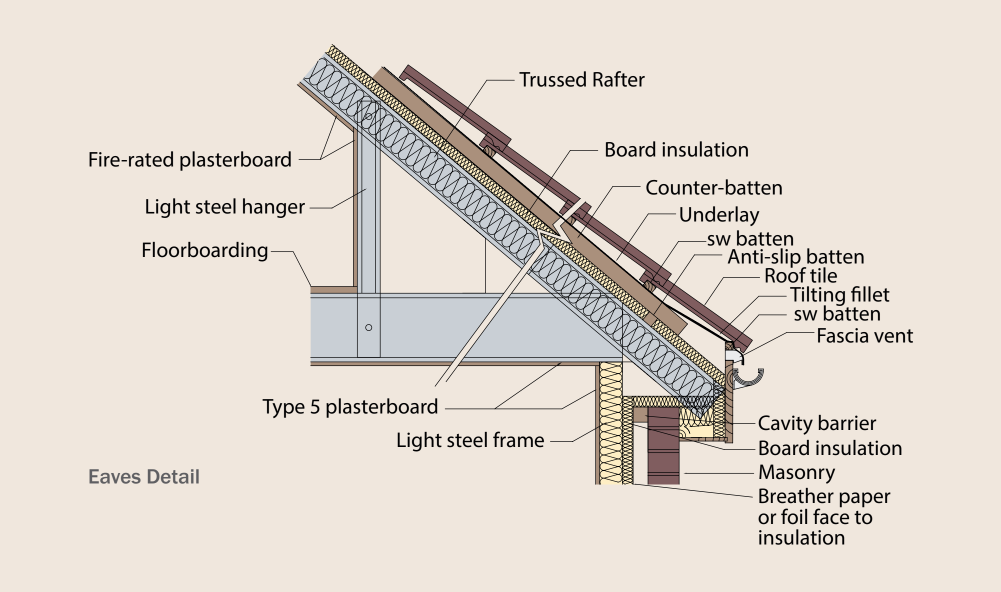


Figure 8.2 Attic truss – Eaves, verge and ridge details for 'warm roof'

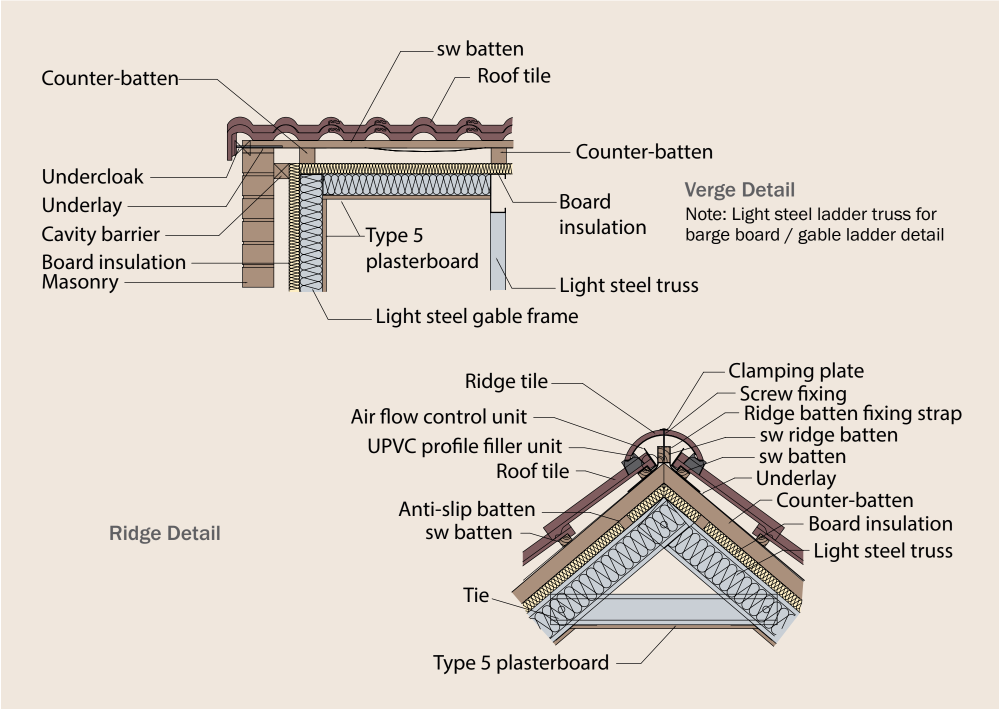


Figure 8.2 (continued) Attic truss – Eaves, verge and ridge details for 'warm roof'

The attic truss consists of six components: Two rafters, a bottom chord, a ceiling joist and two vertical hangers, which are all in the form of lipped C sections with a single bolt at each connection. The bottom chord supports the occupied floor. The trusses are placed at 600 mm maximum spacing and are battened and tiled in a conventional manner, as shown in Figure 8.2. Since the roof space is designed to be habitable, the insulation is located above the light steel rafters; anti-slip battens and counter battens are incorporated as shown.

8.2.2 Mansard roofs

Mansard roofs may be created to increase the useable roof space. A mansard has a steep portion, which generally incorporates 'dormer' windows, and a shallow pitch upper portion over the space. A 'warm roof' is achieved by the details illustrated in Figure 8.3.

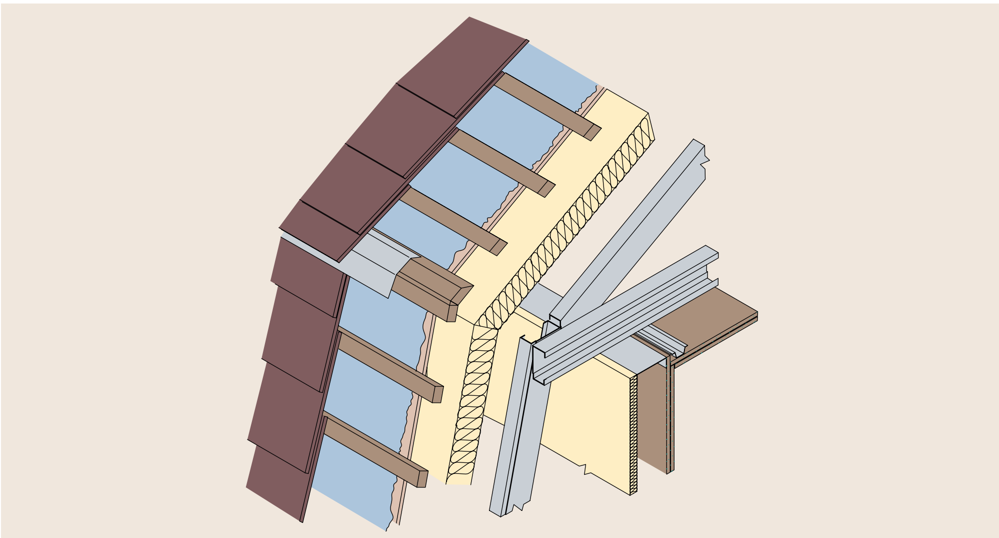


Figure 8.3 Mansard details

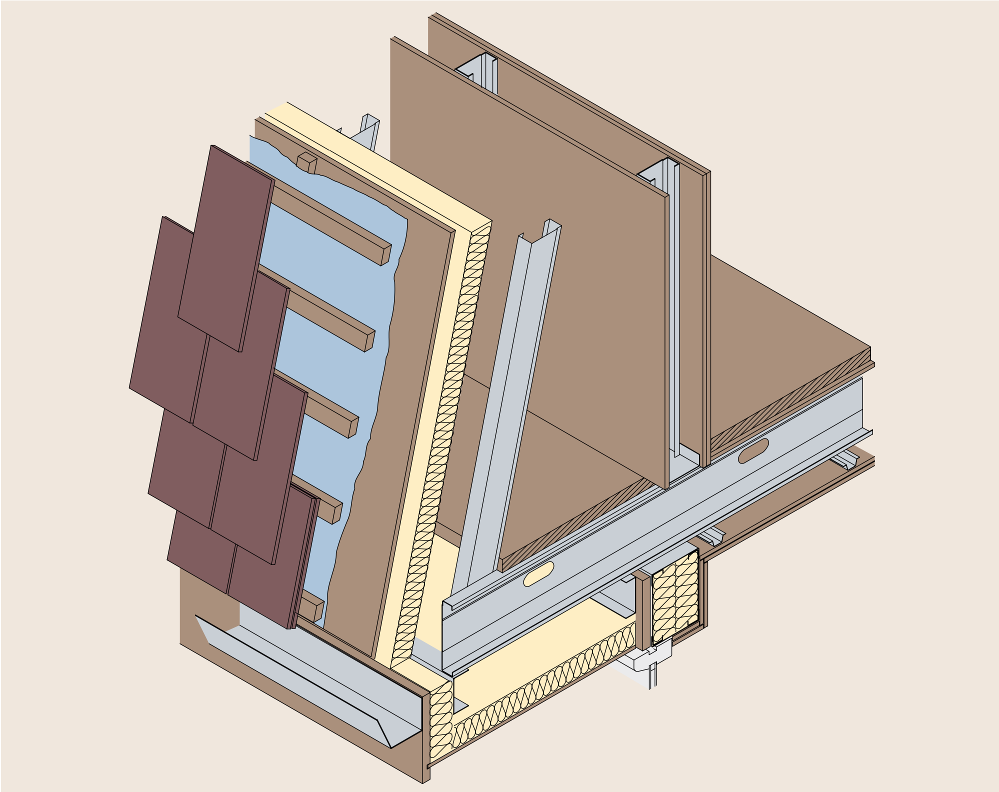


Figure 8.3 (continued)
Mansard details

8.2.3 Purlins supported by trusses

An economic approach for larger buildings is to use light steel 'Fink' trusses placed at much wider centres and to span steel purlins between them. However, roof tiles and plasterboard ceilings should be supported on battens at close centres and to achieve this with purlin-based systems, secondary members such as counter-battens are required (see Figure 8.4 and Figure 8.5). Ceiling and floor boarding can be supported from joists spanning between the trusses.

As an alternative to counter-battens, sarking board (the favoured solution in Scotland), profiled roof sheeting or structural liner trays can be used to provide support to the roof tiles.

8.2.4 Purlins supported on cross-walls

Timber rafters (typically 100 mm × 38 mm at 600 mm centres), or roof sheeting, can be laid over and fixed to the purlins and can support traditional felt and battens. Profiled steel sheeting or structural liner trays may be used to span across the purlins.

The details appropriate to open roof systems with trapezoidal decking or structural liner trays are shown in Figure 8.4.

8.2.5 Panel roofs

In domestic applications, panel roofs use an insulated sandwich board spanning from eaves to ridge or intermediate purlins. The panels are provided with counter battens attached for the support of felt, battens and tiles. The details appropriate to purlin roofs with insulated panels are shown in Figure 8.5.

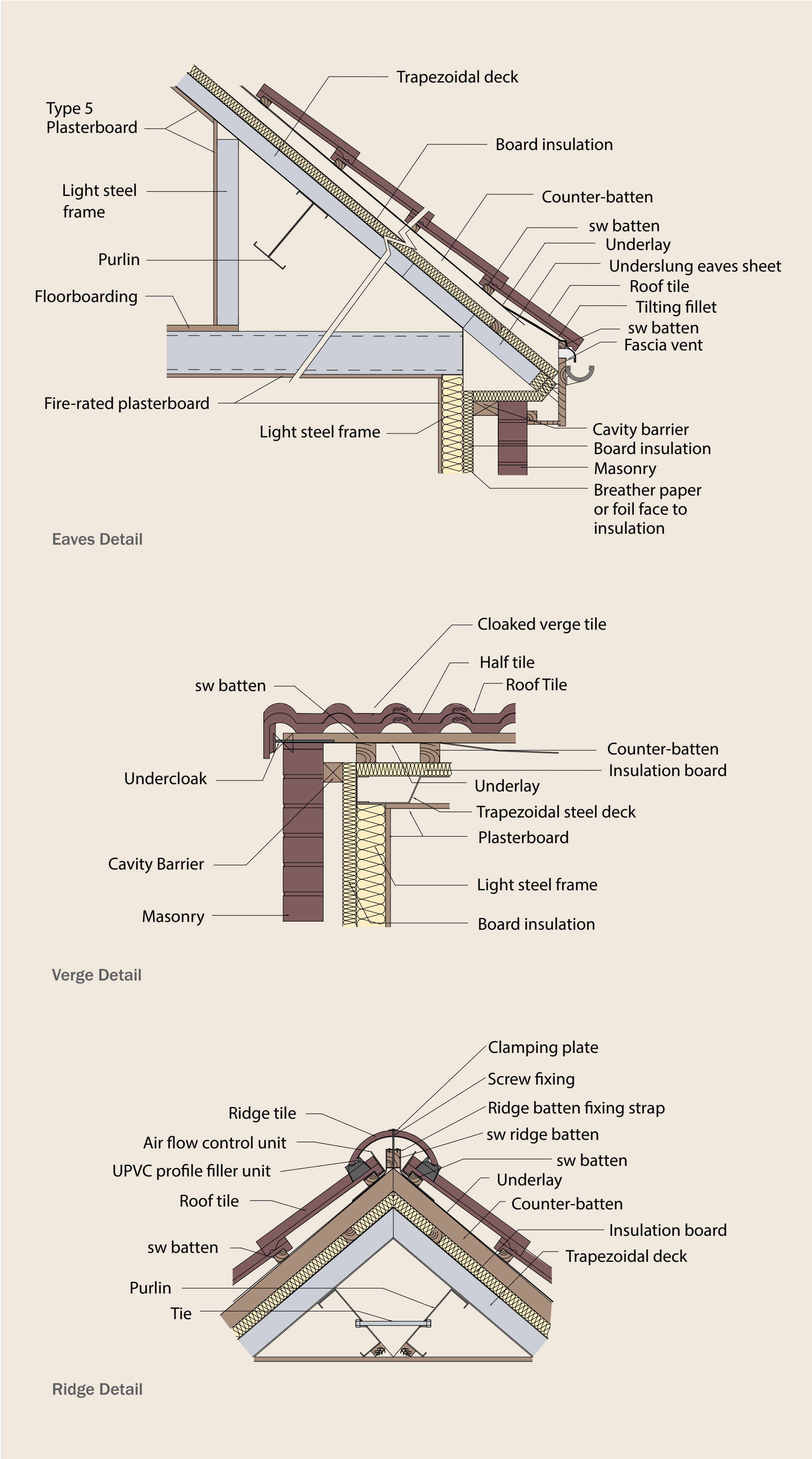


Figure 8.4
Purlins and structural liner tray – Eaves, verge and ridge details for warm roof

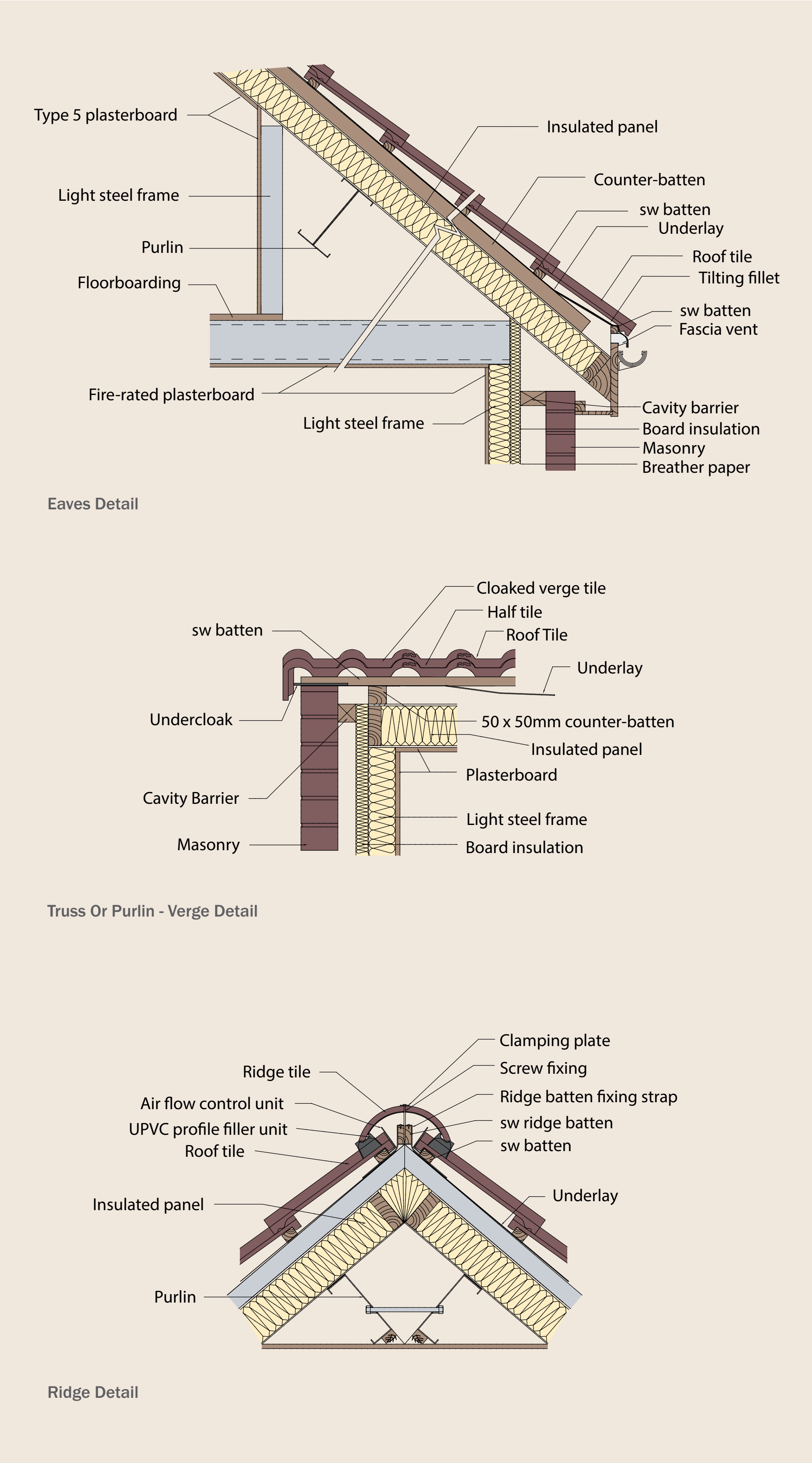


Figure 8.5
Purlins and insulated panels – eaves, verge and ridge details for warm roof

8.3 Construction details

8.3.1 Eaves

Several eaves styles can be achieved with light steel sections. If a 'warm roof' is specified, the insulation should completely enclose the light steel sections, as shown in Figure 8.3 to Figure 8.5. An alternative approach is to cut the steel members short at the eaves to minimise the risk of cold bridging. Timber inserts are then used to extend the rafter members and to attach the barge boards, soffits and guttering.

For 'cold roofs', it may be necessary to introduce a timber wall plate to isolate the light steel trusses thermally from the stud walls.

8.4 Flat roofs

Flat roofs constructed from light steel components do not suffer from the shrinkage and creep problems associated with timber roofs. However, there are certain principles to be followed to ensure that other problems do not occur. For example, where steel decking forms a flat roof, a minimum fall of 1:40 should be introduced to ensure that any moisture runs off. To avoid local ponding of rain water, the pitch may need to be increased to overcome the effective reduction in roof angle caused by the deflection of long span roof purlins or decking.

It should also be noted that the roof provides lateral support to the walls and therefore may be required to have the same fire protection as the walls, when they provide a separating function.

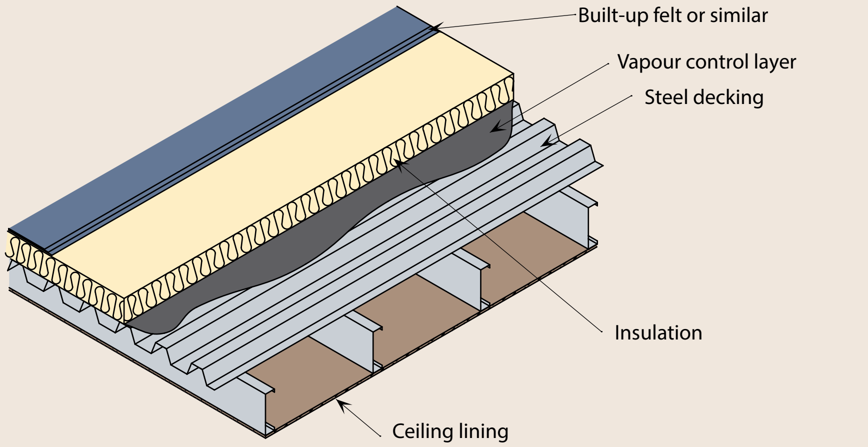
8.4.1 'Warm deck'

In 'warm deck' construction, the insulation is laid above the decking and a vapour control layer is placed between it and the decking (see Figure 8.6). The roof structure is therefore kept warm and, provided that the heating is reasonably constant, this eliminates the risk of condensation in the roof void. Air flow would cool the void and, therefore, this form of construction must not be ventilated.

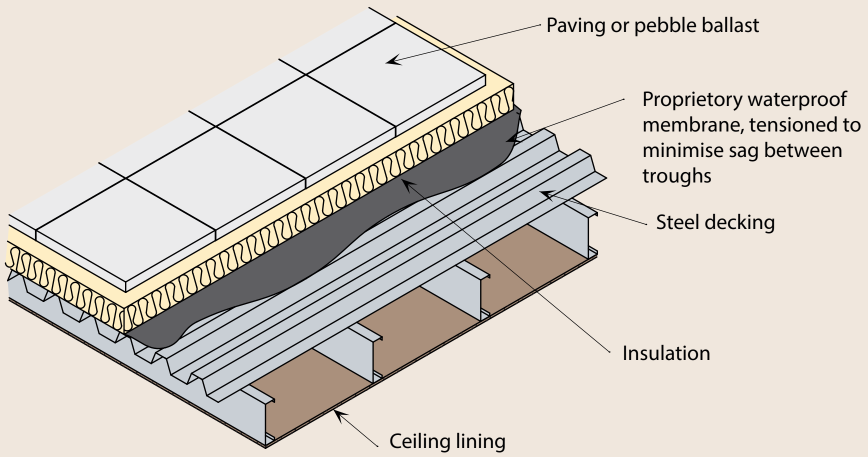
8.4.2 'Cold deck'

In this form of construction, the insulation is placed immediately above the ceiling. In cold weather, the temperature of the deck and the roof void is lower than that of the internal spaces, making it susceptible to condensation from moist air penetrating the void. A vapour control layer should therefore be included beneath the insulation, and good ventilation to the roof void should be provided (see Figure 2.9 c)).

Good air flow requires at least 50 mm of clear space between the top of the insulation and the roof deck and the equivalent of a continuous 25 mm opening along both sides of the roof. Cold roof designs require careful detailing; light steel components should be used with caution in these applications.



a. **Warm deck sandwich design**



b. **Inverted roof**

Figure 8.6
'Warm deck' construction in roofs

SERVICES

In light steel framing used in housing, it is standard practice to provide holes at regular centres through the webs of light steel joists and studs for the incorporation of service cables and pipes. Floor boarding can be installed in advance of the services and provides a safe working platform at an early stage. Services are installed from below and the risk of cutting notches out of the section is eliminated. This is different from traditional construction where the service installation in the floor is usually carried out from above and is complete before the floor boarding is laid.

9.1 Details for service openings in floors and walls

Figure 9.1 shows typical details of floor joists for service openings. These generally allow small diameter pipes and electrical cables to be threaded through the structure, although the lattice joist can accommodate much larger services. Rubber or polyethylene grommets that line the inner face of the openings are used to prevent damage to cables and eliminate contact between the steel and other metals which could cause bimetallic action, leading to possible corrosion.

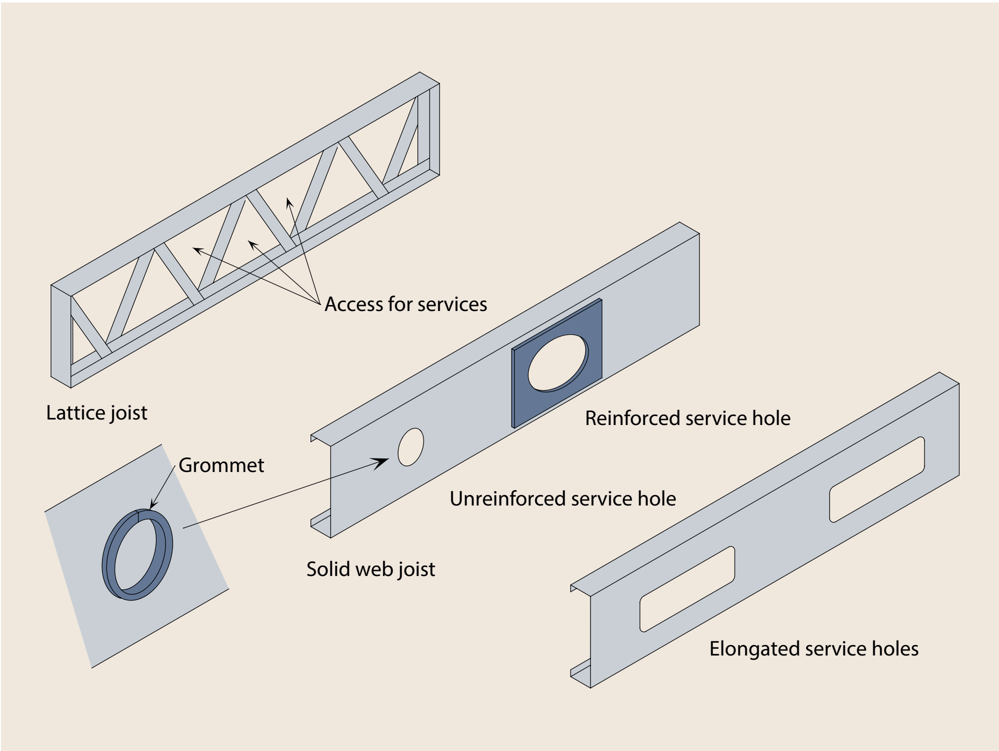


Figure 9.1 Service penetrations in joists

As an approximate guide, the maximum depth of unstiffened rectangular hole or slot in a light steel framing member, should not exceed 40% of the overall depth of the member. Its length should be less than three times the depth of the hole. The diameter of circular holes should not exceed 60% of the depth of the member. Unstiffened holes should be at least the depth of the member apart and should be at least 1.5 times the depth away from the end of the member. In these cases, the holes have negligible influence on the structural properties of the member. Larger openings in the steel joists and studs may require some reinforcing by an additional steel plate.

Cutting holes in the light steel webs on site is not recommended but, where necessary, the holes should be formed with specialist tools to minimise the risk of leaving rough edges and causing damage to the galvanized surface. The steel sections should never be cut by burning. Proprietary grommets and sleeves can be modified to fit non-standard penetrations.

Larger pipes are usually located in the spaces between or below the joists. Where latticed floor joists are used, the installation should be planned to allow the alignment of the diagonal lacings and thus service pipes, ducts and cables can be easily accommodated.

The electrical services design should bear in mind that electrical cables that are surrounded by thermal insulation have an increased risk of overheating and the cable rating should be selected to compensate. Generally, electrical services should be installed in accordance with BS 7671 [60].

Service penetrations in studs and an unacceptable notch detail are shown in Figure 9.2.

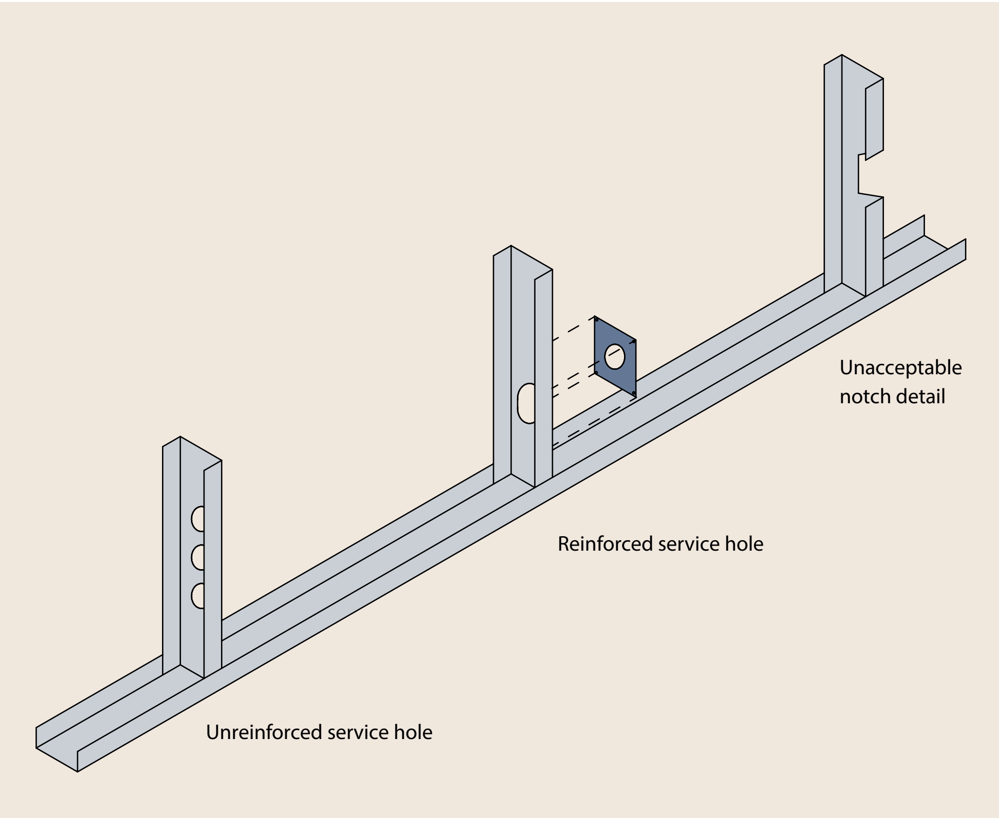


Figure 9.2
Service penetrations in studs

9.2 Separating and compartment walls and floors

It is advisable not to place plumbing services within separating or compartment walls, as any future access may damage the integrity of the walls and penetrations through the linings may affect their performance.

When vertical service ducts such as drainage pipes have to pass through compartment floors it will be necessary to take additional precautions to avoid compromising the fire and acoustic integrity of the compartment. Figure 9.3 illustrates how this should be accommodated. It is important to ensure that an effective fire barrier is maintained and that there is clearance between the service ducts and the steel structure, with effective flexible fire stopping around the services.

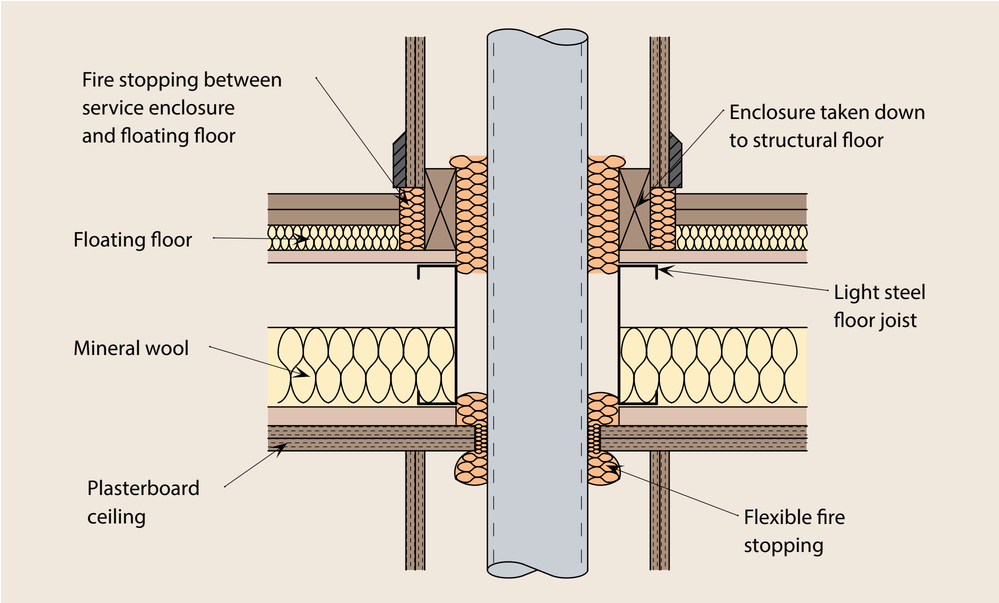


Figure 9.3 Detail of the trimming of vertical risers in separating / compartment floors

Any electrical fittings in separating walls should be protected at their rear with two layers of plasterboard and a mineral wool quilt, as illustrated in Figure 9.4.

In multi-occupancy accommodation with separating floor constructions, access to services through the floor is not practical.

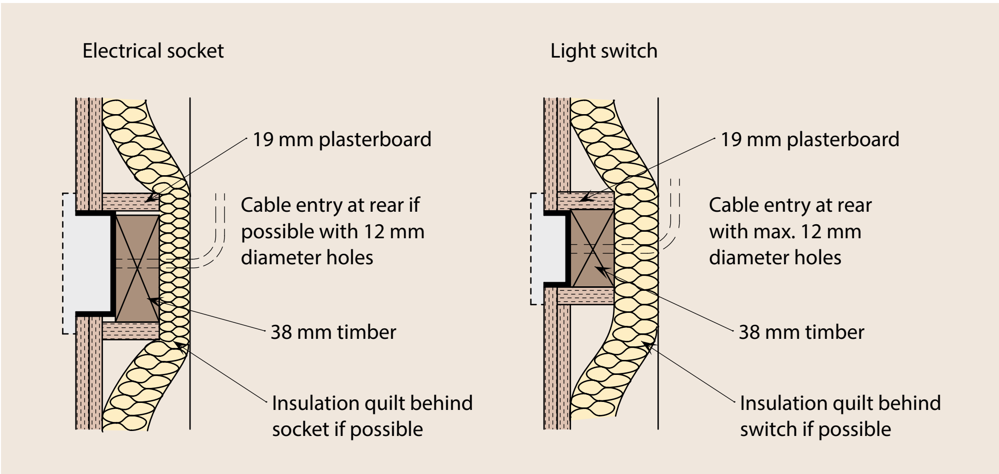


Figure 9.4 Detail of a typical electrical fitting

Figure 9.5 and Figure 9.6 show how services can be incorporated in a separating floor. The services are effectively installed in a duct above the structural floor within the acoustic insulation zone. Care must be taken not to compromise the acoustic insulation performance. Thus, it is important for the pipes to touch neither the floor finish nor the duct walls and base. The duct should be filled with resilient material, with some resilient material also being maintained beneath the duct. Sealant should be used to prevent air paths being formed. Any electric installation penetrating the plasterboard ceiling below should be detailed to prevent direct air paths through the plasterboard by sealing around any penetrations with flexible acoustic sealant.

Compartment floors and walls are required to minimise the risk of the spread of fire and can only be penetrated by services if the fire integrity can be maintained.

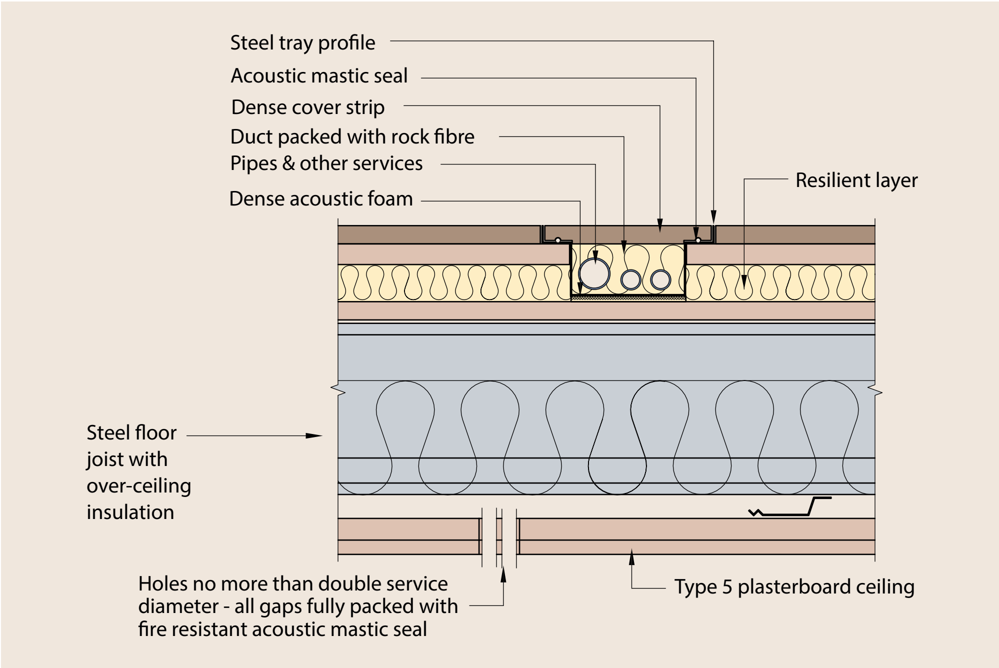


Figure 9.5
Detail of a service duct within the resilient layer of a separating floor

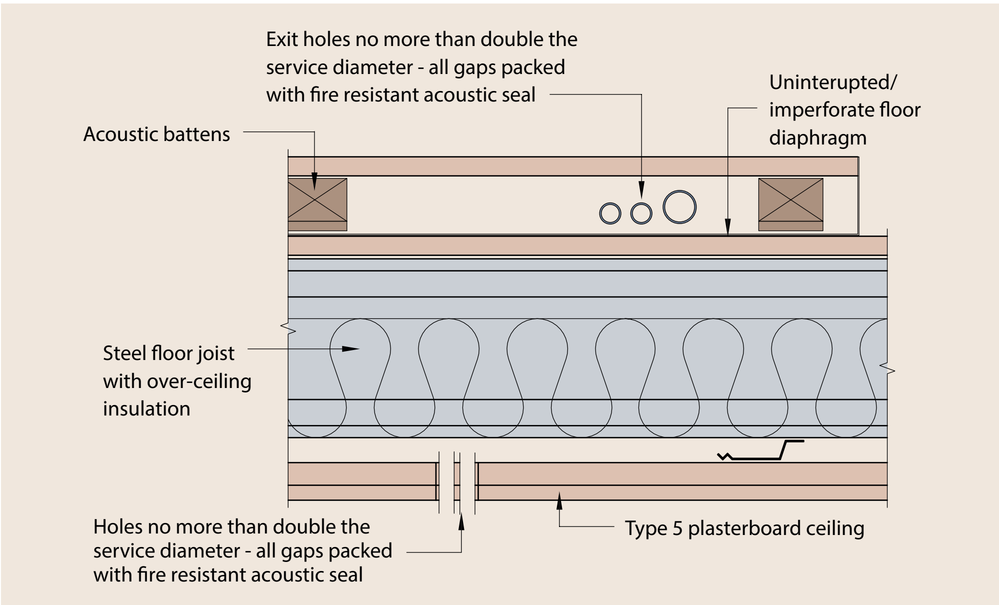


Figure 9.6
Detail of services integrated into a separating floor using acoustic battens to support the floor boarding

9.3 Installation of gas appliances

Domestic gas installations should be in accordance with BS 6400 [61]. The Institution of Gas Engineers and Managers publishes guidance on the installation of gas services to framed residential buildings. Generally, domestic gas installations can follow a conventional pattern. Gas entry must be detailed to avoid leakage into an unventilated void to minimise the risk of explosion.

Wall hung boilers can be used with balanced flues. Balanced flues or other ducts to central heating boilers and air-conditioning units and overflow pipes, may penetrate the external wall. The location of these horizontal penetrations should be planned to miss any structural diagonal bracing. Additional holes or slots must not be cut through any steel member without the prior approval of the structural engineer responsible for the overall design of the structure.

Furthermore, in multi-storey construction, where the external masonry finish has independent vertical support from the ground, adequate provision must be made for differential movement between the external masonry skin and any penetrations through it, such as balanced flues, that are rigidly fixed to the internal structure. This movement is due to the vertical expansion of the masonry that is in the opposite direction to the elastic shortening of the light steel walls. An oversized hole in the external finishes should be provided and sealed with a material, generally mastic, which will tolerate movement to prevent the ingress of water.

9.4 Attachment to walls

When heavy items, such as wall hung boilers or kitchen units are to be attached, additional light steel plates or noggins can be included to strengthen the stud walls. Furthermore, self-drilling self-tapping screws can be used to fix directly into the steel studs and joists. Lightly loaded fixings can be made to plasterboard walls with proprietary fixing devices, many of which are readily available. As an alternative, gypsum fibreboard can be used for wall linings, as this enables higher loads to be supported by fixings directly to the wall lining.

9.5 Lightning conduction

Provision for lightning conduction should be provided as for any other form of construction. The light steel framing is insulated externally and there is no guarantee of a continuous electrical pathway through the frame. Therefore the light steel frame should not be used as part of the lightning conduction solution without agreement with the manufacturer.

9.6 Mobile phone reception

Mobile phone reception is not affected adversely by light steel frame construction.

EXTERNAL WALL SYSTEMS

In multi-storey framed construction, it is now common practice to use light steel external wall systems to create a ‘rapid dry envelope’ supporting the external cladding. The use of light steel external wall systems may be applied to any type of framed construction in steel or concrete. Light weight, speed and ease of installation are important constructional benefits.

There are three generic types of light steel external wall systems:

- Infill walls
- Continuous walls
- Panelised systems.

10.1 Infill walls

Infill walling is the generic name given to external walls that are built between the floors of the primary structural frame of a building and which provide support for the cladding system. Infill walls do not support floor loads but they resist wind loads applied to the façade. Light steel infill walls using vertical C section studs are increasingly used within both steel and concrete-framed buildings, and have largely replaced masonry or timber alternatives.

The panels for infill walls are generally constructed from individual elements, which are cut to length and installed on site (so called stick-built). The panels fit between the elements of the primary structural frame, as shown in Figure 10.1.

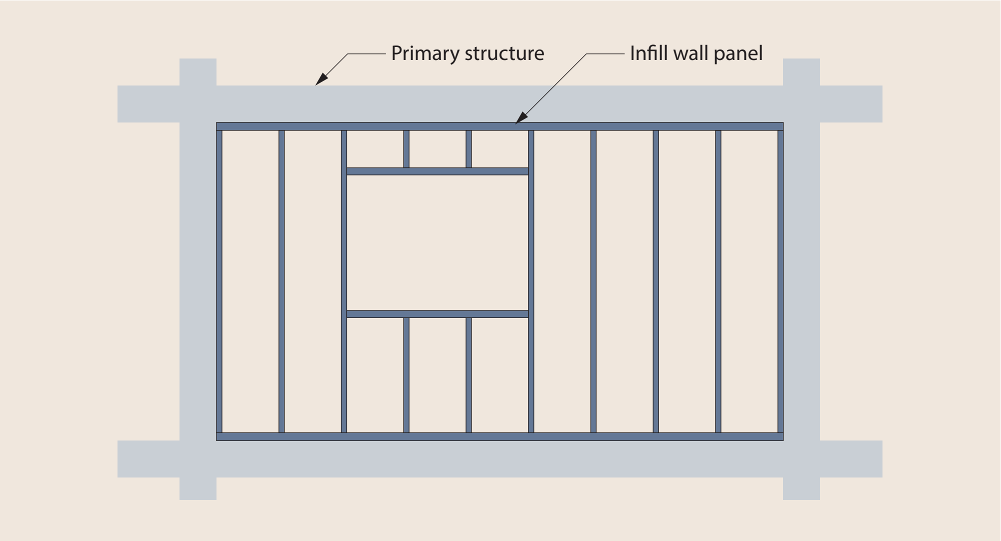


Figure 10.1 Typical infill wall panel within a steel or concrete primary structure

The panels consist of a bottom track attached to the floor and a top track attached to the underside of the floor above. Vertical light steel C sections are fitted between the top and bottom tracks, typically at 600 mm centres (or reduced to 400 or 300 mm where structural design requires closer spacing). The top track must include allowance for relative movement in-service between the wall panel and the floor above. In some cases, the panels may be constructed such that they project past the edge of the primary structure.

The benefits of light steel infill walls include:

- Rapid installation allows other activities within the building to proceed much earlier than would be possible with block-work infill walls.
- The construction process is 'dry', so that shrinkage and other drying out problems are eliminated.
- Design flexibility: tall walls up to 5 m can be readily achieved.
- Large windows, parapets and other architectural features can be incorporated within light steel infill walls.
- Excellent fire resistance: periods of up to 120 minutes can be achieved using multiple layers of fire resistant plasterboard.
- Light steel walls can achieve excellent acoustic insulation: over 60 dB when using double layers of plasterboard and insulating quilt between the vertical C sections.
- A high level of thermal insulation is provided by a variety of insulation boards that attach externally to the vertical studs to create a 'warm frame'.
- Light steel infill walls can be used to support a wide range of cladding systems.
- Light steel walls are much lighter and thinner than conventional block work walls; they do not apply heavy line loads to the floor.

10.2 Continuous wall panels

Figure 10.2 Bracket connection for continuous walling incorporating slotted connections

Continuous wall panels (also known as over-sail panels) which are a variant of infill panels, are placed externally to the primary structural frame, rather than between the floors as in infill walls (Figure 10.2). Continuous walling systems are particularly suited to situations where cladding materials are sensitive to differing movement of the main frame. Adequate base support must be provided to accommodate vertical loading from the cladding. As for the infill system, openings in the building façade and a variety of cladding options can be accommodated. The continuous external wall system consists of vertical light steel C sections and bracket connections to fix them to the primary frame. Allowance for movement of the primary frame must be incorporated into the connections, usually by use of slotted connections (Figure 10.2).

10.3 Design of Infill walling

Infill wall systems are designed to resist wind loading applied to the façade. The wind loading increases with building height, and in some designs, it may be economic to vary the spacing or thickness of the C sections with height. The C sections span between the floor and underside of the edge beam and slab, and typically their span is 2.5 to 3.5m. In residential buildings, the C sections are typically 100mm deep in steel thickness of 1.2 mm for walls up to 2.7m high to 1.6mm for taller walls, depending on the wind loading. In non-residential buildings, the C sections are typically 150 mm deep in steel thickness of 1.2 mm for walls up to 3.5 m high or 1.6 mm for taller walls. Pairs or triple C sections are generally provided adjacent to large openings, and in some cases, it may be more economical to use thicker C sections next to large windows.

The top and bottom 'track' C sections are fixed to the floor slab and edge beams and provide for relative vertical movement of up to 20 mm. The top track is generally about 70 mm deep and 2 mm thick so that the flanges can transfer the required bending effects when the gap at the top of the C section is 20 mm. The bottom track is typically 1.2 mm thick.

For light weight cladding systems, such as insulated render, sheathing boards are generally attached to the outside of the C sections (but not to the top track) and provide weather resistance and add to air-tightness. Heavier cladding systems, such as tiles, are often supported by secondary rail systems that are attached through the sheathing boards to the C sections. Brickwork is laterally restrained by the wall ties connected to furring runners that are attached to the C sections, but the self-weight of the wall is supported by stainless steel angle and brackets systems that are directly attached to the edge beams.

More guidance on design and detailing of infill wall systems is given in SCI publication ED017 [6].

10.4 Panelised system

The panelised system uses prefabricated light steel wall panels, often with insulation and boards attached off-site. These are craned into position and fixed to the primary structural frame (see Figure 10.3). The panels are designed for the temporary lifting forces due to their self-weight and the in-service wind loading.

Light steel external wall systems are typically installed by companies approved as installers by the external wall system supplier. The installers will generally be working as sub-contractors to the main contractor who is responsible for the construction of the building.

Figure 10.3
Typical prefabricated panelised external wall system

10.5 Cladding options

Light steel infill walling systems can be used with a range of cladding types including 'heavy' cladding, such as brickwork, or 'light-weight' claddings such as insulated renders and rain-screens.

10.5.1 Brickwork Cladding

Brickwork can be ground-supported or supported by the primary structural frame at each floor level. The infill walling system provides only lateral support to the brickwork. Lateral support is provided via wall ties connected through the insulation back to the vertical studs of the light steel system. Wall ties must be provided at the correct spacing and additional ties will be required around openings.

10.5.2 Insulated Render

Lightweight insulated render systems can be fully supported by infill walls. Insulated render system can be bonded directly to a sheathing board without a cavity or a small cavity can be included. Render systems vary in detail and application between manufacturers.

10.5.3 Rain-screen Cladding

Rain-screen cladding can be in the form of timber boards, metallic sheets or terracotta tiles attached to horizontal or vertical rails. In most uses of rain–screen cladding, a sheathing board is attached to the external face of the infill wall to provide weather resistance, both in the construction and in-service conditions. See Figure 10.4.

The sheathing board also adds to the air-tightness of the façade. It may be in the form of cement particle board, calcium silicate board or, for insulated render applications, moisture resistant plasterboard.

Figure 10.4
Cedar cladding on light steel infill walling

(Image courtesy of Metek Building Systems)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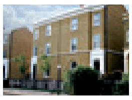
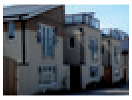
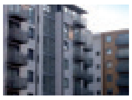
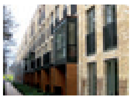
	Cover	Courtesy of Fusion Building Solutions Ltd.
	vi	Courtesy of BW Industries Ltd.
	42	Courtesy of Kingspan
	54	Courtesy of Metek UK Ltd.
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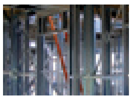
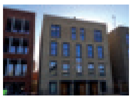
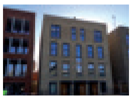
	105	Courtesy of Fusion Building Solutions Ltd.
	112	Courtesy of Ayrshire Metal Products
	118	Courtesy of Metek UK Ltd.

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LIGHT STEEL FRAMING IN RESIDENTIAL CONSTRUCTION

This publication is an update to an earlier SCI guide on the use of light steel framing in residential construction. It has been updated to reflect the latest design standards and building regulations, and current construction methods. The guidance addresses all the criteria that need to be considered and explains how these can be achieved with light steel framing. The publication includes:

- Detailed design information on structural design and robustness, serviceability of floors, thermal and acoustic performance, and fire resistant design. Where appropriate, the design guidance presented is in accordance with Eurocodes.
- Construction practice and detailing of light steel frames and their interfaces with other materials and components. The information is generic for light steel framing and focuses on general construction principles.
- Common applications of light steel framing, methods of construction and achievable benefits.

Complementary titles

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Design of light steel sections to Eurocode 3

P262
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