SYSTEM DESIGN PRINCIPLES

This section provides guidance on the principles of system design. Reference is made to relevant regulatory requirements and International Standard Organisation (ISO), European (EN) and British (BS) standards. It considers various principles from a building theory and practical perspective.

Fire

Fire performance includes fire resistance (compartmentation), fire protection (structural steelwork) and reaction to fire. British Gypsum test solutions to the most up to date BS EN test standards. Our technical specifications, detailed drawings and technical advice is based on the latest BS EN test standards. BS 476 Parts 20-23, while accepted in AD-B for maintaining older buildings, is not recommended for new or future schemes. **See page 2.3.**

Acoustics

Building acoustics includes both sound insulation (airborne and impact) and sound absorption. A key design aspect is how the drylined building element interacts with the associated structure. If this is ignored, the performance of the element can be completely nullified. The key factors that are covered include gap sealing, why it is preferable to take the partition through to the structural soffit, and why it is important to design out flanking sound transmission.
See page 2.7.

Robustness

Consideration needs to be given to the robustness of drylining systems, particularly if required to resist crowd pressure, impacts, abrasions and wind loading. The stiffness of a partition is critical to this and is therefore considered when determining the recommended maximum height.
See page 2.25.

Service installations

Drylining elements need to be fully compatible with building services such as electrical, plumbing, heating and ventilation etc. This means that service installation should be fully assessed at the design stage to ensure that the layout of the services is compatible with the ceiling module or location of stud work. Furthermore, the weight of fixtures and fittings must be considered at the design stage to ensure that the appropriate system with correct detailing is specified. **See page 2.29.**

Thermal insulation

Thermal comfort within a building is primarily dictated by the thermal insulation (heat loss), airtightness, heating regime and ventilation, together with appropriate vapour control to reduce risk of condensation. Carbon dioxide performance and fabric energy efficiency are measures used to optimise the performance of a building. **See page 2.37.**

Fire
System design principles

Legislation, guidance and insurance

Building Regulations – Fire safety
Building Regulations Approved Document B (AD B) and Technical Handbook (Fire - section 2) are a series of approved documents that provide practical guidance on meeting the fire safety requirements of the Building Regulations 2000 (England and Wales) and Building (Scotland) Regulations 2004 respectively.

The documents are divided into two parts, AD B Volume 1 and Technical Handbook – Domestic (Fire - section 2) covers dwelling houses and AD B Volume 2 and Technical Handbook – Non-Domestic (Fire - section 2) covers buildings other than dwelling houses.

The documents classify the use of a building into purpose groups and specify minimum periods of fire resistance to be achieved by the building elements. The periods of fire resistance vary according to the use and the size of building. The greater the fire hazard a building presents, then the greater the period of fire resistance required to protect the elements within the building. The materials used to form the internal surfaces of the building are also controlled to reduce the risk of fire growth and internal fire spread.

Healthcare buildings
Hospitals and healthcare environments by their very nature contain people who are at risk from fire. Health Technical Memorandum (HTM) 05 series (England and Wales) and Scottish Health Technical Memorandum (SHTM) 81 series documents cover the fire safety design of healthcare facilities. These documents provide guidance on the standards of fire safety expected in healthcare facilities and include recommendations on internal fire spread, elements of structure, compartmentation, fire hazard areas, hospital streets, penetrations, protected shafts, ceiling membranes, cavity barriers and fire-stopping.

Educational buildings
The design of fire safety in schools is covered by Building Bulletin 100 (England and Wales) and Fire Safety in Schools (Scotland). The respective Building Regulations will typically be satisfied where the safety guidance in these documents is followed.

Loss Prevention Council (LPC) Design Guide for the Protection of Buildings – Commercial and Industrial
Provides guidance on the general principles of passive fire protection - contribution to fire growth, fire resistance, compartmentation and external fire spread. It also provides guidance on 'active' fire protection such as sprinklers and fire alarms. It presents insurers with standards of fire protection for industrial and commercial buildings. It is intended to assist building designers and other professional advisors in reconciling the provisions of national legislation standards with the recommendations of the insurance industry. It also gives guidance regarding how fire protection measures can be used to augment passive protection.

Fire protection for structural steel in buildings, Association for Specialist Fire Protection (ASFP) Yellow Book
Publication prepared by the ASFP. Presenting the theory behind, and methods for, fire protection of structural steelwork to comply with Building Regulations. It provides a comprehensive guide to proprietary materials and systems, all of which are manufactured, marketed by members of ASFP.

Principles of fire performance

Fire growth
The choice of materials for walls and ceilings can significantly affect the spread of fire and its rate of growth, even though they are not likely to be the materials first ignited. The specification of linings is particularly important in circulation spaces where surfaces may offer the main means by which fire spreads, and where rapid spread is most likely to prevent occupants from escaping.

Two properties of lining materials that influence fire spread are:

- The rate of flame spread over the surface when it is subject to intense radiant heating
- The rate at which the lining material gives off heat when burning

Compartmentation
The spread of fire within a building can be restricted by sub-dividing it into compartments separated from one another by walls and/or floors of fire resisting construction.

The two key objectives are:

- To prevent rapid fire spread, which could trap occupants within the building
- To reduce the chance of fires becoming large, which are more dangerous - not only to occupants and fire service personnel, but also to people in the vicinity of the building

The appropriate degree of sub-division depends on:

- The use and fire loading of the building, which affects the potential for fires and their severity, as well as the ease of evacuation
- The height to the floor of the top storey in the building, which is an indication of the ease of evacuation and the ability of the fire service to intervene effectively

Fire
System design principles

Structural fire precautions

Premature failure of the structure can be prevented by fire protecting loadbearing elements.

The purpose in providing the structure with fire resistance is:

- To minimise the risk to the occupants, some of whom may have to remain in the building for some time (particularly if the building is a large one), while evacuation proceeds
- To reduce the risk to fire fighters engaged on search and rescue operations
- To reduce the danger to people in the vicinity of the building who may be hurt by falling debris, or because of the impact of the collapsing structure on other buildings

Fire limit state
In structural design terms, fire is considered to be an accidental limit state, i.e. an accidental occurrence, and one for which the structure must not collapse. Loads and their factors of safety used in design at the fire limit state reflect the low probability of occurrence.

Typically, structural members that are designed to be fully stressed under normal conditions would be subject to a load ratio of 0.5 to 0.6 under fire conditions. Within this book, loadbearing floors and partitions are quoted with respect to a stated load ratio. Many constructions have been tested at a conservative load ratio of 1.0 (100%) despite the fire state being an accidental load.

Structural behaviour of timber in fire
Timber has a low thermal expansion coefficient, which minimises the possibility of protective layers and charred materials becoming displaced. It also has a low thermal conductivity, which means that undamaged timber immediately below the charred layer retains its strength. Generally, it may be assumed that timber will char at a constant rate when subjected to the standard heating conditions of the test furnace. The rate of reduction in the size of structural timber can be taken as 15mm to 25mm (depending on species) in 30 minutes for each face exposed; different rates apply where all faces are exposed. The undamaged timber can be assessed for structural stability using standard design guides in conjunction with stress modification factors.

For partitions tested with high load ratios it should be noted that when the timber is exposed to fire, the exposed face will shrink causing differential thermal movement. This can be important for axially loaded sections, as it introduces a degree of eccentricity, which may cause a loss of loadbearing capacity.

Structural behaviour of steel in fire
Steel generally begins to lose strength at temperatures above 300°C and eventually melts at about 1500°C. Importantly for design, the greatest rate of strength loss is in the range of 400°C to 600°C.

Using fire design codes such as the Structural Eurocodes EC3-1.2 and EC4-1.2 (designated BS EN 1993-1-2 and BS EN 1994-1-2), the load on the structure at the time of the fire can be calculated by treating it as an accidental limit state. If used, this will allow designers to specify to the fire protection contractor a limiting or failure temperature for a given structural section. The fire protection contractor will then be able to use the required thickness of material to ensure that the steel section does not exceed this temperature within the fire resistance period. This process could be simplified by the designer specifying a maximum steel temperature, based on the worst case, for all beams or columns on one floor level.

Buildings that are not primarily used for storage, e.g. offices, residential units, schools and hospitals, have a high percentage of non-permanent loads. For this type of building, the structural Eurocode BS EN 1991-1-1 assumes that a proportion of the design load will not be present at the time of the fire. Other types of buildings, such as warehouses and libraries, are primarily used for storage, so a high percentage of the load is permanent. The codes allow for no reduction in design load for the fire condition.

The fire testing standards effectively base the failure criteria for loadbearing elements on strength. However, beams should be designed at the fire state limit as well at in the cold state limit.

Columns are frequently designed so that a single length will be two or three storeys high. The lowest storey will be loaded; the highest and the upper storey will be lightly loaded. In buildings with a degree of non-permanent load (in terms of duration and magnitude), the load ratio of the structural members is unlikely to be greater than 0.6. In storage buildings, where the majority of load is permanent, the load ratio would normally be higher, but is unlikely to be greater than 0.65.

In steelwork encasement systems (Section 3), the thicknesses of protection required are specified for design temperatures of 550°C, unless otherwise stated. It is the responsibility of the design engineer, using design codes such as BS EN 1993-1-2, to specify the appropriate limiting steel temperatures.

The loss of strength of cold-formed steel at elevated temperatures exceeds that of hot-rolled steel by between 10% and 20%. Expert advice should be sought in determining the strength reduction factor at the limiting temperature.

Fire
System design principles

Why gypsum is so effective in fire

Our plasters, plasterboards and specialist boards provide good fire protection due to the unique behaviour of gypsum in fire. When gypsum protected building elements are exposed to fire, dehydration by heat (calcination) occurs at the exposed surface and proceeds gradually through the gypsum layer.

Calcined gypsum on the exposed faces adheres tenaciously to uncalcined material, retarding further calcination which slows as the thickness of calcined material increases. While this continues, materials adjacent to the unexposed side will not exceed 100°C, below the temperature at which most materials will ignite, and far below the critical temperatures for structural components. Once the gypsum layer is fully calcined, the residue acts as an insulating layer while it remains intact.

Gypsum products are excellent performers in terms of reaction to fire, as the endothermic hydration reaction requires energy to be taken from the fire, so gypsum is a negative calorific contributor.

Fire resistance test standards

Building Regulations and supporting documentation require elements of structure and other building elements to provide minimum periods of fire resistance, expressed in minutes, which are generally based on the occupancy and size of the building.

Fire resistance is defined in the ability of an element of building construction to withstand exposure to a standard temperature / time and pressure regime without loss of its fire separating function or loadbearing function or both for a given time.

The fire separating function of a construction is defined as the integrity and insulation performance.

- Integrity is the ability of a separating element to remain in tact, resisting the occurrence of holes, gaps or cracks through which flames and hot gases could pass and sustained flaming on the unexposed face.
- Insulation is the ability of a separating element to restrict the temperature rise of the unexposed face to below specified levels.
- Loadbearing function is the ability of the loadbearing element to support its test load without deflecting beyond specified limits.

EN fire resistance test standards

The Construction Products Regulation (CPR) within European legislation is designed to enable free trade across Europe in construction products. To enable free trade, harmonised test standards for technical performance are required. The area of technical performance most affected by this requirement is fire performance.

Fire resistance methods used across Europe were similar but the severity of furnaces varied due to factors such as different fuel sources and furnace geometry. To improve consistency between different furnaces, plate thermometers were introduced to measure the heat flux to which samples are exposed. The use of plate thermometers means the EN fire resistance tests can be more severe than the superseded BS tests, especially in the first 30 minutes.

EN fire resistance test standard also imposes strict rules governing the use of tests to cover specific end use scenarios (field of application). This restricted field of application has most effect on partitions that are built with heights above 4m, as they may need to have enhanced levels of fire protection.

To claim up to 3m, the partition has to be tested at a height of 3m in the fire resistance test. To claim up to 1m above the the tested height, the partition has to pass the test with partition height equal or greater than 3m and not deflect laterally by more than 100mm during the test.

To claim an increase in height greater than 1m, an extended application can be conducted following the design rules given in BS EN 15254-3. The standard permits either an engineering appraisal; where to claim up to 4m, the partition has to pass the test with a partition test height of 3m and not deflect laterally by more than 100mm during the test; or an increase height provided certain criteria given in the relevant section (of the standard) are satisfied. Where an extended application is not permissible the only alternative is to conduct a test at the height under consideration.

We have conducted an extensive series of EN fire resistance tests on partitions with heights up to 6m. Data from these tests are used within the performance tables. Insulation materials, such as glass and stone mineral wool, can affect the fire resistance of a partition. These materials can provide additional insulation / integrity performance but can also increase the thermal bow of the partition and therefore reduce the partition height that can be claimed. Consequently, there are instances where the partition height is reduced when a quilt is included within the cavity of the partition. It cannot be assumed that adding a quilt to a partition specification will not impact on its fire resistance.

Fire
System design principles

EN fire resistance and its application to British Gypsum systems

The EN fire resistance periods claimed for systems in this document are evaluated in accordance with the relevant EN fire resistance test standards.

- BS EN 1364-1
  Specifies a method for determining the fire resistance of non-loadbearing walls.
- BS EN 1365-1
  Specifies a method for determining the fire resistance of loadbearing walls.
- BS EN 1365-2
  Specifies a method for determining the fire resistance of loadbearing floors and roofs.
- BS EN 1364-2
  Specifies a method for determining the fire resistance of non-loadbearing ceilings.
- BS EN 13381-4
  Test methods for determining the contribution to the fire resistance of structural members: Applied protection to steel members.
- BS EN 13381-1
  Test methods for determining the contribution to the fire resistance of structural members - Horizontal protective membranes
- BS EN 13381-2
  Test methods for determining the contribution to the fire resistance of structural members. Vertical protective membranes.
- BS EN 15254-3
  Extended application of results from fire resistance tests. Non-loadbearing walls - Lightweight partitions

British Gypsum systems are tested to the version of the standard current at the time. Typically there is no requirement to re-test solutions to the latest version. For information on which version was used for a particular specification, refer to the relevant report or assessment.

Unlike the EN test standards the BS test standards do not impose restrictions with respect to maximum partition height. Within the BS 476: Part 22 testing regime, the partition height in the fire state is not considered, and if a partition passes the fire test at 3m it is deemed to be suitable in fire resistance terms for any possible heights. Under the BS system, the cold state height would be the maximum height claimed regardless of the fire duration required. It is for these reasons that British Gypsum have decided to stop supporting the use of the outdated test standard.

Reaction to fire test standards

Reaction to fire is the measurement of how a product will contribute to the development and spread of a fire.

The choice of materials for walls and ceilings can be of critical importance when designing a building especially in spaces which occupants will use when escaping from a potential fire.

EN reaction to fire

The European Classification System (Euroclass), devised for the classification of 'reaction to fire', has been introduced as part of the ongoing harmonisation of European standards. Reaction to fire has traditionally been assessed using at least 30 different national standards across Europe. The Euroclass system includes tests designed to better evaluate the reaction of building products to fire.

The Euroclass system predicts the performance of building materials in a real fire more accurately than the British Standard classification system.

The Euroclass test methodology is built around the Single Burning Item (SBI) test method (BS EN 13823), which is an intermediate scale test to evaluate the rate of fire growth from a waste paper basket fire positioned in the corner of a room.

Other tests used in the classification system are the non-combustibility test (BS EN ISO 1182), heat of combustion test (BS EN ISO 1716) and direct flame impingement test (BS EN ISO 11925-2).

The overall reaction to fire performance of a construction product or building element is presented in a classification report in accordance with BS EN 13501-1. This report uses the results from the relevant test methods and determines the Euroclass category rating for the product.

Gypsum products are intrinsically fire safe products and generally fall into the higher Euroclass classifications. Plasterboard is subject to a 'classification without further test' decision. This means that any type of plasterboard can be classified as A2, so long as the paper grammage of the liner does not exceed 220g/m^2, the core of the board achieves a reaction to fire classification of A1 (non-combustible) and has a density greater than 800kg/m^3 for 9.5mm and 600kg/m^3 for 12.5mm or thicker.

All our plasterboard products manufactured in accordance with BS EN 520 are designated Euroclass A2. All our Glasroc products manufactured in accordance with BS EN 15283-1 are designated Euroclass A1.

System design principles

Acoustics
System design principles

Principles of building acoustics

Building acoustics is the science of controlling noise in buildings, including the minimisation of noise transmission from one space to another, and the control of noise levels and characteristics within a space.

Noise can be defined as sound that is undesirable, but it can be subjective and depends on the reactions of the individual. When a noise is troublesome, it can reduce comfort and efficiency. If a person is subjected to noise for long periods, it can result in physical discomfort or mental distress. Within homes, a noisy neighbour can be one of the main problems experienced in attached housing. It's estimated that up to 4 million people in Britain have had their lives disturbed by noisy neighbours.

The best defence against noise is to ensure that proper precautions are taken at the design stage and during construction of the building. The correct acoustic climate must be provided in each space, and noise transmission levels should be compatible with the building's usage. Retrofitted remedial measures taken after occupation can be expensive and inconvenient.

The term 'building acoustics' covers both sound insulation and sound absorption.

Sound insulation

Sound insulation is the term describing the reduction of sound that passes between two spaces separated by a dividing element.

In transmitting between two spaces, the sound energy may pass through the dividing element (direct transmission) and through the surrounding structure (indirect or flanking transmission). When designing for optimum sound insulation, it's important to consider both methods of transmission. The walls or floors, which flank the dividing element, constitute the main paths for flanking transmission, but this can also occur at windows, doorways, heating or ventilation ducts, for example.

The acoustic environment of the room and/or the building, and the ability to reduce or eliminate air paths in the vicinity of the sound reducing element, these include doorsets, glazing, suspended ceiling cavities, ductwork, etc. will have a significant effect on its performance.
For these reasons it is unlikely that figures quoted from laboratory test conditions will be achieved in practice.
When the background noise is low, consideration may have to be given to a superior standard of sound insulation performance in conjunction with the adjoining flanking conditions.

In any existing sound insulation problem, it is essential to identify the weakest parts of the composite construction

The Building Regulation requirements regarding the sound insulation of walls and partitions only relate to the transmission of airborne sounds. These include speech, musical instruments, loudspeakers and other sounds that originate in the air. In most cases, floors must also resist the transmission of impact sounds, such as heavy footsteps and the movement of furniture.

Indirect paths (flanking transmission)
Flanking sound is defined as sound from a source room that is not transmitted via the separating building element. It is transmitted indirectly via paths such as windows, external walls and internal corridors. Refer to figure 1 (page 2.8).

It is imperative that flanking transmission is considered at the design stage and construction detailing is specified so as to eliminate or at least to minimise any downgrading of the acoustic performance. The sound insulation values quoted in system performance tables are laboratory values and the practicalities of construction will mean that acoustic performances measured in the laboratory will be difficult to achieve on site.

One of the main reasons for this difference is the loss of acoustic performance via flanking transmission paths. Good detailing at the design stage will minimise this effect and optimise the overall levels of acoustic privacy achieved.

If designing for residential units, design advice on flanking details must be followed to maximise the possibility of achieving the specified acoustic performance. It is imperative that the design advice is followed, otherwise site sound insulation values may not meet the minimum standards required by Building Regulations and expensive remedial treatment will be required.

Small openings such as gaps, cracks or holes will conduct airborne sounds and can significantly reduce the sound insulation of a construction. For optimum sound insulation a construction must be airtight. Within masonry construction, most gaps can be sealed at the finishing stage using Gyproc SoundCoat Plus, Thistle plaster or Gyproc jointing compounds. At the base of the partition, gaps will occur, particularly when boards are lifted tight to the ceiling. Small gaps or air paths can be sealed with Gyproc Sealant.

For more information on flanking details, visit the Robust Details website robustdetails.com

Acoustics
System design principles

Acoustic performance of deflection head details

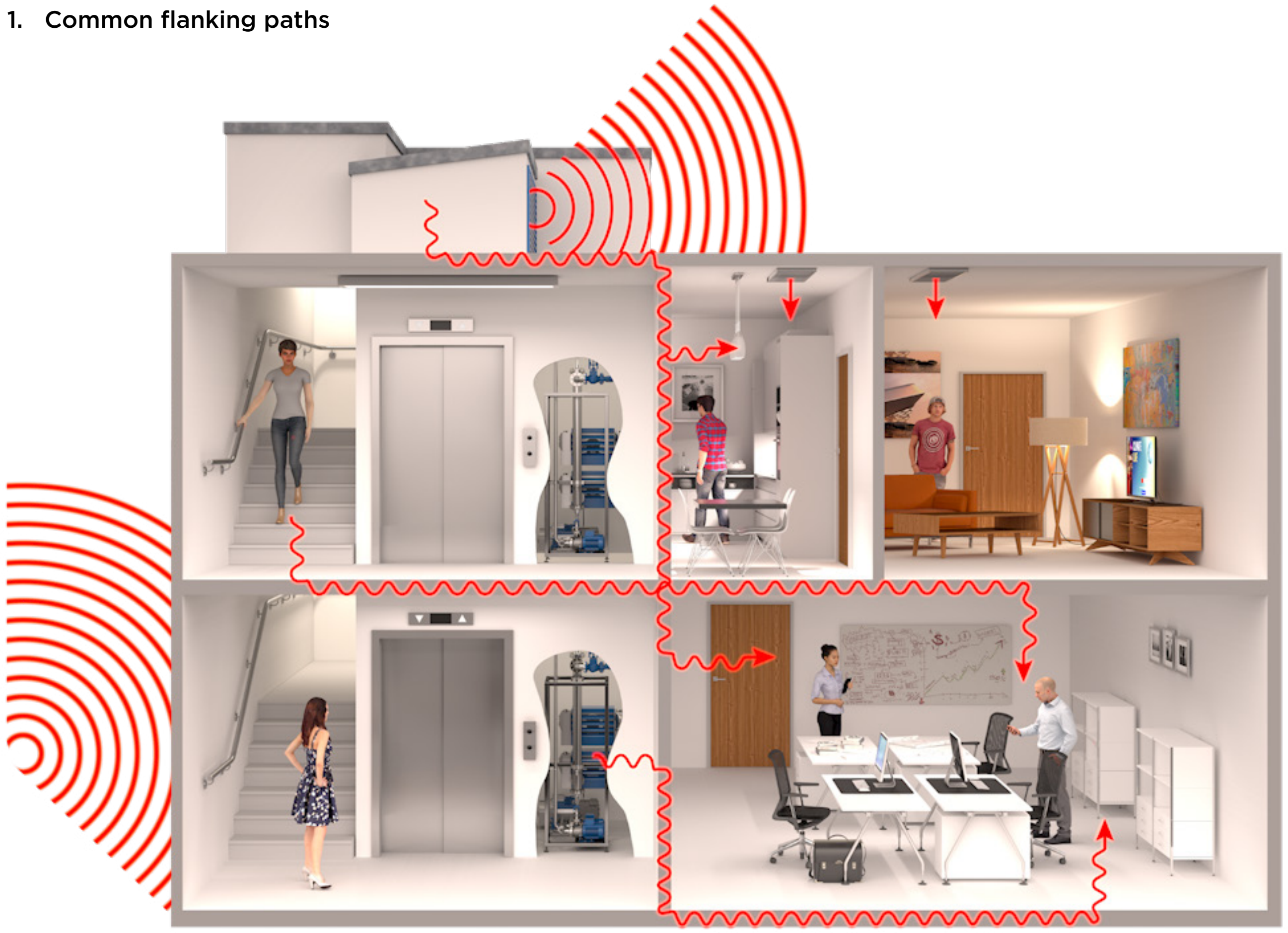
Deflection heads, by definition, must be able to move and, therefore, achieving an airtight seal is very difficult without incorporating sophisticated components and techniques. Air leakage at the partition heads will have a detrimental effect on acoustic performance of any partition.

Other factors, such as flanking transmission through the structural soffit, can significantly affect the overall level of sound insulation. Therefore, other measures may need to be taken.

- In non-fire rated applications, a suspended ceiling installed on both sides of the partition may provide a similar cloaking effect to that of steel angles
- GypCeiling MF incorporating imperforate plasterboard can deliver a similar reduction in air leakage at the partition head. A tight fit between the ceiling perimeter and the surface of the partition lining board is important, although mechanically fixed perimeters are not essential

Ceilings with recessed light fittings may be less effective and if these cannot be sealed in some way, the installation of cloaking angles at the partition head should be considered. A suspended ceiling may also reduce the level of sound flanking transmission via the soffit.

1. Common flanking paths



Acoustics
System design principles

Partition to structural steelwork junctions

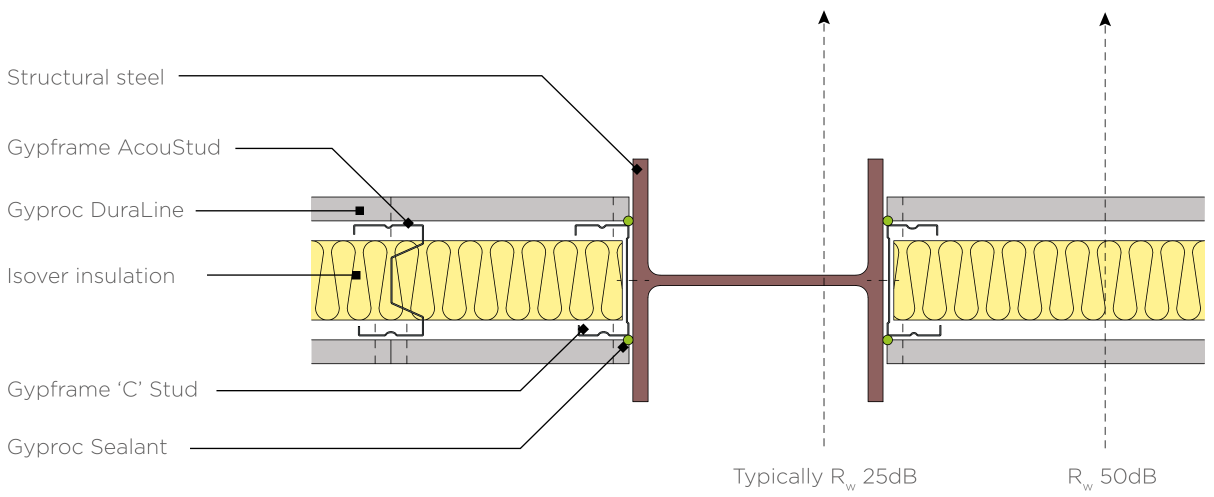
When designing the layout of rooms requiring separation by sound insulating walls abutting structural steelwork, consideration should be given to the potential loss of sound insulation performance through the steelwork.

Figures 2 to 5 (pages 2.9 to 2.11) are example details relating to a typical scenario where a partition is specified against a requirement of R_w 50dB. Although these details refer to structural steel column abutments, similar principles apply when abutting structural steel beams. We recommend that these details are checked by an Acoustic Consultant, in particular the performance via the flanking structure.

Sound by-passing a partition via the void above a suspended ceiling

This is a common source of sound transmission, particularly where the ceiling is absorbent to sound. Sound can easily travel through a perforated tile, or lightweight suspended ceiling, and over the top of a partition where it abuts the underside of the suspended ceiling. Where sound insulation is important, partitions should, wherever possible, continue through the ceiling to the structural soffit, and be sealed at the perimeter junctions. Gyproc plasterboard suspended ceilings offer better insulation where partitions must stop at ceiling level to provide a continuous plenum. In this instance, a cavity barrier can be incorporated above the ceiling line.

2. Exposed or painted steel column



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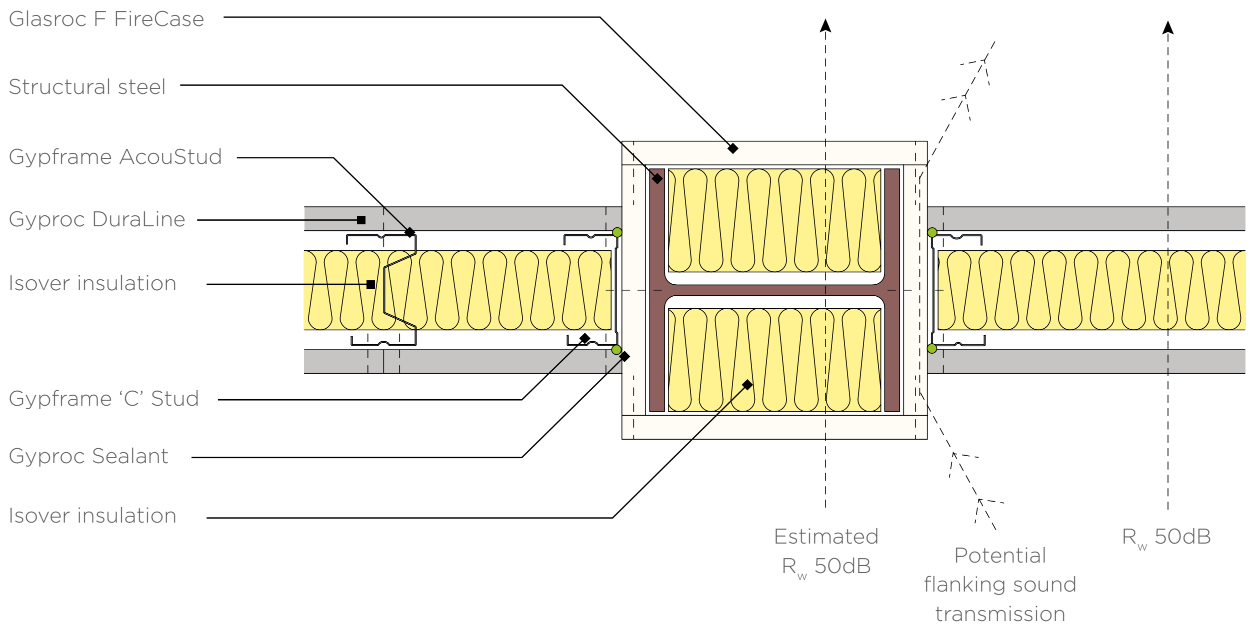
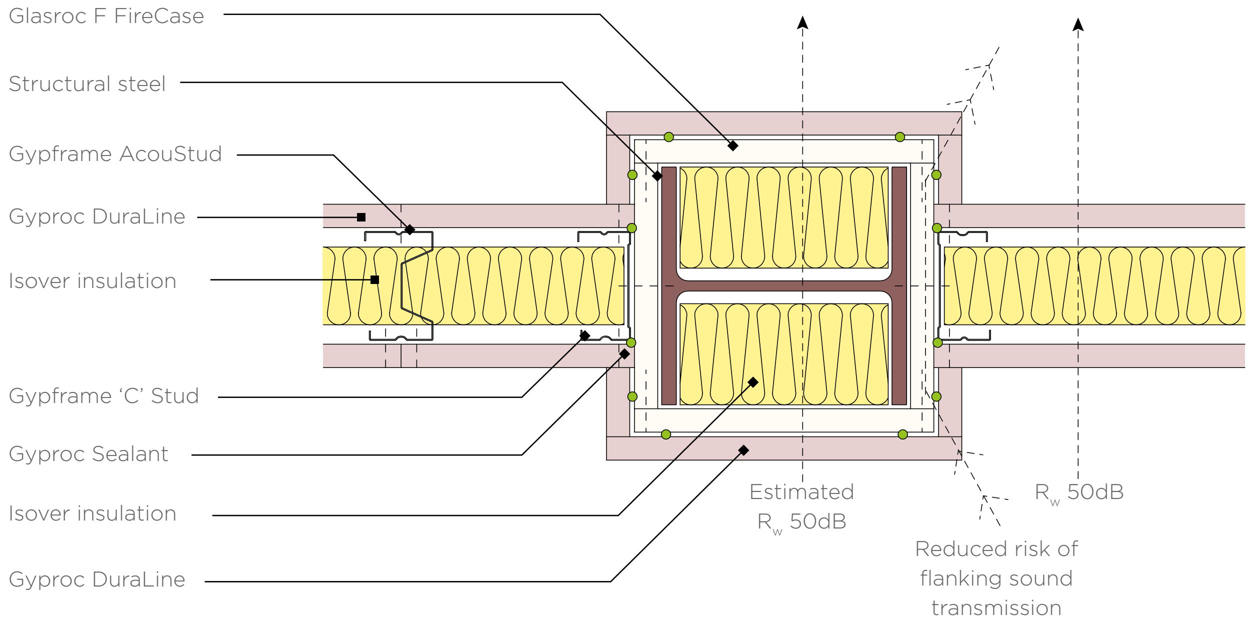
3. Encased steel column



4. Encased steel column with additional plasterboard lining



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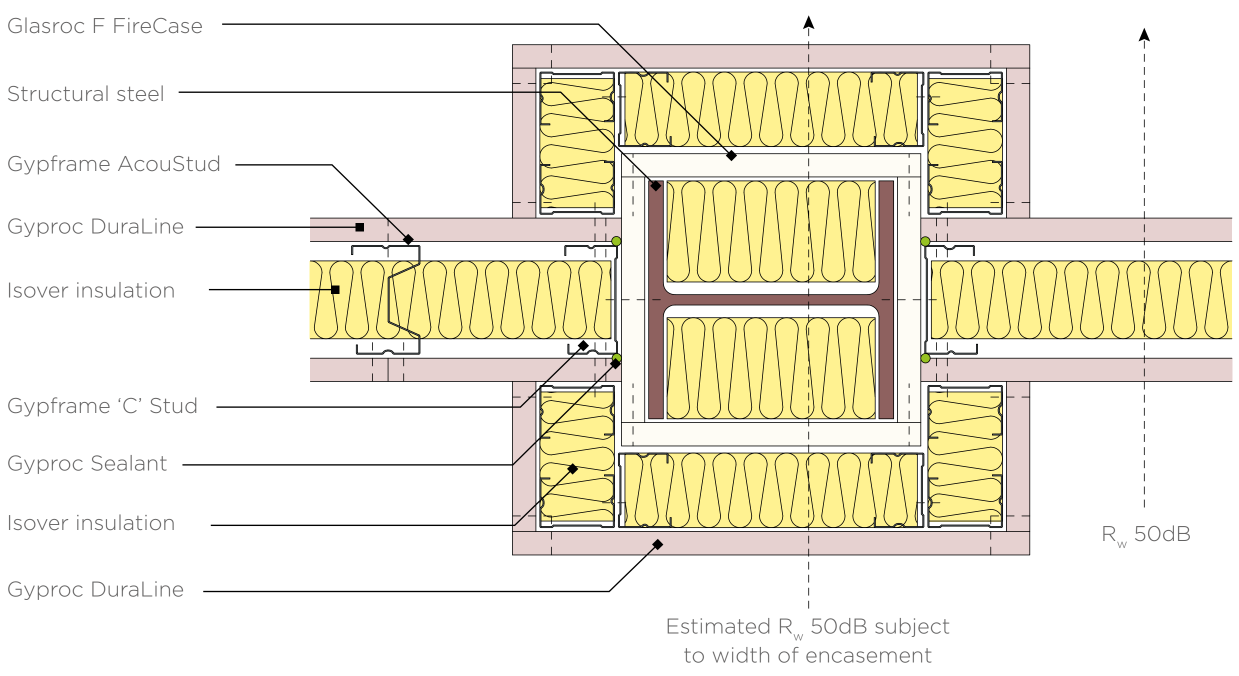
5. Encased steel column with additional framing, insulation and plasterboard lining



Composite construction
A common mistake made when designing a building is to specify a high performance element and then incorporate a lower performing element within it; for example, a door within a partition.

Where the difference between insulation is relatively small (7dB or less), there needs to be a comparatively large area of the lower insulation element before the overall sound insulation is significantly affected. However, where there is a greater difference in sound insulation performance between the two elements, this would normally result in a greater reduction of overall sound insulation performance.

Table 1 shows the acoustic effect various door types have within a partition system. For example; if a poor performance door is included within a partition, it does not matter if the wall achieves 35dB or 50dB sound insulation, as the net performance will never be greater than 27dB. The lowest performing element will always dominate the overall performance.

Acoustic privacy
Two main factors affect the level of acoustic privacy achieved when designing a building:

- The sound insulation performance of the structure separating the two spaces
- The ambient background noise present within the receiving room

The ambient background noise level can be a useful tool when designing buildings, as it is possible to mask speech from an adjacent space and hence provide enhanced speech confidentiality, for example a Doctor's consultancy room next to a waiting room. There are a number of commercially available systems to achieve this. It is, however, more common to treat the problem by specifying appropriate levels of sound insulation. A guide to sound insulation levels is given in table 2.

When designing for residential buildings, the standards of sound insulation given in table 2 are not adequate. Reference should be made to the requirements of Building Regulations Approved Document E (England and Wales) and The Building Standards Technical Handbook Section 5 (Scotland).

Ambient noise levels
Along with acoustic privacy, the acceptable level of sound within a room should be assessed. Factors that affect the ambient noise level of a space are:

- The level of external noise
- The level of sound insulation designed into the surrounding structure
- The amount and type of sound absorbing surfaces within the room
- The noise generated by building services

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Table 1 – The effect various door types have within a partition system						
Door construction	**Mean sound insulation of partition alone (dB)**					
	25	**30**	**35**	**40**	**45**	**50**
	Mean sound insulation of partition with doorways accounting for 7% of area (dB)					
Poor performance door with large gaps around the edge	23	25	27	27	27	27
Light door with edge sealing	24	28	30	32	32	32
Heavy door with edge sealing	25	29	33	35	37	37
Double doors with a sound lock	25	30	35	40	44	49

Where control of ambient noise is critical, advice should be sought from an Acoustic Consultant.

For each room there might be a range of levels that are considered acceptable. The designer should select a level appropriate for the particular circumstances.

For this purpose there are a number of methods, including the Noise Rating (NR) system.

The NR system quantifies the level of noise present within a space, taking into account break-in of noise from the adjacent areas, and also the background noise present within the space from ventilation or other building services. Table 3 gives the recommended maximum noise within different activity spaces, using the NR system criteria. Advice should be sought from an acoustic engineer regarding NR ratings for your project.

BS 8233:2014 gives guidance on sound insulation and noise reduction in buildings. The standard includes a matrix that can be used to determine the sound insulation requirement of separating partitions once the noise activity, noise sensitivity and privacy requirements for each room and space are established. An example matrix, which can be adapted according to the specific building use, is given in table 4. Each room may be both a source and a receiving room. Where adjacent rooms have different uses, the worst case sound insulation should be specified.

Table 2 – Guide to sound insulation levels for speech privacy	
Sound insulation* between rooms R_w	**Speech privacy**
25dB	Normal speech can be overheard
30dB	Loud speech can heard clearly
35dB	Loud speech can be distinguished under normal conditions
40dB	Loud speech can be heard but not distinguished
45dB	Loud speech can be heard faintly but not distinguished
> 50dB	Loud speech can only be heard with great difficulty

* Refer to page 2.14 for explanations of R_w

Sound absorption

Sound absorption is the term given to the loss of sound energy on interaction with a surface. Sound absorbent surfaces are used to provide the correct acoustic environment within a room or space. The choice of material will be influenced by its acoustic efficiency, appearance, durability and fire protection.

By converting some of the sound energy into heat, sound absorbing materials will also help sound insulation because less noise will be transmitted to other rooms. However, this reduction in noise is very small when compared with the potential reduction due to sound insulation. Sound absorption is therefore never a substitute for adequate sound insulation.

Reverberant energy

Reverberation is the persistence of sound in a particular space after the original sound is removed. A reverberation, or reverb, is created when a sound is produced in an enclosed space causing a large number of echoes to build up and then slowly decay as the sound is absorbed by the walls, ceilings, floor and air. The length of this sound decay is known as reverberation time and can be controlled using sound absorbing materials. The appropriate reverberation time for a space will be dependent on the size and function of the space. Examples of typical reverberation times are given in table 5.

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Table 3 – Recommended maximum noise rating for various types of room function	
Situation	**NR* criteria (dB)**
Sound studios	15
Concert halls, large theatres, opera houses	20
Large auditoria, large conference rooms, TV studios, hospital wards, private bedrooms, music practice rooms	25
Libraries, hotel rooms, courtrooms, churches, cinemas, medium-sized conference rooms	30
Classrooms, small conference rooms, open-plan offices, restaurants, public rooms, operating theatres, nightclubs	35
Sports halls, swimming pools, cafeteria, large shops, circulation areas	40
Workshops, commercial kitchens, factory interiors	45

* Refer to 'Ambient noise levels' section on the previous page for explanations of NR.

Table 4 – Example on-site sound insulation matrix ($D_{nT,w}$ dB)

Privacy	Activity noise of source room	Noise sensitivity of receiving room		
		Low	Medium	Sensitive
Confidential	Very high	47	52	57
	High	47	47	52
	Typical	47	47	47
	Low	42	42	47
Moderate	Very high	47	52	57**
	High	37	42	47
	Typical	37	37	42
	Low	No rating	No rating	37
Not private	Very high	47	52	57**
	High	37	42	47
	Typical	No rating	37	42
	Low	No rating	No rating	37

** $D_{nT,w}$ 55dB or greater is difficult to obtain on-site and room adjacencies requiring these levels should be avoided wherever practical. Refer to page 2.12 for explanations of $D_{nT,w}$.

Speech clarity

Speech clarity (intelligibility) is now recognised as essential in helping pupils in an educational environment to achieve their full potential.

Research has shown that pupils who cannot understand clearly what the teacher is saying have a tendency to 'switch off' – limiting their own educational opportunities and creating additional stress for teachers. In a typical classroom with the teacher at one end, sound reaches the pupils both directly from the teacher and via reflections from the ceiling, walls and floor. Refer to figure 6 (page 2.14).

Pupils at the front will generally be able to understand what the teacher is saying, whilst pupils at the back and sides of the room receive a mixture of both direct speech and reflected sound, making it difficult to identify the teacher's words.

Reverberation time alone cannot be relied upon to deliver a suitable environment for good speech intelligibility. In any situation where speech communication is critical, e.g. conference room, lecture theatre or classroom, it is necessary to design the space appropriately using a mixture of sound reflective and sound absorbing surfaces.

Acoustics
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Sound insulation rating methods

The sound insulation rating methods that follow are defined in: BS EN ISO 717: Part 1: 2013 (airborne) and BS EN ISO 717: Part 2: 2013 (impact).

R_w
This single figure rating method is used for laboratory airborne sound insulation tests. The figure indicates the amount of sound energy being stopped by a separating building element when tested in isolation in the absence of any flanking paths.

$D_{nT,w}$
This single figure rating method gives the airborne sound insulation performance between two adjacent rooms within a building as measured on site. The result achieved is affected not only by the separating element, but also by the surrounding structure and junction details.

C_{tr}
The C_{tr} adaptation term is a correction that can be added to either the R_w (laboratory) or $D_{nT,w}$ (site) airborne rating.

The term has been adopted within Building Regulations Approved Document E (England and Wales). The C_{tr} term is used because it targets the low frequency performance of a building element and in particular the performance achieved in the 100 - 315 Hz frequency range. This term was originally developed to describe how a building element would perform if subject to excessive low frequency sound sources, such as traffic and railway noise. Performance tables in this book present relevant sound insulation values both in R_w terms but also in the C_{tr} adapted form. This rating is expressed as $R_w + C_{tr}$ and allows the Acoustic Consultant to critically compare performances. The rating method mainly considers low frequency performance, and has not been universally welcomed due to the difficulties in measuring low frequency performance.

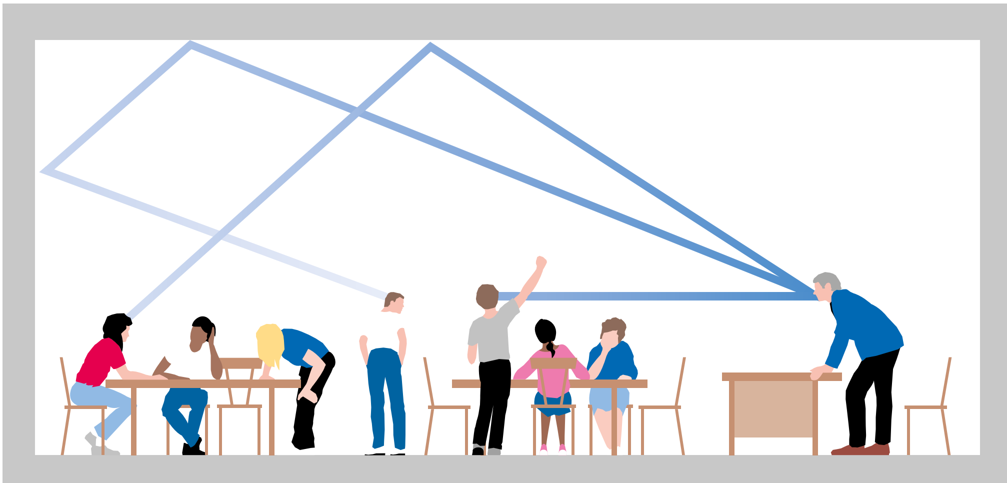
Table 5 – Typical reverberation times	
Type of room/activity	**Reverberation time (mid frequency)**
Swimming pool	<2.0 seconds
Dance studio	<1.2 seconds
Large lecture theatre	<1.0 seconds
Small lecture room	<0.8 seconds
Primary school playroom	<0.6 seconds
Classroom for hearing impaired	<0.4 seconds

Consequently, within separating constructions, British Gypsum can offer enhanced specifications that meet the low frequency performance of the C_{tr} rating whilst also offering good mid and high frequency sound insulation.

$L_{n,w}$
This single figure rating method is used for laboratory impact sound insulation tests on separating floors. The figure indicates the amount of sound energy being transmitted through the floor tested in isolation, in the absence of any flanking paths. With impact sound insulation, the lower the figure the better the performance.

$L'_{nT,w}$
This single figure rating method gives the impact sound insulation performance for floors. The figure indicates the sound insulation performance between two adjacent rooms within a building as measured on site. The result achieved is affected not only by the separating floor but also by the surrounding structure, e.g. flanking walls and associated junction details.

6. Sound transmission in a typical classroom



Acoustics
System design principles

Sound absorption rating methods

The following ratings are calculated in accordance with BS EN ISO 11654: 1997.

Sound absorption coefficient, α_s
Individual sound absorption figures quoted in one-third octave frequency bands are used within advanced modelling techniques to accurately predict the acoustic characteristics of a space. The coefficient ranges from 0 (total reflection) through to 1 (total absorption).

Practical sound absorption coefficient, α_p
A convenient octave-based expression of the sound absorption coefficient; commonly used by Acoustic Consultants when performing calculations of reverberation times within a building space.

Sound absorption rating, α_w
A single figure rating used to describe the performance of a material. The single figure rating can have a modifier added to indicate if the spectral shape is dominated by a particular frequency range

- L - absorption is predominantly in the low frequency region
- M - absorption is predominantly in the mid frequency region
- H - absorption is predominantly in the high frequency region

The absence of a letter followaing the rating indicates that the absorber has no distinct area of sound absorption and has an essentially flat spectral shape.

Noise Reduction Coefficient, NRC
Whilst the sound absorption performance of a ceiling system can be expressed as an NRC, this does not always accurately reflect the product performance. An NRC value is the arithmetic mean of the absorption coefficients across a limited frequency range; this means that it will hide extremes in performance. For instance, a ceiling tile may be a very efficient absorber at high frequencies but very poor at low frequencies, and the NRC value will not reflect this. To optimise the room acoustics the more accurate sound absorption rating, α_w, should be used.

Principles of lightweight construction

Typically the average sound insulation of a material forming a solid partition is governed by its mass; the heavier the material, the greater its resistance to sound transmission. To increase the sound insulation of a solid partition by approximately 4dB, the mass must be doubled. This is known as the empirical mass law.

For example; a 100mm solid block wall of average mass 100kg/m² will have an approximate R_w value of 40dB, whereas a 200mm solid wall of the same material would have an R_w value of 44dB.

Increasing mass is a very inefficient way of achieving sound insulation and one of the advantages of using lightweight cavity partitions and walls is that better than predicted sound reduction values can be achieved. This is why this construction is commonly used in auditoria, e.g. GypWall Twin Frame Audio. Lightweight systems versus the mass law shows how lightweight systems consistently exceed mass law predictions. This demonstrates that adding mass is not always the best method to satisfy acoustic design requirements and that, lightweight systems, if correctly designed, can provide very effective acoustic solutions. Refer to figure 7 (page 2.16).

Acoustic performance is commonly expressed as a decibel (dB) value. The logarithmic scale of decibels provides a simple way to cover a large range of values and show them as a convenient number. Unfortunately the decibel scale can create confusion especially when comparing alternative systems as the difference in acoustic performance can appear to be quite small. In reality an increase of 6dB is equivalent to a doubling of the acoustic performance of the system.

A simple stud partition, for example, can have an R_w rating of 6dB better than predicted by the mass law. In this case, the maximum sound insulation obtainable will be governed by the transmission of energy through the stud frame. The use of other frame types, or configurations, can result in even better insulation. If Gyproc plasterboard or Glasroc specialist boards are fixed to a timber stud frame using a flexible mounting system, such as Gypframe RB1 Resilient Bar, or a more flexible frame is used, for example, Gypframe studs and channels, sound transmission through the framing is minimised and performance significantly better than the mass law prediction can be achieved.

The use of two completely separate stud frames can produce even better results. In this case, the maximum energy transmission is through the cavity between the plasterboard linings. The air in the cavity can be considered as a spring connecting the linings, which allows the passage of energy. The spring will have some inherent damping, which can be significantly increased by the introduction of a sound absorbing material, such as mineral wool, positioned in the cavity. The increased damping of the air-spring results in a reduced coupling between the plasterboard linings and a consequent decrease in sound transmission. Air-spring coupling becomes less significant as the cavity width increases. In practice, cavities should be as wide as possible to insulate against low frequency sounds.

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Two important effects; resonance and coincidence, occur in partitions and walls. These are governed by physical properties such as density, thickness and bending stiffness, and can result in a reduction in sound insulation at certain frequencies.

In lightweight cavity constructions, resonance and coincidence effects can be decreased by the use of two or more board layers. A simple way of increasing the sound insulation performance of a single layer metal stud partition is to add an additional layer of plasterboard to one, or both, sides. This will increase the sound insulation performance by approximately 6dB or 10dB respectively.

Acoustic benefits of applying Thistle MultiFinish to certain GypWall partition systems
Applying 2mm Thistle MultiFinish to both sides of certain GypWall partitions has a positive effect on the sound insulation performance. This is effective on partitions that are limited by their high frequency performance (coincidence region).

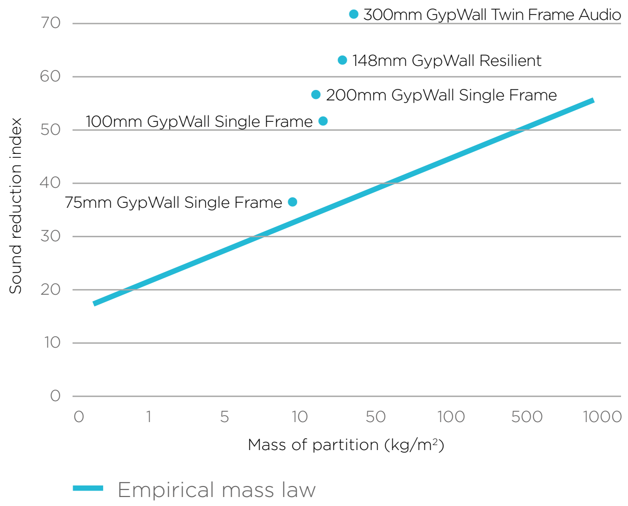
The application of Thistle MultiFinish also adds mass to the partition which has a positive effect on the mid-frequency of the spectrum.

Figure 8 (below) shows an example of a partition that will be positively affected by skim finish using Thistle MultiFinish.

Table 6 – AD E sound insulation requirements (England and Wales)

Where applicable	Minimum airborne sound insulation $D_{nT,w} + C_{tr}$ (site test result)	Maximum impact sound transmission $L'_{nT,w}$ (site test result)	Minimum airborne sound transmission R_w (laboratory test result)
Separating walls between new homes	45dB	–	–
Separating walls between purpose-built rooms for residential purposes	43dB	–	–
Separating walls between rooms created by a change of use or conversion	43dB	–	–
Separating floors between new homes and purpose-built rooms for residential purposes	45dB	62dB	–
Separating floors between rooms created by a change of use or conversion	43dB	64dB	–
Internal wall without a door between a bathroom, or WC, and a habitable room	–	–	40dB
Internal wall without a door between a bedroom and another room within the dwelling	–	–	40dB
Internal floor	–	–	40dB

7. Lightweight systems versus the mass law



8. Acoustic benefits of applying Thistle MultiFinish to certain GypWall partitions

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Refer to system sections within 'Partitions' where systems positively affected by the application of Thistle MultiFinish are shown. Systems with additional performance will show two acoustic figures in the tables - Sound insulation performance for partitions finished using jointing or plaster skim and sound insulation performance for partitions with a 2mm skim finish of Thistle MultiFinish.

Legislation and guidance

Building Regulations Approved Document E – Residential Buildings

Approved Document E (AD E) gives guidance on how to provide reasonable standards of sound insulation in dwellings and other residential buildings. It covers both new-build and refurbishment or conversion, and includes minimum standards of performance.

The standards in table 6 have applied for all new-build homes and purpose-built rooms for residential purposes since July 2004.

Complying with the regulations

In England and Wales, housebuilders and residential developers can follow one of two routes to demonstrate compliance of separating walls and floors for new-build houses and apartments:

- Using 'Robust Detail' constructions
- Using manufacturers' proprietary systems or AD E 'Guidance Constructions' and verifying by Pre-Completion Testing

Robust Details

To avoid Pre-Completion Testing for new-build houses and flats the Home Builders Federation (HBF) developed a series of Robust Details. These forms of construction have been designed and site tested to ensure that they deliver a standard of sound insulation on site to meet the minimum requirements of AD E. The Building Regulations have been amended to allow Robust Details to be used as an alternative to Pre-Completion Testing.

If you are following the Robust Detail route, you must register each plot, with the details you intend to use, and pay a fee. You will then be given a registration certificate to hand to your building control authority before work starts. Robust Details Ltd administers the scheme. Further details are available from the Robust Details Ltd. website robustdetails.com

If you are building to either the Code for Sustainable Homes, or EcoHomes, Robust Details may entitle you to additional credits under the Health and Wellbeing category – check the Robust Details Handbook for the most up-to-date details.

Sound Absorption

Section E3 of AD E covers reverberation noise in the common internal parts of buildings containing flats or rooms for residential purposes. The regulations state that "the common internal parts of buildings which contain flats or rooms for residential purposes shall be designed and constructed in such a way as to prevent more reverberation around the common parts than is reasonable".

The regulations give two methods of calculating the amount of absorption required in any communal areas. The two methods are referred to as 'Method A' and 'Method B'.

AD E specifies sound absorption in terms of a class of absorber. There are five classes (A through to E) with Class A signifying the products with the highest level of sound absorption. However, to comply with AD E using method A, only Class C or D is required. The values ascribed to the different classes are given in table 7.

For more information, refer to Building Regulations Approved Document E, section 7: Reverberation in the common internal parts of buildings containing flats or rooms for residential purposes.

The Building Standards - Scotland (Technical Handbook Section 5)

AD E applies to England and Wales only. In Scotland, Technical Handbook Section 5 is the approved document covering the resistance to the transmission of sound.

A new version of the Domestic Technical Handbook Section 5 was published in October 2010, which increased the standards of sound insulation. This was the first major review of standards for more than 20 years. Its aim is to limit sound transmission from differently occupied parts of a building, and from attached buildings, to a level that will not threaten the health of occupants.

The standards overleaf in table 8 now apply in new build or converted homes and 'traditional buildings'.

Table 7 – Absorption class

Sound absorption class	a_w
A	0.90, 0.95, 1.00
B	0.80, 0.85
C	0.60, 0.65, 0.70, 0.75
D	0.30, 0.35, 0.40, 0.45, 0.50, 0.55
E	0.15, 0.20, 0.25
Unclassified	0.00, 0.05, 0.10

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Table 8 – Section 5 sound insulation requirements (Scotland)

Where applicable	Minimum airborne sound insulation $D_{nT,w}$ (site test result)	Maximum impact sound transmission $L'_{nT,w}$ (site test result)	Minimum airborne sound transmission R_w (laboratory test result)
Separating walls between new homes, purpose-built rooms for residential purposes and conversions (not including traditional buildings*)	56dB	–	–
Separating walls between rooms created by a change of use or conversion (traditional buildings*)	53dB	–	–
Separating floors between new homes, purpose-built rooms for residential purposes and conversions (not including traditional buildings*)	56dB	56dB	–
Separating floors between rooms created by a change of use or conversion (traditional buildings*)	53dB	58dB	–
Internal wall forming a room in a dwelling, or a room in a residential building, which is capable of being used for sleeping	–	–	40dB
Internal floor forming a room in the dwelling, or a room in a residential building, which is capable of being used for sleeping	–	–	43dB

* Definition of traditional buildings – A building or part of a building of a type constructed before or around 1919:
a) using construction techniques that were commonly in use before 1919; and
b) with permeable components, in a way that promotes the dissipation of moisture from the building fabric

Complying with the regulations

Since January 2012, housebuilders and developers in Scotland have been able to use one of three routes to comply with Section 5 performance standards of separating walls and floors for new build houses and apartments.

- Using 'Robust Detail' constructions
- Using 'Example' constructions and verifying by Post-Completion Testing
- Using 'Other' constructions and verifying by Post-Completion Testing

The Post-Completion Testing route, however, remains the only means of compliance for purpose-built rooms for residential purposes and conversions.

Robust Detail constructions

Since 2012, certain Robust Detail (RD) constructions have been permitted for use in new houses and apartments as an alternative to Post-Completion Testing in Scotland. If you are following the RD route, you must register each plot, with details of the RD(s) you intend to use, and pay a fee. You will then be given a registration certificate to hand to your building control authority before work starts.

Example constructions

These are constructions developed to repeatedly achieve required design performance levels, if built correctly with correctly designed flanking details. Use of these constructions does not guarantee regulatory performance levels will be achieved, and the onus is therefore on the housebuilder to demonstrate compliance by Post-Completion Testing on site.

Table 9 – Section 5 sound insulation requirements

Type of construction	No. of attached dwellings	Number of tests for separating walls and floors (flats or maisonettes)
New-build using 'Example Constructions'	2-20	2
	21-40	3
	Over 40	1 extra for every 20 flats or maisonettes (or part thereof)
New-build using 'Other Constructions'	2-10	2
	11-20	3
	21-30	4
	Over 30	1 extra for every 10 flats or maisonettes (or part thereof)

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Other constructions
These include manufacturers' proprietary solutions and new, or innovative, constructions not considered to be 'Example Constructions'. Again, the onus is on the housebuilder to demonstrate compliance by post-completion testing.

Post-completion testing
Post-completion testing is carried out when the building is complete, with doors, access hatches and windows fitted.

To achieve the required approval, homes should be tested as in Table 9.

If a test fails due to the construction of the separating floor or associated flanking elements, other untested rooms may be affected. This will result in additional testing requirements, over and above those in the table above. It may be prudent to seek specialist advice to identify and remedy any problems.

The fundamental differences between Section 5 (Domestic) and AD E are as follows:

- Section 5 has an R_w 43dB requirement for mid-floors, which is also generally applicable for student accommodation
- Section 5 has no requirement for sound absorption in common areas of the building.
- Section 5 measures site performance by way of a $D_{nT,w}$ measure only, whereas AD E also uses a Ctr correction factor.
- Example construction and junction details are available in conjunction with Section 5.

Building Bulletin 93: Acoustic design of schools

Requirement E4 of the Building Regulations Approved Document E states that each room or other space in a school building shall be designed and constructed in such a way that it has the acoustic conditions and the insulation against disturbance by noise appropriate to its intended use.

To satisfy this requirement, it is recommended that buildings comply with the guidance given in Building Bulletin 93 (BB93) Acoustic design of schools, a design guide.

BB93 was written by the Department for Children, Schools and Families (DCSF), formerly the Department for Education and Skills (DfES), and provides a regulatory framework for the acoustic design of schools; including sound insulation between spaces, ambient noise levels and optimum reverberation times for various spaces within educational buildings.

Health and Technical Memorandum HTM 08-01 Acoustics – Healthcare Buildings

Good acoustic design is fundamental to the quality of healthcare buildings. The control of unwanted noise improves patient privacy, dignity and sleep patterns; all key conditions for healing. Good acoustic design also increases the morale and comfort of healthcare professionals.

HTM 08-01 covers the acoustic design criteria that are important for healthcare premises and contains a method of determining the level of sound insulation required between adjacent spaces in a healthcare environment. The document also gives recommended reverberation times for various types of space.

BS 8233 – Sound insulation and noise reduction for buildings

BS 8233 provides guidance on acoustic ratings appropriate to a variety of different building types. It is applicable to the design of new buildings, or refurbished buildings undergoing a change of use. It deals with control of noise from outside the building, noise from plant and services within it, and room acoustics for non-critical situations.

A full revision of the standard, launched in 2014, includes changes which reflect:

- Legislative framework revision since publication of the 1999 edition
- Revisions to Building Regulations Approved Document E
- The publication of specialist documents for specific sectors, such as healthcare and education
- The publication in England of the National Planning Policy Framework in March 2012, with the concurrent withdrawal of numerous individual planning guidance and policy statement documents, including those specifically relating to noise
- A reappraisal of the tabular content with respect to setting targets for various classes of living space in the light of research findings
- The need to transfer some of the more detailed information from the main text to annexes
- Requirements for offices

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Designing for on-site performance

Achieving a $D_{nT,w}$ + C_{tr} performance on site
The C_{tr} rating method puts increased emphasis on the low frequency region of the spectrum. For lightweight construction this means a significant change in some of the design principles. For partitions, the cavity should be as large as possible and double layers of plasterboard should be used.

For masonry walls lined with lightweight panels, cavities with a depth of less than 60mm should be avoided. Two linings, with small, identical sized cavities either side of a solid masonry wall, should not be specified. These cavities can interact and cause a significant downgrade in the critical low frequency zone. If a small cavity is required, one side only should be lined with a double layer of plasterboard. Optimum performance is achieved by lining one side only and having a cavity depth of at least 85mm.

To increase the sound insulation of new or existing masonry walls, GypLyner wall lining systems can be used in conjunction with Isover insulation and Gyproc plasterboard. The cavity depth of the GypLyner lining should be as large as possible, and small, identical sized cavities to either side of the wall should be avoided.

For lightweight separating floors, partially de-coupling the plasterboard ceiling from the floor structure, using Gypframe RB1 Resilient Bars, helps to achieve the required performance. Floating floor treatments, for example timber battens, should have a cavity depth of at least 70mm to avoid low frequency resonance effects in the critical low frequency zone. Performance can be further enhanced by specifying Gyproc Plank within the walking surface.

Floating floor and resilient bar ceiling systems should be tested in a UKAS laboratory to ensure good low frequency performance. The Robust Details handbook outlines a benchmarking procedure for this purpose (robustdetails.com) to support specification of such systems to meet the requirements for new-build residential construction.

A method of determining the achievable site $D_{nT,w}$ + C_{tr} performance is to refer to a laboratory R_w + C_{tr} rating. Depending on the wall specification, a minimum drop of 4dB is typical when comparing R_w + C_{tr} and $D_{nT,w}$ + C_{tr}. However, we recommend that a safety margin of + 9dB should be used to reduce the risk of failure to comply with Building Regulations. This assumes all flanking paths are appropriately detailed, ideal site lay-out exists and a high quality of workmanship is applied.

For purpose-built dwelling houses and flats requiring $D_{nT,w}$ + C_{tr} 45dB for separating walls, separating floors and stairs, we recommend specifications capable of achieving R_w + C_{tr} 54dB.

For purpose-built rooms for residential purposes requiring $D_{nT,w}$ + C_{tr} 43dB for separating walls, and $D_{nT,w}$ + C_{tr} 45dB for separating floors and stairs, we recommend specifications capable of achieving R_w + C_{tr} 52dB for separating walls, and R_w + C_{tr} 54dB for separating floors and stairs.

For dwelling houses, flats and rooms for residential purposes formed by material change of use requiring $D_{nT,w}$ + C_{tr} 43dB for separating walls, separating floors and stairs, we recommend the use of specifications that are capable of achieving R_w + C_{tr} 52dB. Refer to table 10 for more information.

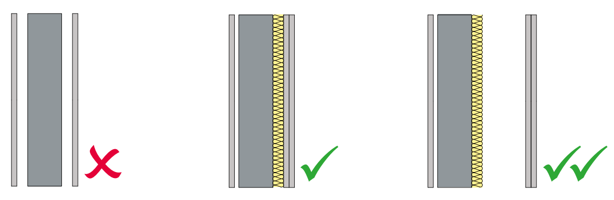
Achieving a $D_{nT,w}$ performance on site
Similar to the principles of achieving a $D_{nT,w}$ + C_{tr} performance on site, a realistic safety margin should be incorporated when designing to meet a $D_{nT,w}$ requirement, to reduce the risk of failure. We recommend a safety margin of + 7dB when comparing site performance, $D_{nT,w}$ to laboratory performance, R_w.

For example, to comply with Scottish Technical Handbook Section 5 in Scotland for a requirement of $D_{nT,w}$ 56dB, a system capable of achieving R_w 63dB under laboratory conditions should be specified. Refer to table 11 for more information.

Achieving a $L'_{nT,w}$ performance on site
A minimum reduction of 5dB is typical when comparing site performance, $L'_{nT,w}$, to laboratory performance, $L_{n,w}$. However, when designing separating floors to reduce the risk of impact sound flanking transmission, in particular timber joist, the walking surface should be de-coupled from the joists, for example using GypFloor Silent or a batten floating floor system. This is in addition to the de-coupling of the ceiling, using GypCeiling MF ceiling or Gypframe RB1 Resilient Bar, for example.

Therefore, in some cases the safety margin in the laboratory for timber joist separating floors is likely to be in the region of + 10dB, rather than the typical minimum + 5dB for concrete floors.

9. Optimum design of panel linings for C_{tr}



Avoid	OK	Best
Matched cavities less than 60mm to be avoided.	If space restrictions limit the cavity size then install one side only. Ensure glass mineral wool is used in the cavity and use a double layer of plasterboard.	Single cavity as large as possible (preferably greater than 85mm), lined with a double layer of acoustic plasterboard and glass mineral wool included in the cavity.

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Table 10 – Recommended laboratory performance to meet requirements of Building Regulations Approved Document E (England and Wales)

Where applicable	Minimum airborne sound insulation $D_{nT,w} + C_{tr}$ (site test result)	Recommended performance $R_w + C_{tr}$ (laboratory test result)	Maximum impact sound transmission $L_{n,w}$ (site test result)	Recommended performance $L_{n,w}$ (laboratory test result)
Separating walls between new homes	45dB	54dB	–	–
Separating walls between purpose-built rooms for residential purposes	43dB	52dB	–	–
Separating walls between rooms created by a change of use or conversion	43dB	52dB	–	–
Separating floors between new homes and purpose-built rooms for residential purposes	45dB	54dB	62dB	57dB - 52dB (depending on test method)
Separating floors between rooms created by a change of use or conversion	43dB	52dB	64dB	59dB - 54dB (depending on test method)

Table 11 – Recommended laboratory performance to meet requirements of Technical Handbook Section 5 (Scotland)

Where applicable	Minimum airborne sound insulation $D_{nT,w}$ (site test result)	Recommended performance R_w (laboratory test result)	Maximum impact sound transmission $L_{n,w}$ (site test result)	Minimum airborne sound insulation $L_{n,w}$ (laboratory test result)
Separating walls between new homes, purpose-built rooms for residential purposes and conversions (not including traditional buildings*)	56dB	63dB	–	–
Separating walls between rooms created by a change of use or conversion (traditional buildings*)	53dB	60dB	–	–
Separating floors between new homes, purpose-built rooms for residential purposes and conversions (not including traditional buildings*)	56dB	63dB	56dB	51dB - 46dB (depending on test method)
Separating floors between rooms created by a change of use or conversion (traditional buildings*)	53dB	60dB	58dB	53dB - 48dB (depending on test method)

* Definition of traditional buildings – A building or part of a building of a type constructed before or around 1919:
a) using construction techniques that were commonly in use before 1919; and
b) with permeable components, in a way that promotes the dissipation of moisture from the building fabric

Acoustics
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The key points for consideration when designing to meet any acoustic performance requirement are below:

- Inappropriate detailing of flanking conditions can greatly reduce the level of performance of the system from that achieved in the laboratory. Refer to figures 2-5 (pages 2.9 to 2.11) for more information
- For separating wall and floor constructions to be fully effective, care must be taken to correctly detail the junctions between the separating wall or floor and associated elements such as external walls, other separating elements and penetrations or door openings, etc.
- If junctions are incorrectly detailed then the acoustic performance will be limited and Building Regulations requirements will not be achieved in practice
- Pre-Completion Testing exposes poor flanking details and inadequate separating wall and floor specifications. Good flanking detailing and specifications that provide a reasonable margin of safety on site are therefore essential

Examples of practical solutions

Gypframe AcouStuds
Gypframe AcouStuds are metal stud sections optimised to give enhanced sound insulation performance. These unique shaped studs are used for increased acoustic performance. Gypframe AcouStuds can be used to upgrade the acoustic performance of 70mm, 92mm and 146mm wall systems.

Figure 10 (page 2.23) shows the performance improvement possible using acoustic stud technology compared with a standard 'C' stud of the same cavity dimension.

GypWall Staggered
GypWall Staggered features staggered studs that are located within a head and base channel by means of retaining clips. This arrangement means there is limited connection through the framework to the plasterboard face on the opposite side of the partition. The system design enables a higher level of sound insulation to be achieved with modest cavity sizes.

Figure 11 (page 2.23) shows the improvements possible using a staggered stud arrangement compared to a standard GypWall Single Frame 'C' stud partition with the same partition cavity size.

GypWall Resilient
GypWall Resilient utilises Gypframe RB1 Resilient Bars to partially de-couple the plasterboard linings from the partition stud frame, leading to enhanced levels of sound insulation.

Figure 12 (page 2.24) shows the improvements possible when including Gypframe RB1 Resilient Bar on one or both sides of a standard Gypframe 70mm 'C' Stud partition.

GypWall Twin Frame Audio and GypWall Twin Frame Independent
The most acoustically effective wall designs are twin frame walls. Minimal or no bridging between the plasterboard linings and the increased cavity size allows optimum performance from the wall.

Figure 13 (page 2.24) shows the difference achievable by using a twin framed wall approach as opposed to a standard GypWall Single Frame stud partition. The plasterboard linings and insulation are the same for both partitions and the key difference is the overall partition thickness – typically 211mm for the standard partition and 300mm for the twin framed option. With this type of design, further improvements in performance can be achieved by increasing the cavity size and/or increasing the board specification.

Gypframe RB1 Resilient Bar (ceilings)
Gypframe RB1 Resilient Bar is an engineered metal component used predominantly with lightweight separating floors to de-couple the ceiling from the floor structure and thereby improve the airborne sound insulation performance of the separating floor.

The value of this component is recognised in Robust Details, where all lightweight floor solutions feature resilient bars to partially de-couple the ceiling from the floor structure.

Figure 14 (page 2.24) shows the substantial performance improvements achievable for airborne sound insulation when Gypframe RB1 Resilient Bar is utilised instead of a directly fixed ceiling.

Floating floor treatment
Floating floor treatments are used with both lightweight and concrete separating floors to de-couple the walking surface from the floor structure and thereby improve both the airborne and impact sound insulation performance of a separating floor.

The value of this technique is recognised in Robust Details, and is currently featured in a number of separating floor solutions.

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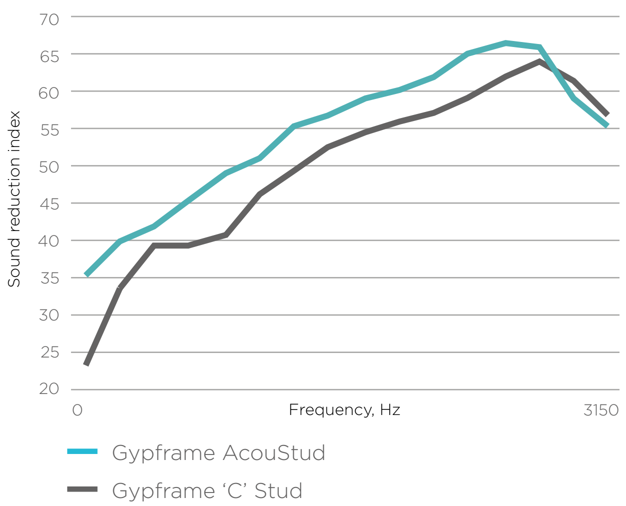
Sound insulating dry linings
In designing for sound insulation, care should be taken to ensure that flanking transmission via the associated structure does not downgrade the performance of the partition or wall to a level below that required in use. This applies especially when a lightweight partition or wall is constructed in a masonry building. Care should therefore be taken to ensure the associated structure is able to achieve the level of sound insulation required.

The performance of sound resisting floors of timber joist or lightweight concrete construction, supported on or flanked by conventionally finished masonry walls, can be adversely affected by flanking transmission in the walls. This effect can be significantly reduced by the application of a GypLyner wall lining system, to the flanking walls.

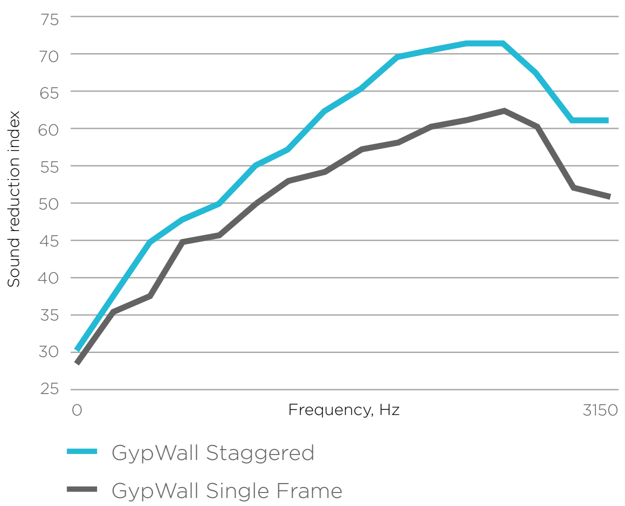
Lining treatments can also be beneficial in refurbishment work when applied to flanking walls of new or existing sound resisting walls.

Refer to Section 6, wall linings.

10. Acoustic benefits of Gypframe AcouStuds

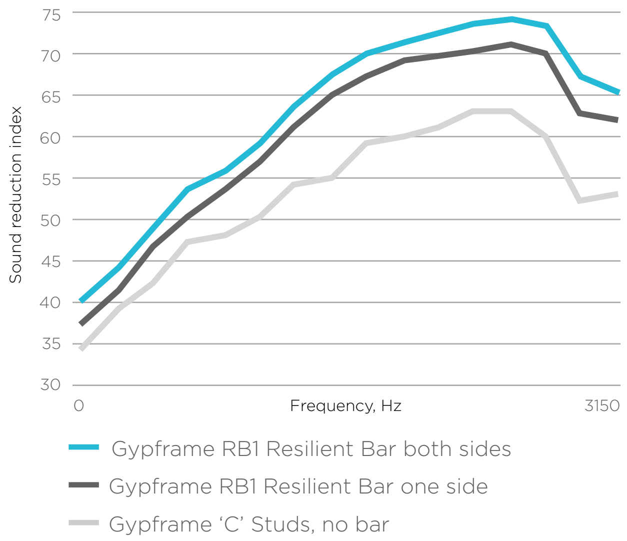


11. Acoustic benefits of staggered studs

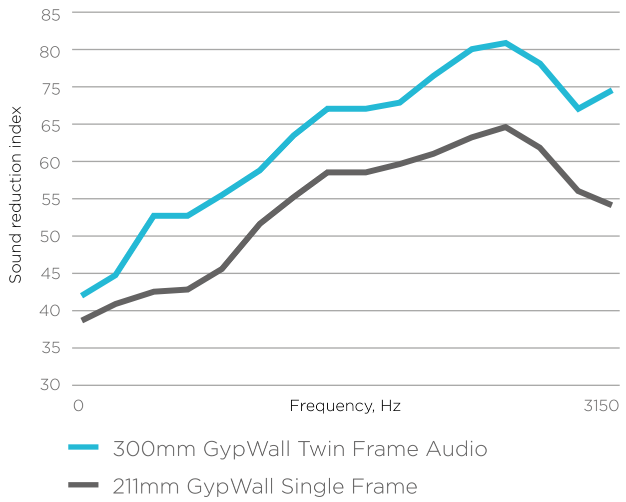


Acoustics
System design principles

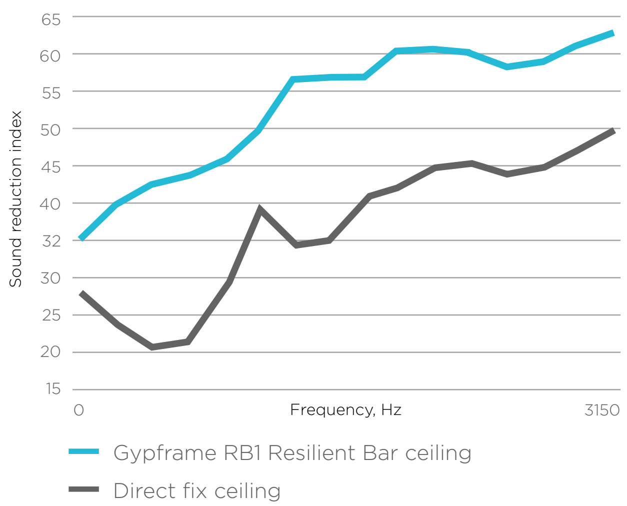
12. Acoustic benefits of Gypframe RB1 Resilient Bars (partition)



13. Acoustic benefits of twin stud framework



14. Airborne sound insulation benefit of Gypframe RB1 Resilient Bars (ceiling)



Robustness
System design principles

Legislation and guidance

BS 5234 - Partition (including matching linings)
BS 5234 comprises two parts – Part 1 Code of practice for the design and installation, and Part 2 Specification for performance requirements for strength and robustness including methods of test in relation to end-use categories. The standard covers performance aspects such as stiffness, crowd pressure, impact resistance, anchorages and door slamming resistance.

BS EN 1991-1-1 Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings.
This code of practice gives dead and minimum recommended imposed loads for use in designing buildings. Whilst our GypWall partition systems are non-loadbearing, they are able to provide resistance to levels of horizontal line load applied at a height of 1.2m as detailed within this standard for parapets, barriers and balustrades, etc.

For requirements for horizontal loads on partition walls and parapets see BS EN 1991-1-1:2002 National Annex table NA.8.

Principles of robust design

Partition Duty Ratings
All our partition systems have a Duty Rating established in accordance with all the full requirements of BS 5234. This rating relates to the strength and robustness characteristics of the partition system against specific end-use applications. Table 12 gives details of the four duty categories.

A series of tests are used to assess the resistance to damage, both aesthetic and structural, from a range of impacts and load applications.

The tests are conducted at the maximum height for the partition system. BS 5234 itself does not have a method for establishing an acceptable maximum height, and the partition height must be established using a separate method. It is suggested within BS 5234 that the crowd pressure test may be suitable for evaluating heights up to 4200mm, but we would strongly advise against using this inconsistent approach and would never rely solely on BS 5234 for evaluating heights, especially above 4200mm.

Tests within BS 5234-2 include:

- Partition stiffness
- Resistance to damage from a small hard body impactor
- Resistance to damage from a large soft body impactor
- Resistance to perforation from a small hard body impactor
- Resistance to structural damage from a large soft body impactor
- Resistance to damage from door slamming

BS 5234-2 does not identify specific points of contact on a partition that should be impacted. However, we understand that there are limiting points in terms of impact resistance. These are then subjected to the impact tests to ensure that the most onerous situation is assessed.

Optional tests are also detailed within the standard, but these are not used in the partition grading. These include:

- Resistance to damage from a crowd pressure load
- Lightweight anchorages pull down
- Lightweight anchorages pull out
- Heavyweight anchorages wall cupboard
- Heavyweight anchorages wash basin

Refer to Service installations within this section, for more information on fixing to drywall systems.

Important design considerations
To achieve Heavy Duty Rating or Severe Duty Rating, the door detail needs to be reinforced otherwise the door opening will undergo too much deflection and damage during the onerous door slamming test.

The level of deflection and strength performance required to achieve Light Duty Rating within BS 5234-2 is, in our opinion, unsuitable for any application. We do not offer any systems with a rating less than Medium Duty Rating.

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System design principles

Table 12 – BS 5234-2 Duty Ratings

Partition duty rating	Category	Examples
Light	Adjacent space only accessible to persons with high incentive to exercise care. Small chance of accident occurring or misuse.	Domestic accommodation
Medium	Adjacent space moderately used, primarily by persons with some incentive to exercise care. Some chance of accident occurring or misuse.	Office accommodation
Heavy	Adjacent space frequently used by the public and others with little incentive to exercise care. Chance of accident occurring or misuse.	Public circulation areas, industrial areas
Severe	Adjacent space intensively used by the public and others with little incentive to exercise care. Prone to vandalism and abnormally rough use.	Major circulation areas, heavy industrial areas

Maximum partition heights
As stated previously, BS 5234-2 does not contain a consistent methodology for establishing the performance of a partition in terms of height. The UK has therefore adopted a methodology, which is based on the level of lateral deflection under a given uniformly distributed load (UDL). The criterion is that the maximum lateral deflection of the partition should not exceed L/240 (where L is the partition height) when the partition is uniformly loaded to 200Pa.

We utilise a UKAS accredited test laboratory to evaluate partition system heights against this performance criteria. The test evidence comes from a full-scale test procedure where the test specimen is subjected to a UDL and the induced lateral deflection recorded. From this procedure, it is possible to establish the maximum height for a range of partition systems.

When cutting Gypframe studs to suit the partition height, avoid cutting the stud within 100mm from a service cut-out.

Important information

To claim a partition Duty Rating, all tests must achieve the designated performance level. It is not possible, for example, for a partition lined with a single layer of Gyproc WallBoard (12.5mm) to achieve a Duty Rating better than medium, because of the board's performance in the hard body perforation test. In the majority of cases, the type of board used will determine the maximum partition Duty Rating. Table 13 shows the maximum rating available based on a single layer board lining. In all cases, a double layer lining achieves Severe Duty Rating.

Table 13 – Board type required to achieve a given Duty Rating (single layer) solutions

Board type	Maximum rating
Gyproc WallBoard 12.5mm	Medium
Gyproc WallBoard 15mm	Medium
Gyproc SoundBloc 12.5mm	Medium
Gyproc SoundBloc 15mm	Medium
Gyproc FireLine 12.5mm	Medium
Glasroc H TileBacker 12.5mm	Medium
Gyproc FireLine 15mm	Heavy
Gyproc SoundBloc 15mm	Heavy*
Gyproc SoundBloc F 15mm	Heavy
Glasroc F MultiBoard 10mm	Heavy
Glasroc F MultiBoard 12.5mm	Severe
Gyproc DuraLine 15mm	Severe
Rigidur H 12.5mm / 15mm	Severe

* Minimum Gypframe 70mm Stud for Heavy Duty Rating.

Robustness
System design principles

Assessing acoustic performance of GypWall Single Frame with reduced stud centres
Reducing the centres of the metal studs within GypWall partition systems can have a detrimental effect on the sound insulation performance of the system.

The effect may vary depending on the precise specification, e.g. board type, number of board layers, stud size and stud type, insulation within stud cavity.

Where Thistle MultiFinish is specified to obtain a 1 or 2 dB uplift, this will be negated when closing down stud centres or changing stud profile.

If the partition system is also performing a fire compartmentation function to EN standards, the partition height in the fire state also needs to be established for the required duration. It should not be assumed that the cold state height is still valid in the fire state.

Movement
Deflection of upper floor and roof slabs can cause appreciable stress in partitions. Where such deflection is likely to occur, the partition to structural soffit junction detail must be designed to accommodate movement, whilst still complying with any fire or acoustic performance requirements. Typical deflection head details for fire-rated GypWall partition systems are given in the relevant partition and wall system sections within this book. Additional attention to detailing will be required to optimise sound insulation performance.

Where linings (partitions, wall linings and ceilings) cross a movement joint in a structural wall, floor or roof slab, they should be provided with a movement joint at the same point, and be capable of the same range of movement as the wall, floor or roof joint. Gyproc Control Joint provides a suitable solution for movement up to 7mm. Gyproc Control Joint may also be required to relieve stresses induced by extreme environmental conditions. For example, consideration could be given to installing control joints at 10m centres in linings that are subjected to either extreme or variable temperatures.

Refer to the construction details in GypLyner Independent.

Environmental conditions

Temperature
Gyproc plasterboards, Glasroc specialist boards and Thistle plasters should not be used where the temperature will exceed 49°C. Prolonged exposure to high temperature, and/or multiple exposure for short periods, results in the gradual continued calcination of the gypsum and loss of its inherent properties. Gyproc plasterboards, Glasroc specialist boards and Thistle plasters (once fully dried) can be subjected to freezing conditions without risk of damage.

Moisture
Plasterboards have different levels of moisture performance designed for different applications or different construction stages. If a plasterboard is incorrectly specified for a particular application it could lead to non-performance and/or damage. If project timelines change, product choice may need to change.

Our products should not be used in continuously damp conditions or in buildings that are not weather tight. However, our Gyproc Moisture Resistant grade plasterboards and Glasroc specialist boards are suitable for use in intermittently damp conditions or sheltered external situations in conjunction with an appropriate decorative finish. This should take the form of ceramic tiling or other suitable moisture impervious coating by others. Glasroc H TileBacker can be used as a tiling substrate in high moisture applications.

Two coats of Gyproc Drywall Sealer applied to the face of standard grade plasterboards, with the edges adequately protected from moisture may also be suitable to receive a tile finish. The application of Gyproc Drywall Sealer provides surface water absorption resistance only, and does not meet the performance requirements for moisture resistant grade boards as defined in BS EN 520, type H1.

Relative humidity (RH)
In moderate humidity situations, i.e. 40% to 70% RH, no special precautions need to be taken when using Gyproc plasterboards, other than those necessary to prevent interstitial condensation. However, whenever the building's heating system is turned off a rapid increase in the relative humidity can occur as the building cools down. This could lead to the occurrence of potentially harmful surface condensation. Precautions to avoid this problem should be taken, e.g. by continuing to run the ventilation system after the heating is turned off.

Low humidity does not affect the plasterboards, but may lead to distortion of timber framing members as they dry to below their usual moisture content. Intermittently high relative humidity, i.e. above 70% RH, requires special treatment to the face of the plasterboards, and only moisture resistant grade plasterboards or Glasroc specialist boards should be used. Suitable surface treatments include ceramic tiling and water vapour resistant paint systems. Gyproc plasterboards are not considered suitable in continuously high humidity conditions. Certain British Gypsum ceiling products are suitable for use in environments above 70% RH.

Robustness
System design principles

Special environments – swimming pools and similar environments

Ceiling lining
Our products and systems are regularly specified for ceilings in and around swimming pool halls and similar areas. With regard to ceiling specifications attention to detail is critical.

The following guidance should be considered:

- The boards to be used should be moisture resistant grade or Glasroc F specialist boards. They should be screw-fixed to a framed system at their recommended centres
- The surface of the board should be finished using our recommended methods, and they must be set and dry before applying decoration. Thistle finish coat plasters are not recommended for this type of environment
- The decoration should take the form of a suitable moisture impervious finish supplied by other manufacturers
- Penetrations in the ceiling linings and perimeters should be avoided where possible. All service penetrations must be sealed using a moisture resistant sealant (even though the recommended plasterboards are moisture resistant it is unwise to allow moisture to gain access to the core of the board)
- The air in the pool area should be conditioned such that condensation will not form on the surface of the boards
- In situations where there is a risk of condensation occurring within the ceiling cavity, it must be mechanically ventilated or the decorative finish must be impervious to water vapour. This will minimise the risk of condensation forming on 'cold' surfaces in the cavity, which could then come in to contact with the unprotected back face of the plasterboard lining
- It is good practice to protect the cut ends of Gypframe metal components using suitable material to prevent corrosion
- Ensure that the Gypframe metal frame is totally encapsulated by suitable Gyproc plasterboard and waterproof finishing system (by others).

Wall lining
Glasroc H TileBacker is suitable for use as a wall lining in areas such as shower enclosures, swimming pool halls and adjacent areas.

Gyproc Moisture Resistant grade boards are not suitable to be used in those areas, but can be considered for use in adjacent areas of wall lining and in most domestic situations. Attention to detail is critical and, in addition to the guidance given above for ceiling linings, the following additional guidance should be considered:

- The lining boards must be lifted clear from any floor where free water is possible and a suitable skirting detail must be employed which will not allow water penetration
- In extreme moisture environments, Glasroc H TileBacker must be used in conjunction with a tanking system
- Thistle plasters are not recommended for this type of environment with the exception of Thistle DriCoat undercoat which could be considered in conjunction with a completely sealed, impervious, tiling system
- Important guidance is given within BS 5385-1 and BS 5385-4, within which gypsum plasterboard and gypsum plaster are deemed unsuitable backgrounds for tiling in 'frequently wetted' areas. These areas include communal showers and pool halls

Ceilings
EN 13964 includes class definition relating to exposure conditions and maximum deflection. The standard GypCeiling MF ceiling layout is capable of complying with deflection Class 2 and exposure Class A, however the system can be modified to meet Classes 1 and B. See Technical Support on british-gypsum.com for further guidance.

Service installations
System design principles

Services within partitions and lining cavities

The installation of electrical services must always be carried out strictly in accordance with BS 7671 Requirements for electrical installations. IET Wiring Regulations.

Services can be incorporated within all our partition and lining systems. As shown in figure 15 and figure 16 (page 2.33), Gypframe studs either have cut-outs or push-outs to accommodate routing of electrical services and other small services. Grommets or isolating strips should be installed in the cut-out to prevent abrasion of the cables.

Gypframe channels do not generally have cut-outs and so, if required, they need to be cut on-site, paying attention to Health & Safety guidance. Grommets or isolating strips should be installed in these cut-outs to prevent abrasion of the cables.

When installing electrical services within a partition, this might result in the concealed cable being less than 50mm from the surface of the partition, particularly if the partition is less than 100mm thick. Whilst it may be apparent that electrical services are contained within a partition cavity due the appearance of electrical sockets / switches on the partition surface, this might not be obvious from the reverse side. Therefore, before carrying out work, e.g. drilling into the surface, the reverse side of the partition must always be checked to determine the location of any concealed cables. It is good practice to maintain a clear zone. Where the location of electrical outlets cannot be determined from the reverse side, then the cable must either be mechanically protected or run at least 50mm from the surface of the wall or partition on the reverse side. Refer to figure 17 and figure 18 (page 2.34).

Where heating pipes, particularly micro-bore systems, are to be located within the GypWall system, it is recommended that only one pipe is passed through each aperture in the metal framework. If this cannot be accommodated for whatever reason, it may be necessary to incorporate proprietary pipe restraining clips, or other means of keeping the pipes apart, to prevent vibration noise.

If a lining system, such as DriLyner, does not have sufficient depth to accommodate the service then the background should be 'chased out' to the appropriate depth considering maximum allowable tolerances. Pipes or conduits should be fixed in position before work commences.

The insulating backing of Gyproc ThermaLine should not be chased to accommodate services. PVC covered cables must not come into contact with polystyrene insulation and so suitable isolation methods such as conduit or capping should be used. Please see National House Building Council (NHBC) Standards 8.1 and Building Research Establishment (BRE) Thermal Insulation: avoiding risks (BR262)'.

Thermal insulation covering or around cables has the effect of reducing the current carrying capacity and so the cable may need to be de-rated and increased in size.

Refer to BS 7671 for guidance.

To maintain an airtight construction, the perimeter of any penetration through the lining should be sealed as necessary at the time the services are being installed.

Hot and cold water pipes should be installed strictly in accordance with manufacturers instruction.

In the case of gas service pipes behind drylined walls, BS 6891 states that the pipe should be encased in building material, which could take the form of Thistle plaster. Alternatively, apply a continuous band of Gyproc DriWall Adhesive or timber battens either side of the pipe to receive a plasterboard lining.

Service penetrations and fixing into drywall systems

Switch boxes and socket outlets can be supported on brackets formed from Gypframe 99 FC 50 Fixing Channel or cut and bent channels fixed horizontally between the studs. Alternatively, services can be fixed to the face of the partition, using a Gypframe Service Support Plate, which carries 18mm plywood within the cavity of the partition as shown in figure 19 (page 2.34).

In fire-rated walls, the fire-stopping design is dependent on the period of fire resistance. Where acoustic performance is not a specific requirement, refer to figure 20 (page 2.34) and figure 21 (page 2.35).

Fixing electrical socket boxes into our partitions and walls can affect the technical performance e.g. fire, acoustic, air leakage, but careful detailing can minimise this. Building Regulations Approved Document E and Robust Details offer specific guidance on the installation of socket boxes in separating walls, particularly with regard to the avoidance of back-to-back services. Refer to figure 22 (page 2.35).

There are a number of putty pad products available on the market from a range of manufacturers and whilst we have no objection to the use of putty pads (by others) within drylining systems, all performance substantiation has to be provided by the fire-stopping manufacturer as is the case for any fire-stopping material. Refer to figure 23 (page 2.35), for example. The Robust Details pattern book also offers the alternative of a 'sacrificial' lining in front of a separating wall to create a zone for service installation. These service zones remove the need for service penetration of the actual Robust Detail separating wall construction, which in turn removes the risk of a loss in acoustic performance as a result of service penetrations. Refer to figure 24 (page 2.36).

Service installations
System design principles

This method is increasingly migrating to projects where Pre-Completion Testing is being used, as best practice. However, it can lead to a downgrading of the $D_{nT,w} + C_{tr}$ performance of the base wall due to the introduction of additional cavities within the overall construction. Robust Detail walls are designed to exceed the Approved Document E requirement so the slight potential downgrade in performance caused by the 'sacrificial' lining would not lead to system failure.

Where Pre-Completion Testing is required however, depending on the system specified, there may not be this level of 'safety margin', particularly at lower frequencies. Therefore, where additional 'sacrificial' service installation zone linings have been specified in non-Robust Details systems the most appropriate solution to ensure no reduction in the acoustic performance of the base partition is a 70mm cavity with 50mm Isover Acoustic Partition Roll (APR 1200) and a single layer 15mm Gyproc SoundBloc board lining installed on one or both sides of the base partition construction. Refer to figure 25 (page 2.36), for example.

The plasterboard should always be neatly cut and Gyproc Sealant should be applied where optimum acoustic performance is required.

In wall linings and ceilings, access for services may be required for routine maintenance, inspection, upgrading or repair. Services should be routed through the lowest acoustic performing wall where possible. Penetrations of fire-resistant constructions for services need careful consideration to ensure that the integrity of the element is not impaired, and also that the services themselves do not act as the mechanism for fire spread. It is important to use only those services and their installations that have been shown by a fire test to be able to maintain the integrity of the construction. By designing service zones, through which all services pass, the number of individual service penetrations can be minimised. Service zones can be sealed after installation of the services using a tested and substantiated fire-stopping system.

In most situations, the services will be installed by contractors other than the drylining contractor. It is important, therefore, that all relevant contractors are advised as to where and how their service penetrations should be made and maintained. The necessity to independently support services will depend on their size and weight and the drylining specification.

There is a wide variety of fixing devices suitable for securing fixtures and fittings to our systems. Generally, the choice of individual fixing devices will depend on the type of system and the loading requirements. This section gives recommendations on the selection of generic devices and proprietary fixings. Tables 14 and 15 gives example fixing devices and typical applications in drywall systems to meet the specific load criteria for single fixtures. It is important to ensure that the drylining system specified is capable of supporting the loads, particularly if installing multiple fixtures. Furthermore, it may be necessary to incorporate several fixings per fixture to ensure the weight is distributed across the drylining system rather than a point load, particularly for medium to heavy fixtures.

The guidance given is primarily concerned with fixtures at the time of installation. For subsequent installation, especially for heavier fixtures, the identification of studs and noggings within the lining / partition system will be required in order to attach the fixtures at these points.

Duct / damper penetration through drywall systems

Fire and smoke resisting dampers can be installed in our systems. Dampers prevent fire and smoke from passing from one fire compartment to another through heating, ventilation and air conditioning systems. 'An Industry Guide to the Design for the Installation of Fire and Smoke Resisting Dampers' is available from the Association of Specialist Fire Protection (ASFP) or as a download from asfp.org.uk. This document refers the designer to the principles of construction, and in particular to tested constructions, or to constructions assessed for performance in fire by a suitably qualified person.

Service installations

System design principles

Table 14 – Example fixing devices and typical Safe Working Loads (SWL) on partitions and wall linings

System	Lightweight fixtures up to 3kg (e.g. socket)	Lightweight to medium fixtures up to 4 - 8kg (e.g. small mirror)	Medium weight fixtures 9 - 20kg (e.g. shelf)	Medium to heavy fixtures 21 - 50kg (e.g. cupboard)	Heavy fixtures 51 - 100kg (e.g. basin)
GypWall Shaft and GypLyner Independent	A	B or C	D, E or I	G, H or I	K
Timber stud	A	B or C	K or D	K	K
DriLyner Dab and DriLyner Fix	A	B	F	L	L
GypLyner Single	A	B or C	D or E	K	K

Reference and detail		Description	Typical SWL** (typical failure load)
A		No. 10 woodscrew into Gyproc plasterboard	3kg (12kg)
B		Steel picture hook and masonry nail into Gyproc plasterboard	4kg (16kg)
C		Metal self-drive into single layer Gyproc plasterboard Metal self-drive into double layer Gyproc plasterboard	6kg (24kg) 8kg (32kg)
D		Steel expanding cavity fixing, e.g. M5 x 40, into Gyproc plasterboard (board thicknesses up to 12.5mm) Steel expanding cavity fixing, e.g. M5 x 65, into plasterboard (board thicknesses from 15mm to 28mm)	12kg (48kg) 18kg (72kg)
E		British Gypsum Drywall Screw fixed through Gyproc plasterboard into 0.5mm Gypframe metal stud / Gypframe 99 FC 50 Fixing Channel	19kg (76kg)
F		Heavy duty plastic plug fixed through Gyproc plasterboard into masonry with 55mm minimum penetration	20kg (140kg)
G		British Gypsum Jack-Point Screws fixed through Gyproc plasterboard into minimum 0.9mm Gypframe metal stud	30kg (120kg)
H		No.12 self-tapping screws fixed through Gyproc plasterboard into minimum 0.9mm Gypframe metal stud	50kg (200kg)
1		Steel expanding metal cavity fixing, e.g. M4 x 40, through Gyproc plasterboard into 0.9mm Gypframe metal stud (board thicknesses up to 12.5mm) Steel expanding metal cavity fixing, e.g. M4 x 65, through Gyproc plasterboard into 0.9mm Gypframe metal stud (board thicknesses from 15mm to 28mm) Steel expanding metal cavity fixing, e.g. M5 x 65, fixing through Gyproc plasterboard into plywood supported by Gypframe Service Support Plate	40kg (160kg) 50kg (200kg) 50kg (200kg)
J		8mm steel frame fixing fixed through Gyproc plasterboard into masonry with minimum 55mm penetration	60kg (240kg)
K		No.12 self-tapping screw fixed through Gyproc plasterboard into timber sub-frame	120kg (480kg)
L		M8 steel bolt / anchor fixed through Gyproc plasterboard into masonry with minimum 55mm penetration	130kg (520kg)

* For GypWall Resilient, ensure that the fixings do not bridge the Gypframe RB1 Resilient Bars, otherwise the acoustic performance will be compromised.
** Safe Working Load (SWL) - a safety factor of 4 (steel fixings) and 7 (plastic fixings) has been used.

Service installations

System design principles

Table 15a – Example fixing devices and typical Safe Working Loads (SWL) on partitions incorporating Rigidur H

Reference and detail		Description	Typical SWL** (typical failure load)
B		Steel picture hook and masonry nail into Rigidur H 12.5mm Steel picture hook and masonry nail into Rigidur H 15mm	17kg (68kg) 18kg (72kg)
F		Fischer PD nylon plug and screw into Rigidur H 12.5mm or 15mm	20kg (72kg)
A		No. 10 woodscrew into Rigidur H 12.5mm or 15mm	15kg (60kg)
I		Fischer HM8 x 55 steel cavity fixing into Rigidur H 15mm	49kg (196kg)
M		Fischer KD6 steel cavity fixing into Rigidur H 12.5mm Fischer KD6 steel cavity fixing into Rigidur H 15mm	58kg (232kg) 74kg (296kg)

Table 15b – Example fixing devices and typical Safe Working Loads (SWL) on partitions incorporating Gyproc Habito

Reference and detail		Description	Typical SWL** (typical failure load)
B		Fischer HM4 x 45.5 steel cavity fixing into Gyproc Habito 12.5mm Fischer HM5 x 52.5 steel cavity fixing into Gyproc Habito 12.5mm Fischer HM6 x 37.5 steel cavity fixing into Gyproc Habito 12.5mm Fischer HM6 x 52.5 steel cavity fixing into Gyproc Habito 12.5mm	13kg (52kg) 28kg (113kg) 35kg (141kg) 41kg (167kg)
M		Fischer KD6 steel cavity fixing into Gyproc Habito 12.5mm	65kg (262kg)

* For GypWall Resilient, ensure that the fixings do not bridge the Gypframe RB1 Resilient Bars, otherwise the acoustic performance will be compromised.
** Safe Working Load (SWL) - a safety factor of 4 (steel fixings) and 7 (plastic fixings) has been used.

For technical assistance on above fixings please contact the fixings manufacturer. The suitability of the fixing must be confirmed by the building designer / fixing manufacturer.

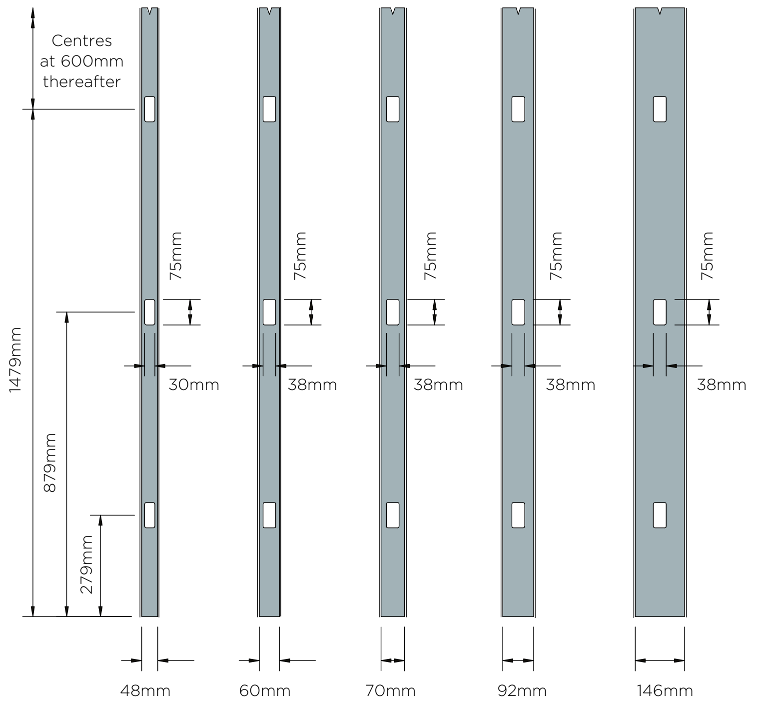
Reference can also be made to the Construction Fixing Association (CFA) guidance note 'Fixing For Plasterboard', which can be accessed at fixingscfa.co.uk

The information within tables 14, 15a and 15b, does not take into consideration any additional forces that may be applied, whether it be accidental, abusive or otherwise. The example fixing devices, typical safe working loads and typical failure loads given in table 16 relate to the installation of single fixtures. It is important to ensure that the drylining system specified is capable of supporting the loads, particularly if installing multiple fixtures. Furthermore, it may be necessary to incorporate several fixings per fixture to ensure the weight is distributed across the drylining system rather than a point load, particularly for medium to heavy fixtures. Careful assessment must be done if anchors are spaced in close proximity to each other. To achieve the quoted maximum allowable loads, fixings must not influence each other and shall be spaced far apart so that the zone of influence is not overlapping each other.

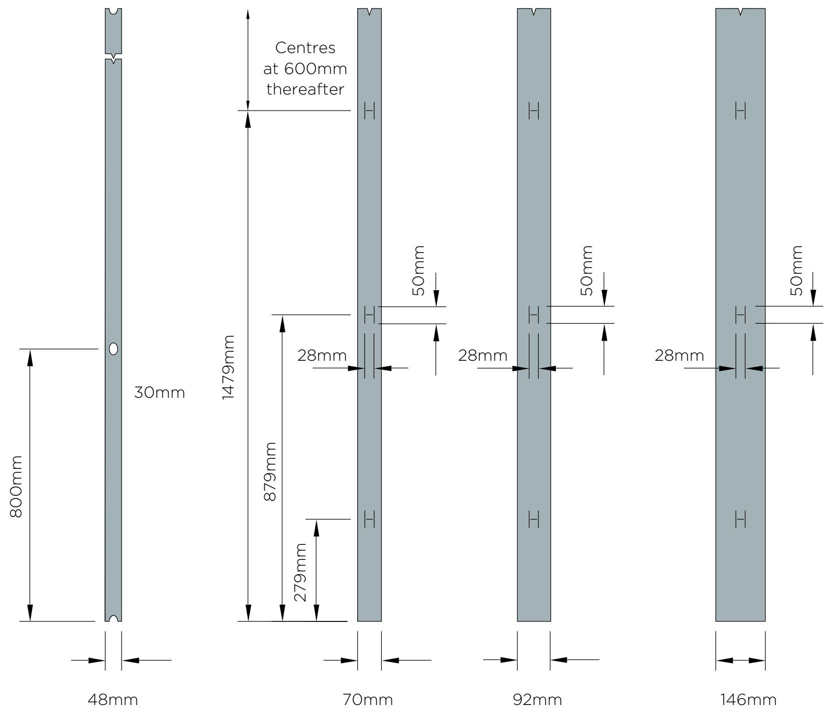
When specifying a fixing to / through Gyproc ThermaLine, please give consideration to the thickness and compressibility of the insulation to ensure that the fixing used is fit for purpose.

Service installations
System design principles

15. Gypframe studs service cut-out details – Gypframe ‘C’ and Gypframe ‘I’ Studs

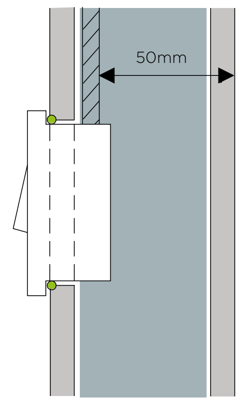


16. Gypframe studs service push-out details – Gypframe AcouStuds

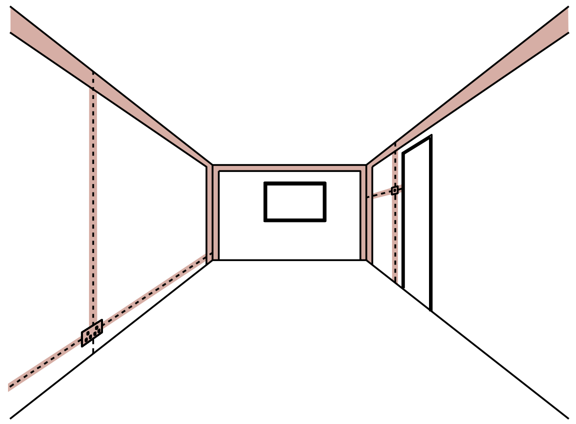


Service installations
System design principles

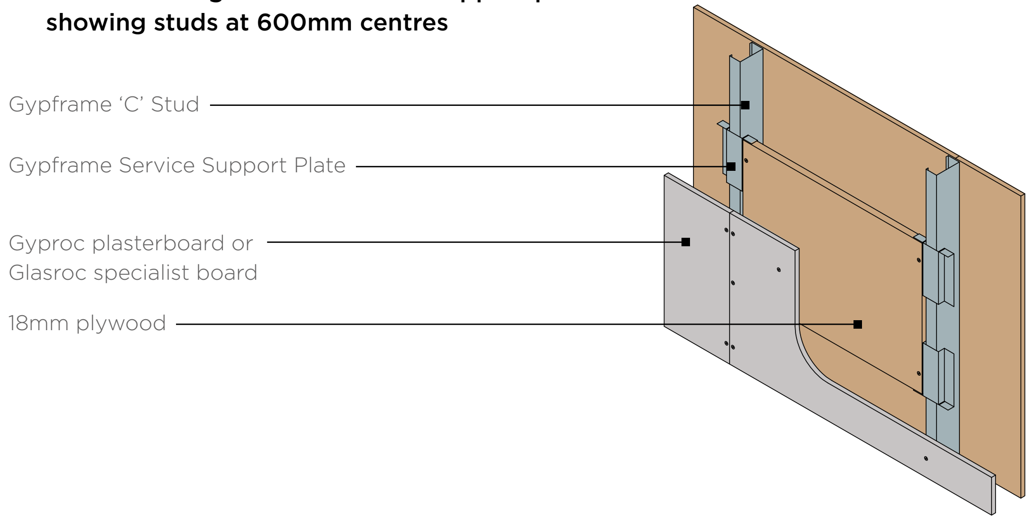
17. Minimum distance of cabling



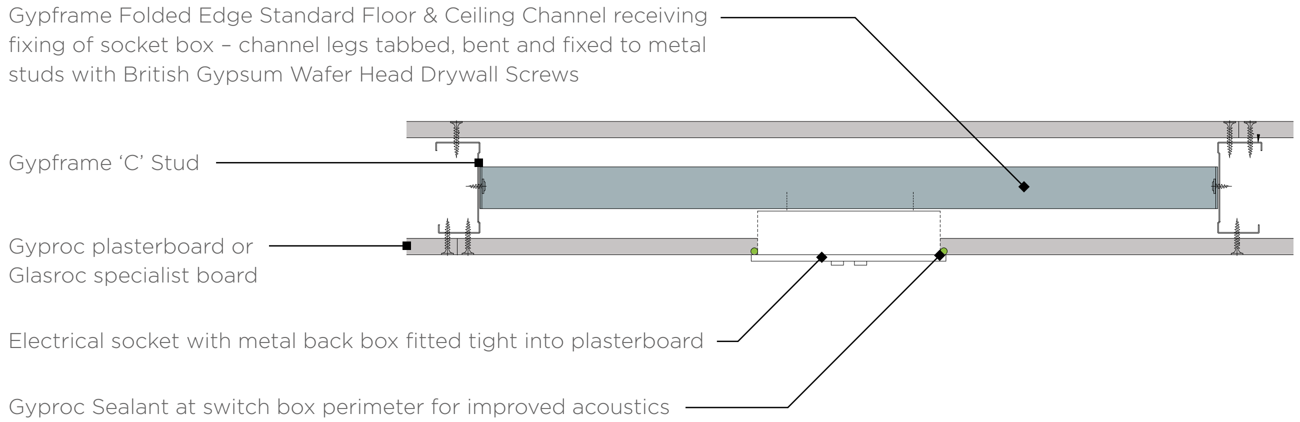
18. Standard zones of cabling



19. General arrangement of service support plates showing studs at 600mm centres



20.Socket box installation – up to 30 minutes fire resistance



Service installations
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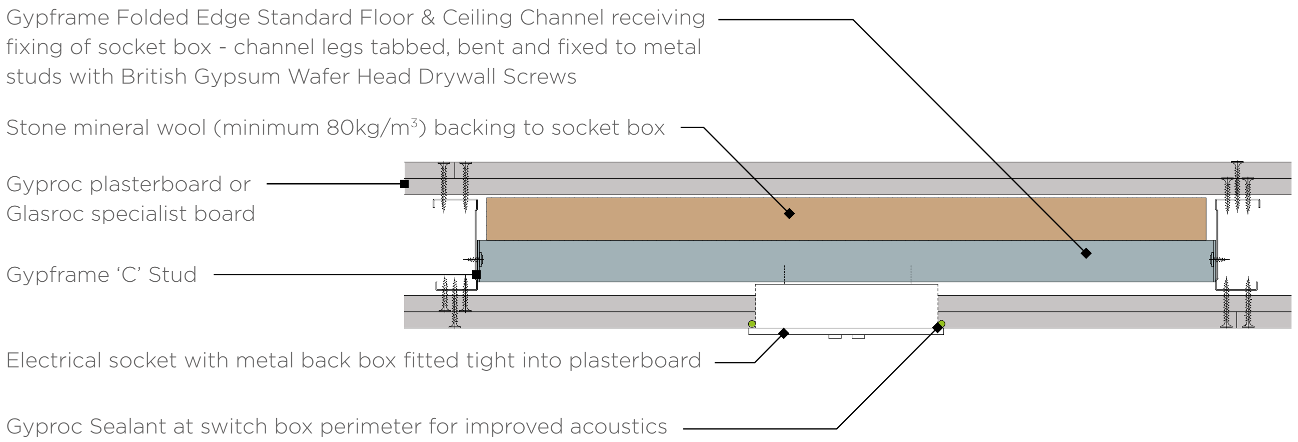
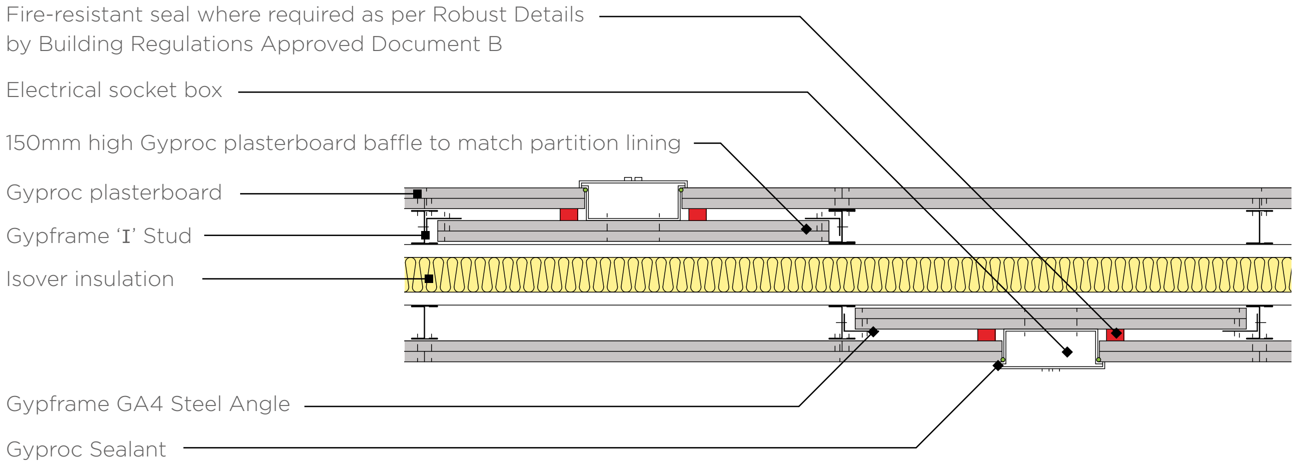
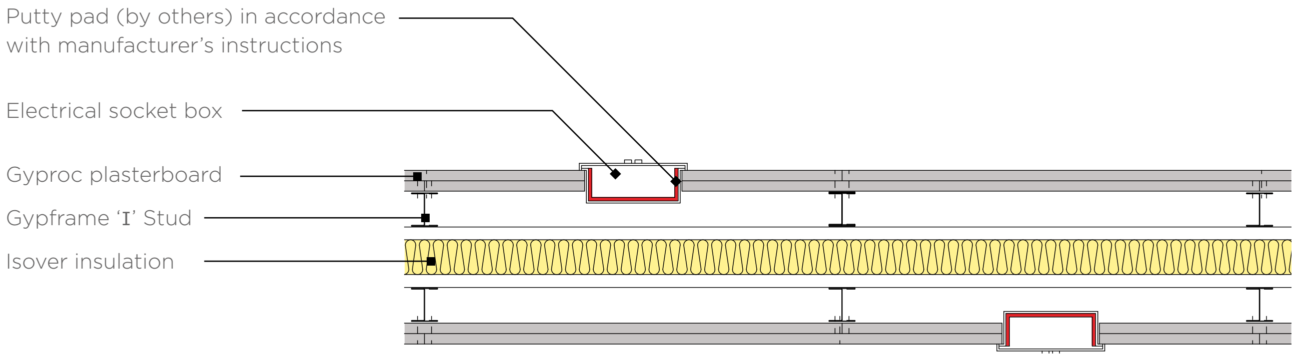
21. Socket box installation – up to 120 minutes fire resistance (subject to board type)



22. Electrical socket box with plasterboard baffle in GypWall Twin Frame Independent



23. Electrical socket box with putty pad in GypWall Twin Frame Independent



Service installations
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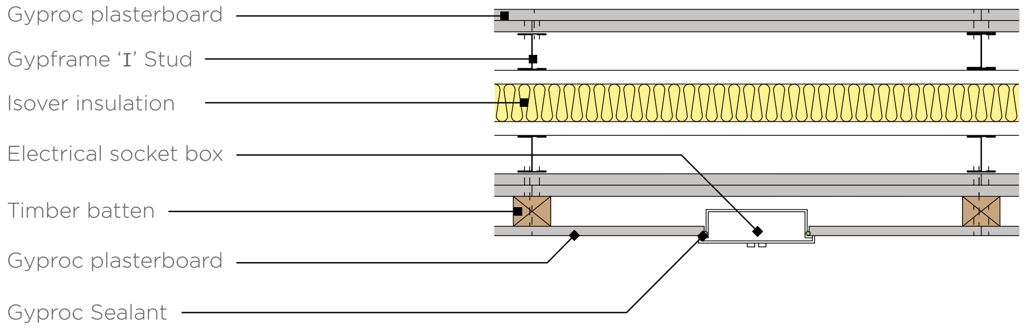
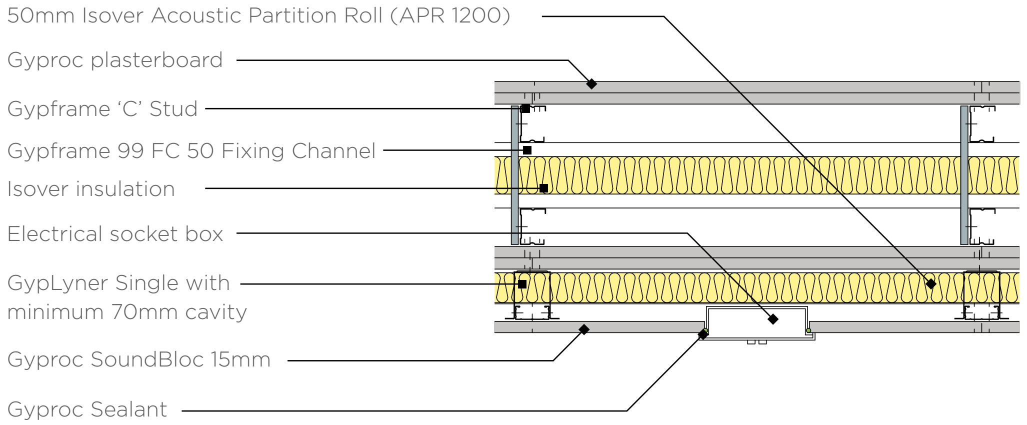
24. Robust Details sacrificial lining where a slight performance downgrade is not detrimental to the system



25. Electrical socket box in sacrificial lining to GypWall Twin Frame Braced



Thermal insulation
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Legislation and guidance documents

Building Regulations (England) - Thermal insulation
Minimum energy efficiency requirements in England are set out in Building Regulations Approved Document L (AD L), Conservation of fuel and power.

AD L comprises the following four documents:

- AD L1A Conservation of fuel and power in new dwellings
- AD L1B Conservation of fuel and power in existing dwellings
- AD L2A Conservation of fuel and power in new buildings other than dwellings
- AD L2B Conservation of fuel and power in existing buildings other than dwellings

Compliance with AD L1A for new dwellings is based on both the carbon dioxide performance and the fabric energy efficiency of the dwelling. Compliance targets are given through the use of the Standard Assessment Procedure (SAP calculation) and although compliance cannot be demonstrated by the elemental U-value method, U-values are important requirements within the SAP calculation. Limiting fabric parameter U-values are given in AD L1A but U-values better than these are likely to be required and AD L1A includes model U-values within a concurrent notional dwelling specification. Air permeability / airtightness is also a requirement within the SAP calculation. Refer to table 16a.

Compliance with AD L2A Conservation of fuel and power in new buildings other than dwellings is based upon the carbon dioxide performance. Compliance targets are given through the use of the Simplified Building Energy Model (SBEM) and although compliance cannot be demonstrated by the elemental U-value method, U-values are important requirements within the SBEM calculation. Limiting fabric parameter U-values are given in AD L2A but U-values better than these are likely to be required and AD L2A includes model U-values within a concurrent notional building specification. Air permeability is also a requirement within the SBEM calculation. Refer to table 16b.

AD L1B Conservation of fuel and power in existing dwellings and AD L2B Conservation of fuel and power in existing buildings other than dwellings are based on carbon dioxide performance with the need to meet U-values targets. Where an existing element forms part of the thermal envelope it must have a certain thermal value. This is known as the 'threshold' value. If the existing value of the element equals or is better than the threshold, no thermal renovation will be required. If it is worse than the threshold value then thermal renovation to achieve the required U-values has to be carried out. Refer to tables 17a and 17b.

Table 16a – AD L1A New dwellings

	England		Wales	
	Limiting fabric parameters (U-value)	Concurrent notional dwelling specification (U-value)	Worst acceptable fabric performance (U-value)	Elemental specification (U-value)
Wall	0.30	0.18	0.21	0.18
Floor	0.25	0.13	0.18	0.13
Roof	0.20	0.13	0.15	0.13
Party Wall	0.20	0.00	0.20	0.00

Table 16b – AD L2A New buildings other than dwellings

	England		Wales	
	Limiting fabric parameters (U-value)	Concurrent notional dwelling specification (U-value)	Worst acceptable fabric performance (U-value)	Elemental specification (U-value)
Wall	0.35	0.26	0.35	0.26
Floor	0.25	0.22	0.25	0.22
Roof	0.25	0.18	0.25	0.18

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Table 17a – AD L1B Existing dwellings

	England		Wales	
	New thermal elements (including replacements for existing elements) (U-value)	Upgrading retained thermal elements (U-value)	New thermal elements (including replacements for existing elements) (U-value)	Upgrading retained thermal elements (U-value)
Wall	0.28	0.30	0.21	0.30
Floor	0.22	0.25	0.18	0.25
Pitched roof, insulation at ceiling level	0.16	0.16	0.15	0.16
Pitched roof, insulation at rafter level	0.18	0.18	0.15	0.18
Flat roof or roof with integral insulation	0.18	0.18	0.15	0.18

Table 17b – AD L2B Existing buildings other than dwellings

	England		Wales			
	New thermal elements (including replacements for existing elements) (U-value)	Upgrading retained thermal elements (U-value)	New thermal elements (including replacements for existing elements) (U-value)			Upgrading retained thermal elements (U-value)
			Buildings essentially domestic in character*	All other buildings	Conservatories and porches	
Wall	0.28	0.30	0.21	0.26	0.28	0.30
Floor	0.22	0.25	0.18	0.22	0.22	0.25
Pitched roof, insulation at ceiling level	0.16	0.16	0.15	0.15	0.16	0.16
Pitched roof, insulation at rafter level	0.18	0.18	0.15	0.18	0.18	0.18
Flat roof or roof with integral insulation	0.18	0.18	0.15	0.18	n/a	0.18

* e.g. student accommodation, care homes

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Table 18a – Technical Handbook Section 6 (Domestic) New buildings		
	Scotland	
	Maximum (U-value W/m²K)	Notional dwelling, package of measure (U-value W/m²K)
Wall	0.22	0.17
Floor	0.18	0.15
Roof	0.15	0.11
Cavity separating wall	0.20	0.00

Table 18b – Technical Handbook Section 6 (Non-Domestic) New buildings				
	Scotland			
	Maximum (U-value W/m²K)		Notional dwelling (U-value W/m²K)	
	Fully fitted building	Shell only	Heated and naturally ventilated	Heated and mechanically ventilated / cooled
Wall	0.27	0.23	0.23	0.20
Floor	0.22	0.20	0.22	0.20
Roof	0.20	0.15	0.18	0.16

Table 19a – Technical Handbook Section 6 (Domestic) Existing buildings			
	Scotland		
	Extensions (and conversion of previously unheated buildings) (U-value W/m²K)		Conversion of heated buildings (and conservatories) (U-value W/m²K)
	Existing building U-values worse than 0.70 for walls and 0.25 for the roof	Existing building U-values equal/better than 0.70 for walls and 0.25 for the roof	
Wall	0.17	0.22	0.30
Floor	0.15	0.18	0.25
Pitched roof, insulation between ceiling ties or collars	0.11	0.15	0.25
Roof	0.13	0.18	0.25

Table 19b – Technical Handbook Section 6 (Non-Domestic) Existing buildings		
	Scotland	
	Extensions (and conversion of previously unheated buildings) (U-value W/m²K)	Conversion of heated buildings (U-value W/m²K)
Wall	0.25	0.30
Floor	0.20	0.25
Roof	0.15	0.25

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Building Regulations – Condensation

In England the requirements are set out in Building Regulations Approved Document C – site preparation and resistance to contaminants and moisture.

The walls, floors and roof of the building shall adequately protect the building and people who use the building from harmful effects caused by interstitial and surface condensation. To provide resistance to surface condensation and mould growth, guidance is also given to ensure that the U-value does not exceed 0.70 W/m²K at any point within an external wall and within a floor (ground floor and other floors exposed from below) and 0.35 W/m²K at any point within a roof.

Guidance documents

Accredited Construction Details
Published by Local Government, it is intended to assist the construction industry to comply with the performance standards published in AD L. It focuses on issues concerning insulation continuity and airtightness, providing theoretical information and large scale indicative drawings. It can be accessed via the website planningportal.gov.uk

BR443 U-value conventions
Published by the Building Research Establishment (BRE), it provides calculation methods for the determination of U-values of building elements and includes common issues, together with data on typical constructions and the thermal conductivity of materials.

BR262 Thermal insulation avoiding risks
Published by the BRE, it highlights risks, causes and solutions of thermal design. The guidance supports the Building Regulations and represents the recommendations on good design and construction practice associated with thermal standards.

BS EN 12524 Building material and products. Hygrothermal properties. Tabulated design values
This gives design data in tabular form for heat and moisture transfer calculations, for thermally homogeneous materials and products commonly used in building construction. It also gives data to enable calculations and conversion of design thermal values for various environmental conditions.

BS EN ISO 13788: 2012 Hygrothermal performance of building components and building elements. Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation method

Commonly known as the 'Glaser' method, this deals with the critical surface humidity likely to lead to problems such as mould growth on the internal surfaces of buildings and interstitial condensation within a building component. It also deals with estimation of the time taken for a component, between high vapour resistance layers, to dry, after wetting from any source, and the risk of interstitial condensation occurring elsewhere in the component during the drying process.

BS EN ISO 15026 Hygrothermal performance of building components and building elements – Assessment of moisture transfer by numerical simulation
Commonly known as the 'WUFI' method, this standard defines the practical application of hygrothermal simulation software used to predict one-dimensional transient head and moisture transfer to multi-layer building envelope components subjected to non steady climate conditionsl on either side. In contrast to the steady-state assessment of interstitial condensation by the Glaser method (as described in EN ISO 13788), transient hygrothermal simulation provides more detailed and accurate information on the risk of moisture problems within building components and on the design of remedial treatment. While the Glaser method considers only steady-state conduction of heat and vapour diffusion, the transient models covered in this standard take account of heat and moisture storage, latent heat effects, and liquid and convective transport under realistic boundary and intial conditions.

BS EN ISO 6946 Building components and building elements. Thermal resistance and thermal transmittance. Calculation method
This gives the method of calculation of the thermal resistance and thermal transmittance of building components and building elements, excluding doors, windows and other glazed units; components that involve heat transfer to the ground; and components through which air is designed to permeate. The calculation method is based on the appropriate design thermal conductivities or design thermal resistances of the materials and products involved.

BS 5250 Code of practice for control of condensation in buildings
This describes the causes and effects of surface and interstitial condensation in buildings, and gives recommendations for their control.

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The provision of thermal insulation

Reducing heat loss
Any building with an internal temperature higher than the external temperature will lose heat. Thermal insulation reduces this heat loss and therefore helps to conserve energy and reduce heating costs.

To comply with Building Regulations, levels of thermal performance are required for the external walls, roof and floors of almost all building types. Adequate insulation must also be provided for hot water heating services, pipes, warm air ducts and hot water storage vessels.

Savings are maximised where insulation is supported by other measures such as automatic controls, which govern the operation and output of heating systems and the temperature of stored water.

In addition to providing high levels of thermal performance in newly constructed buildings, insulation products and systems are also incorporated into existing buildings where the energy efficiency of the building may be inadequate. This will apply equally to both non-domestic buildings and to the existing housing stock. The scale of inefficiency for the latter has been highlighted by various Government surveys and subsequent corrective measures.

When specifying the insulation system for a particular building it is important to take into account both the heating regime and the pattern of usage of the building.

Infrequently heated buildings
If a building is only infrequently heated, thermal insulation materials should be located as near as possible to the internal surface of exposed building elements to provide a quick thermal response to heating input. This is essential in such conditions to reduce internal surface condensation during the warm-up period, when the maximum amount of water vapour is often produced. It will also ensure that comfortable room temperatures are quickly achieved.

Gyproc ThermaLine laminates are extensively used in both new and existing buildings to provide internal lining and insulation in one fixing operation. They can allow national Building Regulation standards to be achieved using clear cavity external wall construction and provide a continuous insulation layer over the whole external wall area, helping to reduce the thermal bridge effects at lintels and reveals.

Regularly heated buildings
Heating regimes may be of a regular nature, with relatively equal periods of heating activity and non-activity, as may occur in housing during winter months. In this situation, traditional forms of high mass construction, such as double leaf cavity walls, can effectively exploit the 'heat store' concept when thermal insulation is positioned within the cavity. Extreme air temperature fluctuations within the building can be subdued as heat stored in components within the insulation 'envelope' is dissipated back into the building. Further benefits can be derived from the reduced size and complexity of space heating equipment necessary to maintain room temperatures.

Airtightness
Airtightness describes the air leakage characteristics of a building. This determines the uncontrolled background ventilation or leakage rate of a building.

Airtightness is expressed in terms of a whole building leakage rate at an artificially induced pressure (usually 50Pa). The lower the air leakage rate, the greater the airtightness. For example, within AD L1A an upper limit on air permeability of $10m^3/hour/m^2$ is required. In practice, most designs will need to be significantly better than this. Improving a building's airtightness is crucial to improving the energy performance of a building.

Although air leakage can occur directly, the majority of leaks occur indirectly. Air leakage paths are often complicated and therefore air leakage can be difficult to trace and seal effectively. However, the following is a list of some example air leakage paths:

- Cracks, gaps and joints in the structure
- Timber floors
- Joist penetrations of external walls
- Windows and doors
- Loft hatches
- Skirting boards
- Chimney and flues
- Service entries, ducts and electrical components
- Areas of un-plastered walls

To improve airtightness when using a plasterboard internal drylining system, e.g. DriLyner Dab, continuous ribbons of adhesive should be applied around the perimeter of the wall and around openings / penetrations to seal airpaths. Gyproc SoundCoat Plus can be used on most external masonry walls to seal air paths. This may also improve the airtightness before a drylining system is applied to the wall.

Terminology

Thermal conductivity (λ)
This is a measure of a material's ability to transmit heat, and is expressed as heat flow in watts per metre thickness of material for a temperature gradient of one degree Kelvin (K). It is expressed as W/mK.

Generally, dense materials have high thermal conductivity and are inefficient thermal insulants. Lightweight materials have low conductivity and can be efficient thermal insulants. The lower the λ value of a material, the better its insulating efficiency.

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Thermal resistance (R)
This is the measure of the resistance to the passage of heat offered by the thickness of a material and is expressed as m^2K/W. The thermal resistance of a material is obtained by the following calculation:

$$R = \frac{t}{\lambda}$$

Where t = thickness in (m) and λ = thermal conductivity (W/mK)

Thermal transmittance (U-value)
This is a property of the whole construction, including air spaces, and is a measure of its ability to transmit heat under steady state conditions. It is calculated by taking the reciprocal of the sum of all the individual thermal resistances, taking into consideration any thermal bridging, and is expressed as W/m^2K. The lower the U-value of the element the better its thermal insulation.

For the purpose of calculating U-values, thermal resistances for the inside and outside surfaces of a building element, and for any cavities within it, have to be taken into account. This is in addition to thermal resistances directly relating to the actual thickness of materials.

The R-values of inside surfaces, outside surfaces and of any cavities will vary according to the surface emissivity. Emissivity should be taken as high for all normal building materials other than polished or metal surfaces, such as aluminium foil, which are regarded as low.

U-values are used as a common basis for comparing different constructions or for meeting a stated figure. When calculating the U-value of some constructions the effect of components that repeatedly bridge the insulation layer, such as mortar joints in lightweight blockwork, studs in timber and metal framed walls, wall ties, and roof joists, should be taken into account. The U-value is calculated through the thermal bridge and combined with the U-value through the insulation in proportion to its face area, often resulting in a higher U-value for the element. More insulation may be needed to compensate for the presence of thermal bridges and return the U-value to a specified level. This can also be achieved by changing to a more efficient insulant. The additional heat loss for non-repeating thermal bridges, such as details at window and door openings, is determined separately.

Thermal mass / heat sink
Thermal mass describes a material's capacity to absorb, store and release heat. For example, water and concrete have a high capacity to store heat and are referred to as 'high thermal mass' materials. Insulation foam, by contrast, has very little heat storage capacity and is referred to as having 'low thermal mass'. Gyproc plasterboards and Rigidur H are effective in contributing towards the thermal mass effect. Thermal mass design, for example in school buildings, is a means of ensuring overheating is kept under control.

This principle is included with the SBEM and SAP procedure within which it is expressed as a Kappa (κ) value in calculating the thermal mass parameter to characterise the thermal mass of the building. As an example within SAP, the heat capacity κ of a single layer plasterboard partition is given as 9 kJ/m^2K.

Condensation control in buildings

Harmful effects of condensation
Condensation can be one of the worst problems that designers, owners or occupants of buildings experience. Dampness and mould growth caused by surface condensation can not only be distressing to the occupants of a building, but can eventually lead to damage in the building itself.

The thermal insulation and ventilation requirements of national Building Regulations aim to reduce the risk of condensation and mould growth occurring in new buildings. However, designers should take care to eliminate all problems caused by condensation, particularly in refurbishment projects on existing buildings, where situations exist that are not directly covered by the regulations.

Reducing the risk
Due to changes in building design, occupancy patterns and increased thermal requirements, all buildings, particularly houses, are more sensitive to condensation now than in previous years. Homes tend to be heated intermittently and moisture-producing activities are concentrated into relatively short periods of time.

Thermal insulation correctly positioned within specific building elements, combined with adequate heating and the necessary water vapour control and ventilation, where appropriate, should ensure trouble-free design.

How condensation occurs
At any given temperature, air is capable of containing a specific maximum amount of water in vapour form. The warmer the air, the greater the amount of water vapour it can contain. Conversely, the lower the temperature, the smaller the amount.

Water vapour in air exerts a pressure, called the vapour pressure. Any differential in vapour pressure causes vapour to diffuse from high to low pressure areas.

Warm air inside a building usually contains more moisture than external air, due either to the occupants' activities or resulting from the evaporation of residual moisture in new construction. This creates a pressure differential across structural elements. Water vapour in the internal air, being at a higher pressure, tends to diffuse through the structure towards the colder, lower pressure exterior.

If moisture-laden air comes into contact with a cold surface it will cool. As it cools, the amount of water it can hold in vapour form reduces until, at a specific temperature called the dew point, it becomes saturated. Water is then deposited in the form of condensation.

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Surface condensation
Surface condensation occurs when air containing water vapour comes into contact with highly vapour resistant surfaces, which are at, or below, the dew point temperature. Refer to figure 29 – 'Surface condensation' (page 2.47). It usually shows itself as beads of water, damp patches, and, where the condition persists, mould growth.

Surface condensation can be in localised zones in a particular building element caused by the presence of 'cold bridges', such as mortar joints in walls, which can be colder than the rest of the wall structure.

In addition, warm moist air will diffuse through a building into colder rooms, such as poorly heated bedrooms and stairwells. This is one reason why surface condensation does not always occur in the room where water vapour is produced.

Interstitial condensation
Warm moist air will also diffuse through building elements to reach colder, lower pressure conditions outside. If the building materials have low water vapour resistance it is possible for condensation to occur within the building element. This will occur on the first cold surface, at or below dew point temperature, which is encountered by the moisture vapour on its passage through the structure. As an example, for double skin masonry walls, the position for condensation to form is on the inner face of the outer leaf whether or not insulation is included in the cavity. Refer to figure 30 – 'Interstitial condensation' (page 2.47).

There is no evidence to suggest that interstitial condensation will occur within the core of building materials under general building and climatic conditions. For other types of building structure vapour control layers can help to eliminate the risk of interstitial condensation. It is recommended that the risk of harmful condensation be assessed using an appropriate calculation procedure, for example as described in BS 5250. Refer to table 21 for typical hygrothermal properties.

Designing to reduce condensation risk

Thermal insulation
Thermal insulation helps to reduce the risk of surface condensation by maintaining surfaces above the dew point temperature subject to adequate heating being provided.

In buildings that are heated infrequently, the thermal insulation should be located as near as possible to the internal surface of building elements to provide rapid thermal response. These surfaces will then be less prone to surface condensation during the warm-up period, which is often when the maximum amount of water vapour is produced. Being located on the warm side of the structure, Gyproc ThermaLine will help to provide this rapid thermal response and will also reduce the thermal bridge effects in a building, e.g. at lintels and reveals.

With some construction types the potential problem may be one of interstitial condensation. Gyproc ThermaLine is available with integral vapour control to minimise the risk. Alternatively, the choice of construction may demand a different position for insulation, away from the surface lining. Surface condensation will not generally be a problem in these circumstances, particularly where adequate heating is provided. Consideration should be given to establishing whether the particular construction brings with it any increased risk of interstitial condensation.

For most constructions the use of vapour permeable insulation, in combination with other building materials of low vapour resistance, will allow the structure to breathe naturally. In this instance, the likely occurrence of interstitial condensation will be shifted to less problematic areas, such as masonry walls (inner face of the outer leaf).

Thermal bridging, particularly at junctions, abutments and openings can occur and therefore good detailing is essential. Information on Psi (j) values (linear thermal transmission) relating to thermal bridging details is contained within SAP, and within Accredited Construction Details (ACDs) which are available to view at planningportal.gov.uk/buildingregulations/approveddocuments/partl/bcassociateddocuments9/acd

Heating
Adequate heating helps to keep the temperature of the internal surfaces above the dew point. Ideally, an air temperature above 10°C should be maintained in all parts of the building.

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Ventilation
Ventilation removes the water vapour produced within a building to the outside air. Adequate ventilation, including the provision of small controllable slot ventilators in windows, electrical extractor fans controlled by humidistats in bathrooms and kitchens, and cooker hoods extracted to the outside air, will help to reduce harmful condensation and mould growth. Ideally, ventilation should control the internal air to between 40% and 70% relative humidity (RH) for human occupation.

Condensation can occur in roof spaces of slated or tiled pitched roofs of dwellings, and in timber joisted flat roofs with insulated ceilings, unless adequate ventilation is provided. Precautions should be taken, in particular the provision of adequate cross-ventilation of the roof spaces to the outside. The main requirements for ventilation in buildings are given in the national Building Regulations Approved Document.

Vapour control layer
A vapour control layer, usually in the form of a membrane, is used to substantially reduce the transfer of water vapour through a building element in which it is incorporated. Refer to table 20 for a few example wall and roof constructions.

A vapour control layer, positioned on the warm side of the thermal insulation within a building element, helps to reduce the risk of interstitial condensation occurring within that element. However, other precautions may also be necessary, either in combination with, or as alternatives to, a vapour control layer. These include the use of ventilated cavities and the provision of materials of low vapour resistance, particularly on the colder side of the construction.

Vapour control layers should be as airtight as possible. Holes and penetrations for services should be cut neatly and suitably sealed, or localised condensation may still occur. It is recommended that the risk of harmful interstitial condensation is assessed using the calculation procedure given in BS 5250.

Existing masonry walls
Internal drylining system:
Gyproc ThermaLine containing vapour control layers can reduce the risk of interstitial condensation, provided the existing wall has low vapour resistance and does not incorporate any other material of high vapour resistance on the cold side of the construction.

New masonry walls
Full fill or partial fill cavity:
Positioning Isover CWS 32 or 36 Batt insulation within the cavity, either full fill or partial fill, can maintain the internal surface of the wall above dew point temperature and negate the cold bridging effects of mortar joints. Therefore a water vapour resistant treatment to the surface of internal plaster finishes is not always necessary because any interstitial condensation will occur on the inner surface of the outer leaf. Thistle plaster, or Gyproc WallBoard, fixed in the DriLyner or GypLyner systems, form suitable linings. Where a vapour control layer is required, the plasterboard lining surface can be treated with two coats of Gyproc Drywall Sealer. Alternatively, Gyproc WallBoard Duplex can be specified in conjunction with the DriLyner Fix or GypLyner systems.

Refer to NHBC categories of exposure to wind driven rain for suitability of project location.

Gyproc ThermaLine, internal drylining system:
Where cavity insulation is not appropriate or does not meet the U-value requirement alone, a drylining system using a Gyproc ThermaLine could be considered which will provide both thermal performance and a vapour control layer.

Timber / steel frame walls
To reduce the risk of interstitial condensation occurring on the inner surface of the sheathing, a vapour control layer is required as part of the internal lining, refer to NHBC (Technical Standards for domestic applications) at nhbc.co.uk. Isover timber frame insulation is positioned within the stud cavity and Gyproc duplex grade plasterboards can be used as the internal face lining. The dew point will then fall within the outer cavity or external cladding.

Where the insulation does not meet the U-value requirement alone, a drylining system using a Gyproc ThermaLine could be considered which will provide both thermal performance and a vapour control layer.

Provision should also be made for water vapour to escape outward, through very low vapour resistance sheathing boards, breather membranes, external claddings and by vented cavities. It is also good practice to ensure that any accumulation of moisture is directed outwards by incorporating flashings, drainage outlets and suitable timber detailing.

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Table 20 – Recommendations for the use of vapour control layers to reduce the risk of interstitial condensation in some example external wall and roof constructions in dwellings

Element	Type of external wall	Vapour control layer required?	Comments
External walls	Timber or metal frame (brick outer leaf)	Yes	Low vapour resistance sheathing board and breather membrane.
	Brick / insulated cavity / block Gyproc plasterboard lining or Thistle plaster	No	Consider vapour control layer in adverse conditions
	Brick / clear cavity / block Gyproc ThermaLine lining	Yes	N/a
	Solid masonry* Gyproc ThermaLine lining on Gypframe metal framing or timber battens	Yes	Ventilation of lining cavity to outside may be required depending on vapour resistance of masonry
Roofs	Cold pitched roof, tiles or slates on battens on membrane over loft space – Ceiling and insulation horizontal	No	Ventilated in accordance with BS 5250 and Approved Document F. Consider vapour control layer in adverse conditions.
	Warm pitched roof, tiles or slates on battens on membrane – Ceiling and insulation inclined	Yes	Ventilated in accordance with BS 5250 and Approved Document F. Minimum 50mm ventilation zone above insulation (unless ventilated tiling battens/counter batten cavity over breathable membrane used)
	Cold flat roof – Insulation at ceiling level (horizontal)	Yes	Ventilated in accordance with BS 5250 and Approved Document F. Minimum 50mm ventilation zone above insulation

Where a vapour control layer is used, it must be airtight, e.g. holes and penetrations for services etc., cut neatly and suitably sealed.

* Solid masonry wall - internal insulation. We reference to the use of Hygrothermal properties of buildings components within modelling software, and in compliance with BE EN 5250 (August 2016), we now recommend specialist guidance to be obtained prior to commencing the installation of internal insulation to solid masonry walls in order to determine the effects of condensation and moisture within the building fabric. This area of expertise is documented within BS 5250 'Code of practice for the control of condensation of building components and building elements - Assessment of moisture transfer by numerical simulation.'

Table 21 – Hygrothermal properties

Material	Specific heat capacity, Cp** J/(kgK)	Water vapour resistance factor, dry** μ	Equivalent water vapour resistivity*** MNs/gm	Typical vapour resistance MNs/g
Gypsum plasterboard	1000	10	50	0.63 (12.5mm thickness)
Gypsum plaster	1000	10	50	0.65 (13mm thickness)
Mineral wool	1030	1	5	0.25 (50mm thickness)
Expanded polystyrene	1450	60	300	15.0 (50mm thickness)
Extruded polystyrene	1450	150	750	37.5 (50mm thickness)
Polyisocyanurate foam	1400	60	300	15.0 (50mm thickness)
Vapour Control layer in duplex grade Gyproc plasterboard	–	–	–	60
Vapour Control layer in Gyproc ThermaLine PIR	–	–	–	4000

** Taken from BS EN 12524 Building materials and products - Hygrothermal properties - Tabulated design values.
*** Using conversion factor as per BS 5250 Code of practice for control of condensation in buildings.

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Pitched roofs

Horizontal insulated ceilings, e.g. cold loft space

Positioning a vapour control membrane at ceiling level should reduce the amount of water vapour migrating into the roof space. In practice, however, a continuous barrier is unlikely to be achieved because of the difficulty of sealing leaks through loft access hatches, electrical wiring drops, pipe penetrations and cracks. Gaps in the ceiling can be much more important in the mechanism of water vapour migration than diffusion through the ceiling itself. Appropriate cross-ventilation of the roof space is necessary.

Insulation, e.g. Isover Spacesaver range, is located on top of and between the ceiling joists and Gyproc plasterboard fixed to the underside. Gyproc duplex grade plasterboards can be used as the ceiling lining if a vapour control layer is required.

Sloping insulated ceilings, e.g. warm room-in-the-roof

Isover Timber Batt insulation is located between the rafters and a minimum 50mm ventilation zone above the insulation is required. However, if the tiling batten / counter batten cavity is vented and a breathable membrane is used, the 50mm vented zone may not be required.

A vapour control layer is required at sloping ceiling level and given that it is likely additional thermal insulation is required to meet the stringent U-value requirements, Gyproc ThermaLine can be used as the sloping internal ceiling lining.

Flat roofs

Cold construction

In a cold roof construction, the thermal insulation, e.g. Isover Timber Frame Batts, is located directly above the ceiling. Most of the structure is on the unheated side of the insulation and is therefore vulnerable to the risk of interstitial condensation.

To reduce this risk, cross-ventilation must be provided above the insulation to disperse water vapour to the outside. Generally a minimum 50mm clear cavity well vented to the external air is required. An effective vapour control layer should be provided at ceiling level and perforations for pipes, electrical wiring drops, etc., should be sealed. Refer to figure 31 – 'Timber flat roof, cold type' (page 2.47). Gyproc duplex grade plasterboards or Gyproc ThermaLine can be used as the internal face ceiling lining.

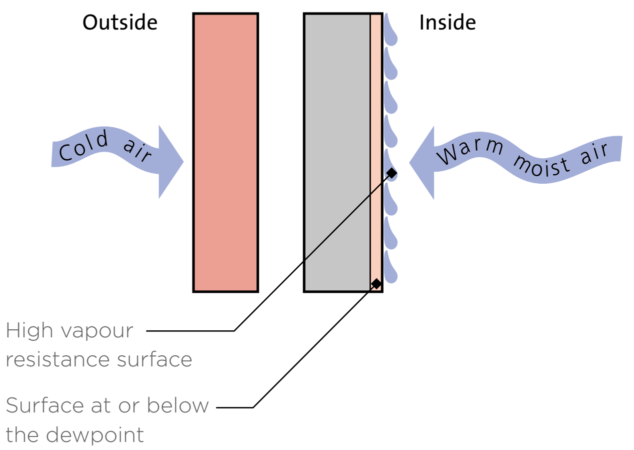
Warm construction

In warm roof construction, the thermal insulation (by others) is located on top of a high performance vapour control layer over the roof decking. The construction is referred to as a warm roof because in winter, with adequate heating, the temperature of the vapour control layer, and of the materials below it, is maintained close to that of the internal air. It may not be necessary to include a vapour control layer at ceiling level or to ventilate the roof cavities. Consideration should be given, however, to the provision of vertical vapour control layers as necessary, e.g. the use of Gyproc duplex grade plasterboards in roof voids between rooms, to reduce the movement of vapour to adjacent rooms, which may be at different temperatures. Refer to figure 32 – 'Timber flat roof, warm type' (page 2.47).

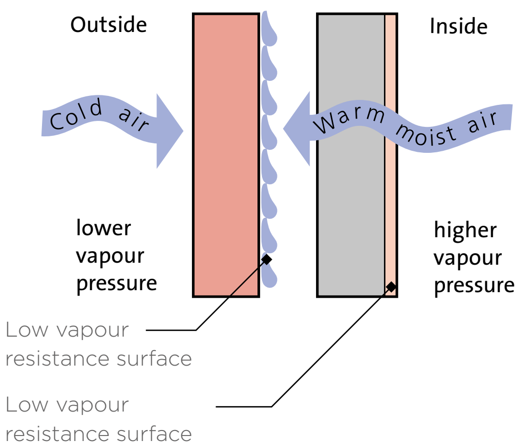
Thermal insulation

System design principles

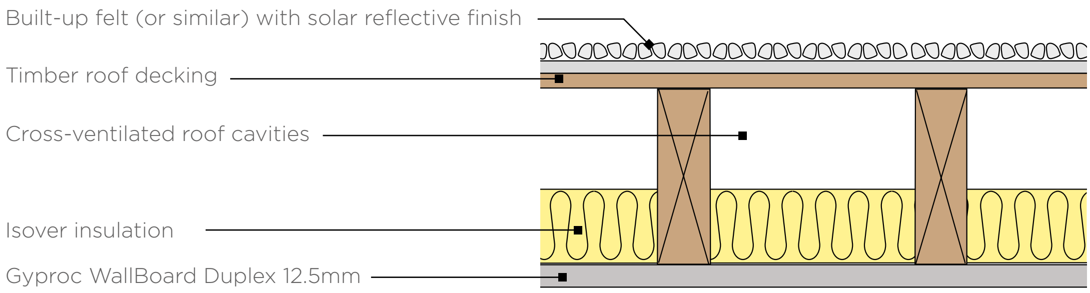
29. Surface condensation



30. Interstitial condensation



31. Timber flat roof, cold type



32. Timber flat roof, warm type