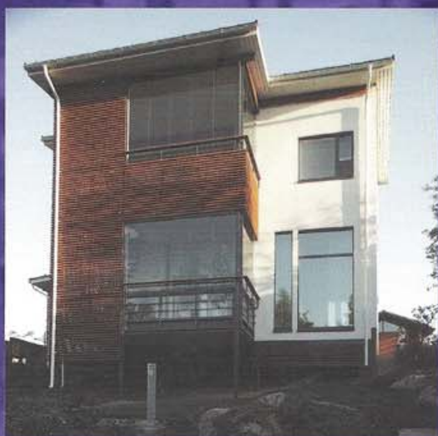
European
Lightweight Steel-framed
Construction



lsk European Light Steel Construction Association

Contents

Light steel solutions for a better world...

As you probably know, steel is one of the most popular prime materials used in construction. Its applications range very broadly from structure, cladding, roofing, floors and partitions, fittings, electricity, HVAC, to decoration. Numerous steel solutions have been successfully developed and implemented in this market for many years.

You may not know that, in the world, every day 45 000 keys are turned into new houses or flats, in cities, in order to accommodate roughly 200 000 people. To have a home or even a mere roof is a will, but also a concern for a lot of people on the Earth, even in developed countries.

The steel industry as a whole, including producers, transformers, distributors, fabricators... is by the way interested to contribute to the satisfaction of these customers. Of course, this specific residential market is fragmented, difficult to reach due to a long supply chain and numerous decision makers.

However, we have an excellent offer, so called "steel framed house", described in this document. We propose to frame houses with light gauge cold rolled galvanized steel profiles, assembled by fasteners, and able to withstand currently two or three levels.

We want to point out few but huge advantages of the steel solution: easy to produce in shops from slitted coils, easy to cut with common tools, easy to assemble with self drilling screws (or some of the other interesting assembling possibilities).This technique allows in addition easy integration of services (plumbing, electricity, air conditioning,...) in the thickness of walls and partitions.

From a sustainability point of view, steel framed house is very efficient. Steel is 100% recyclable, and actually 80% of the steels used in construction come from recycling. Steel is light: you need less foundation, and you can build on regular even poor soils. In addition, thanks to the flexibility of the parameters and to composite materials used in this construction, you can monitor in an efficient way thermal, acoustic and comfort requirements, including the quality of the air.

Architects can develop their skill to present aesthetics homes, with revival of spaces and colours. Steel is a very valuable solution regarding the price of construction (including foundations), the delay to complete the construction (reduction of mortgages and fees), and the costs of functioning and maintenance during the whole life of the house.

I am convinced that in this document, presenting these solutions and their adaptation in various countries, coping with local regulations, you will find ideas to feed your creativity and to develop your own expertise and business efficiency. Of course this building method can be applied to other categories of buildings such as medium commercial or industrial ones.

I invite you to join the European Light Steel Construction Association (LSK), headquartered in Brussels to get more information to design with Eurocode 3 (part 1.3) and to share building experiences.

Pierre Bourrier

President LSK

Introduction

Lightweight steel frame panels have the advantage of lightness, high load-bearing capacity and a wide range of possible uses. Main contractors prefer dry constructions for fitting out offices, warehouses or production premises. However, in some countries, quite a large proportion of private houses and multi-storey residential buildings are also being built at low cost with lightweight steel sections **(fig. 1)**. New products in thin steel sheets, combined with improved plating and insulating materials, make steel an interesting option with an increasing number of applications in modern construction.

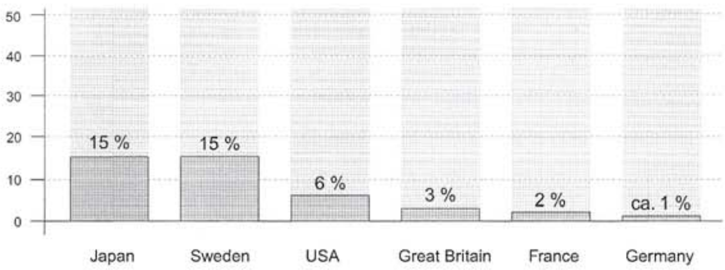


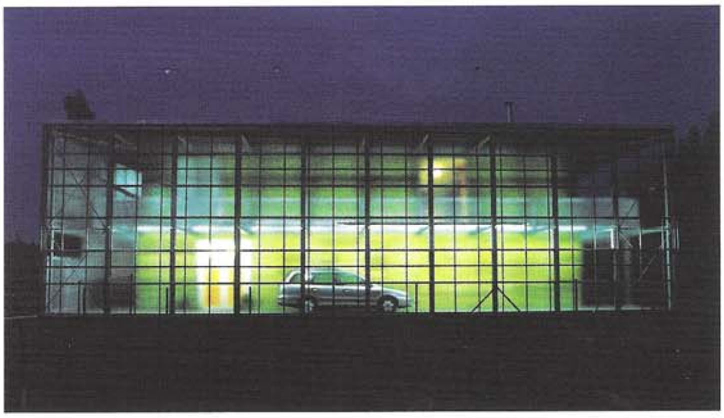
Fig. 1
Percentage of self-supporting steel framing used in residential buildings [3]

With its variety of sections, colours, assembly techniques, associations with other materials and forming techniques, steel can be practically used in an unlimited number of ways. Its recyclable nature is an advantage for the construction of residential buildings.
It has many different finishes and a wide range of forms that enable it to meet all requirements. In addition to being environmentally-safe, this "natural" material is also magnetic; making it easy to extract from disparate waste heaps. All pieces that are collected, regardless of type (for example, scrap) can be fully recycled to produce extremely fine qualities. Currently, nearly 50% of total steel production is derived from recycled used metals.
Steel meets the requirements of a type of building that protects natural resources. It can be used to make members that are durable, separable, dismountable and reusable, that on the whole use up very little of the earth's non-renewable reserves.

Lightweight steel-framed constructions are composed of studs and beams made from thin C, U or Z-shaped cold-formed sections. The thickness of the sheet can range between 0.6 to 2.5 mm for a maximum mass per unit of length of 0.075 kN/m.
This is a relatively new process with many functional and technological qualities that make steel particularly well-suited for building construction **(Fig. 2, 3, 4)**.
Lightweight steel constructions have many advantages:
- very light;
- exceptionally solid in relation to weight;
- dimensional stability;
- excellent acoustic properties;
- stability of shape in case of humidity;
- rapid on-site erection;
- considerable potential for the recycling and reuse of all the materials used;
- incombustibility (category A material): however its resistance to fire depends on the plating material; no increased risk of fire during building;
- top-quality assembly techniques;
- easy to prefabricate.

The structure in light sections is covered with plates. The choice of the material used to cover the sections and the thickness of this material depend on the physical constraints of the member. For internal partitions, plasterboard or fibre-plaster plates are preferred because they provide good acoustic properties when they are used to cover thin sections. Also, in the event of a fire, they reduce the heat that reaches the sections. They are also easy to paint and wallpaper **(Fig. 5, 6, 7)**.
Lightweight steel construction can be used to build up to four storey-buildings at low cost.
Taller residential buildings are usually built with a frame made of steel girders. The main advantages of lightweight steel frames is their weight and the fact that they make it possible to erect incombustible buildings. They therefore provide solutions for urban residential re-densification. In buildings where inflammable materials are now prohibited and where the weight of raised parts is very limited because the allowable load of foundations cannot be increased at an economical cost, this process has become essential.

Fig. 2, 3, 4
Building with light-weight steel framing on site and on completion (Rautaruukki Oyj, Finland)



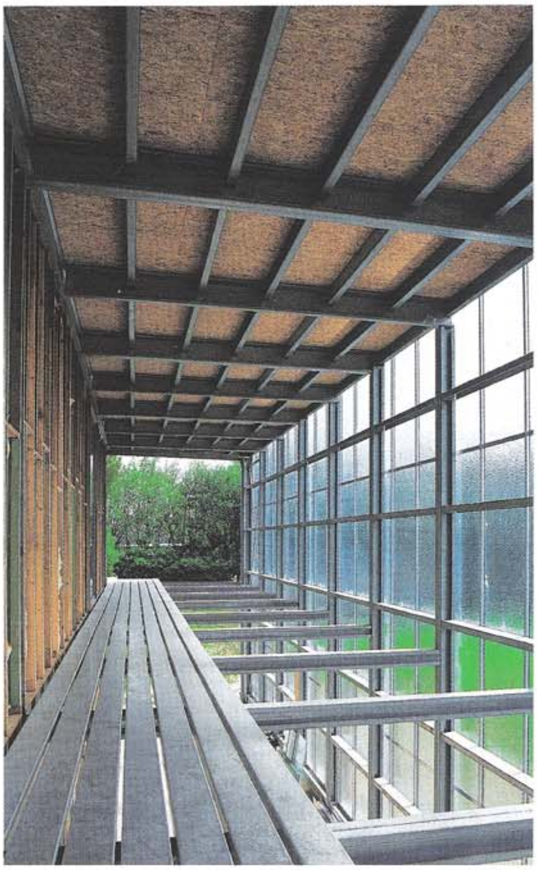
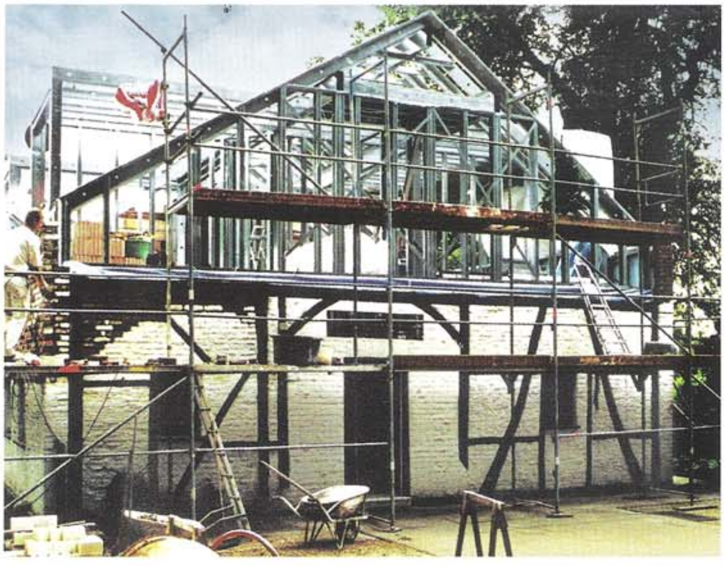


Fig. 5, 6, 7
Building with light-weight steel construction with exposed and visible steel frame (Sadef, Belgium)

Fig. 8:
Story added to a half-timbered house dating from the 17th century (Rasta-Haus GmbH, Wesel, Germany). Due to the weight restrictions of the superstructure, the addition could only be added as a light-weight steel frame



The so-called "open" construction systems hold a lot of promise: these are methods and techniques based on smart principles and flexible assemblies. They are called "third-generation" systems. These are made up of sub-systems that do not depend on situations and projects, and they can therefore be mass-produced. Open processes offer greater flexibility and more freedom during design. As in the automobile industry, it is possible to cover nearly all the needs of designers with a smaller amount of elements that can be combined in many different ways.
The advantage of this system lies in the latitude that it provides designers, both in terms of the technical quality of assembled members and overall profitability.
Because of the increasingly strict requirements relating to physical properties, the quality of the construction, its flexibility and individual character, it is constantly becoming more important to build affordable residential buildings.
Manufacturing and assembly constraints must therefore be taken into account right from the project design phase.

Project and construction

Behaviour of a building with studs and beams

Building with a frame in lightweight sections is similar to building with studs and beams in a different material.

Each upright stud is inserted at the top and base into a horizontal U-section and this system distributes the load on the uprights studs.

Cross beams are, depending on the construction mode, mounted on cantilevers or between studs.

From a static viewpoint, there is a significant difference between a lightweight steel structure construction and a construction with a traditionnal frame. The load is not borne by a structure that is independent of the building shell. It is borne by load-bearing panels that also serve to partition the building.

The plating is placed on uprights in cold formed sections. This gives a sandwich construction where each panel can bear perpendicular pressure on its surface as well as horizontal loads and forces.

These thin panels with cold-formed plated structures, can be used for horizontal as well as vertical surfaces, and for floors as well as load-bearing walls.

These panels are so rigid that the sections will not sag or buckle if they are properly fixed.

Wall panels are used not only for carrying vertical loads, but also to brace the building against wind thrusts, or to enable it to resist pressure due to the imperfect positioning of walls. The type, thickness and laying of the plating are very important.

Illustration 12 shows the transmission of loads on wall and floor panels. Each wall panel carries the floor load uniformly along its length. The panels transmit the stresses from the top to their base, namely a bending moment and a horizontal thrust.

The anchoring of the sections into the floor must therefore be solid enough not only to transmit the tensile stress to the floor and thus to the lower storey, but also the transversal forces.

Different methods are used in different countries to calculate the diaphragm effect obtained with plasterboards. For example,

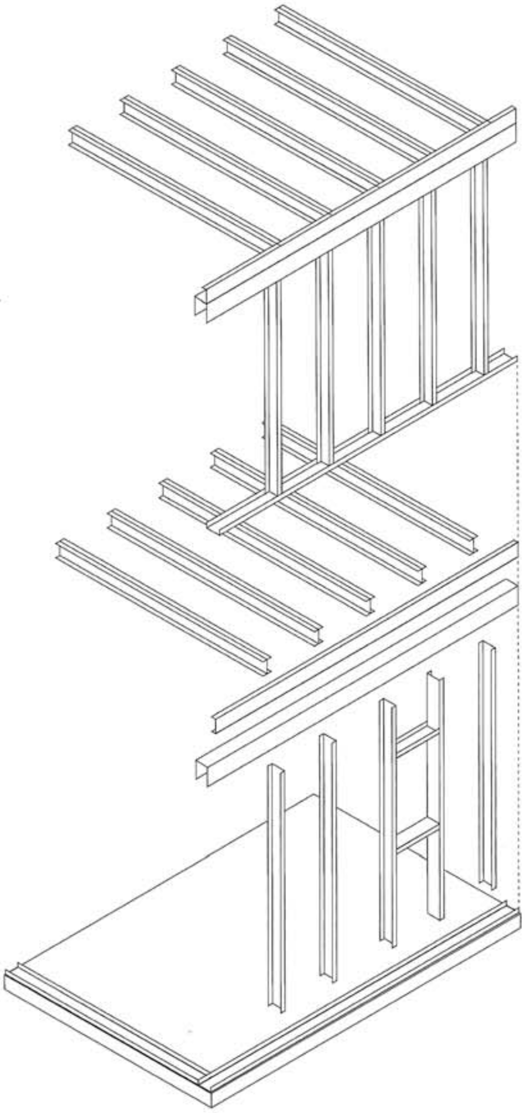


Fig. 9
Principle of design of light-weight steel construction

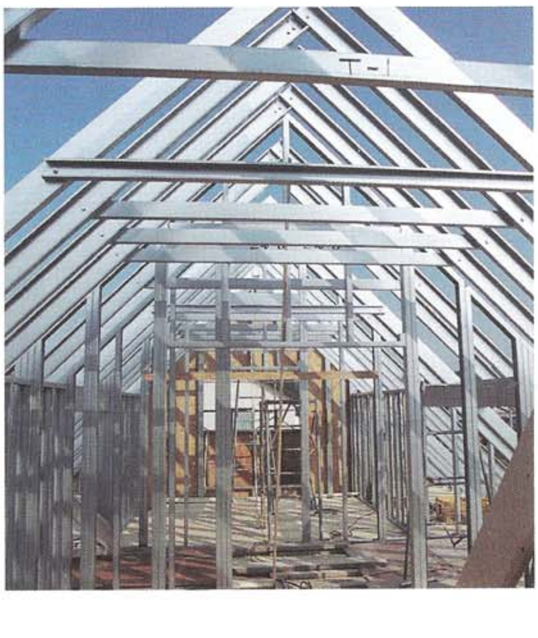


Fig. 10
Roof truss of a residential building made of cold-formed steel profiles
(The Japan Iron and Steel Federation, Japan)

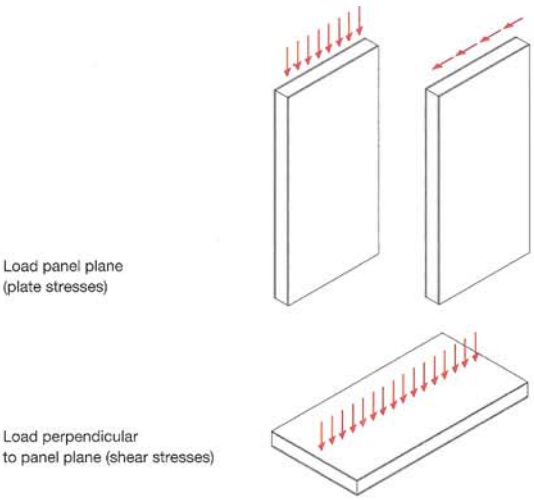


Fig. 11:
Shear and plate stresses of a panel

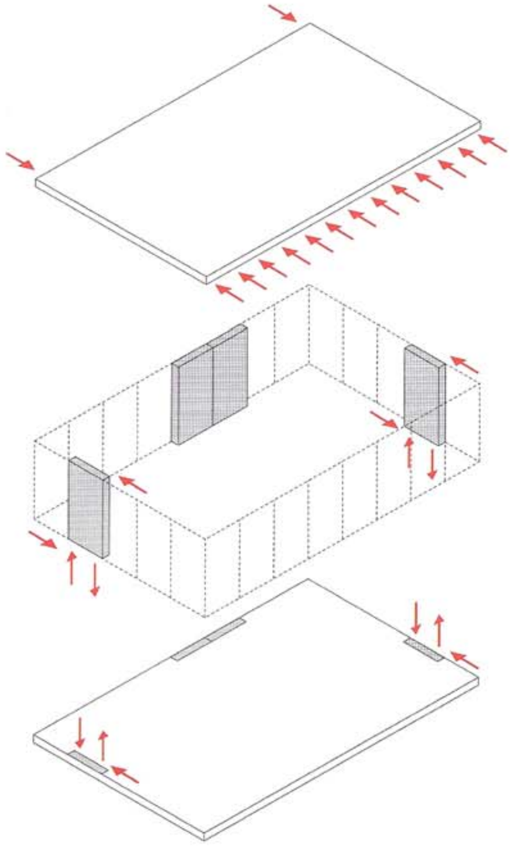


Fig. 12
Reinforcing of a building with ceiling and shear walls

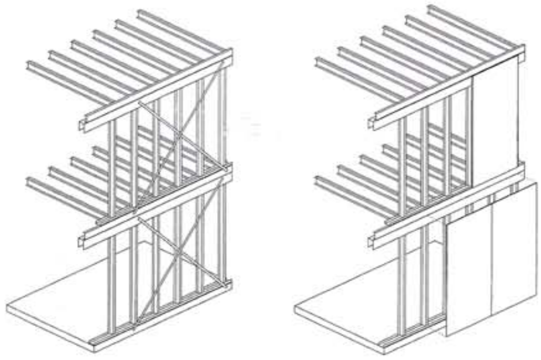


Fig. 13
Reinforcing with struts and shear walls

the application of the design rules of the Swedish Code for Light-Gauge Metal Structures for skeleton framings associated with plasterboard reveals their suitability for experimental measures. In the United States a whole range of tests was carried out with section panels, OSBs, plywood and plasterboard. The results were translated into standards in 1998 in the form of a table of load-bearing capacities and resistance to static and seismic stress.

However, in certain countries, such as Germany, the absence of a specific standard means that residential buildings have to be braced with diagonals inside the panels **(Fig. 13)**. The approval of the engineering departments for a construction with panels can be obtained on a case-by-case basis. Tests conducted in the Institute of the Darmstadt Technical University, however, show that a partition made of two 12.5 mm-thick fibre-plaster boards, fixed on C-sections measuring 100 x 50 x 10 x 1.5 each, subjected to a load NS,d = 39 kN with a space between each screw of eR = 100 mm, can bear a horizontal thrust of 8 kN (with a gamma safety factor of 5).

In the same vein, the deflection resulting from wind thrust is considered to be insignificant for buildings that have no more than two full storeys, on condition that bracing panels are placed on the four outer walls. The values given in fig. 16 are divided between two walls. Although this table states that only one bracing panel is needed, it is recommended to place two in the parallel walls to ensure static stability, using as a basis a building with a width of 7.50 m and 2.80 m-high floors.

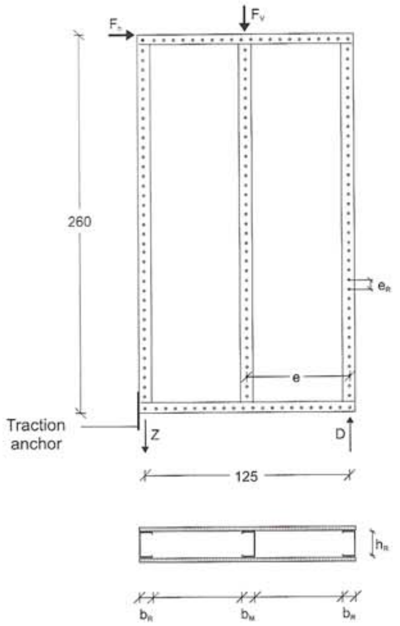


Fig. 14. Shear wall superstructure of a snap-in element

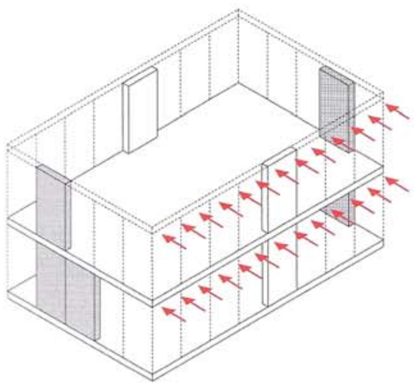


Fig. 15. Arrangement of reinforcing shear walls

Building length	Roof slope	Number of 1.25 m-wide braces	
		On ground floor	On first floor
5,00 m	Flat roof	2	1
	30°	3	2
	45°	3	2
7,50 m	Flat roof	3	1
	30°	4	2
	45°	6	3
10,00 m	Flat roof	3	1
	30°	5	3
	45°	6	4
12,50 m	Flat roof	4	2
	30°	6	3
	45°	8	5
15,00 m	Flat roof	5	2
	30°	7	4
	45°	9	6

Fig. 16. Table of wind braces required to reinforce the structure

Fig. 17
Building in light-weight steel construction (The Japan Iron and Steel Federation, Japan)

Construction principles

As with the various construction processes with columns and beams, there are two different systems in lightweight steel structure construction: balloon-frame and platform-frame.

Platform-frame

With this system, the wall panels are erected on each floor in such a way that it is the floor that transmits the load. This is a very common construction system. Compared with the balloon-frame, it has the advantage of using the completed floor as a work platform for erecting the next storey.

Balloon-frame

With this system, the floors are nailed to the front or side of the columns. Load-bearing wall members or studs can be higher than a floor, thus making it possible to work on larger surfaces. This method also saves on horizontal connection material. These joints are also an advantage in terms of air tightness. However, they can make work slightly more complicated technically.

Combination systems are also very common. Hot rolled sections or a classic steel frame may be used to obtain a wider span. Load-bearing panels in lightweight steel structures can be used for the outer walls while erecting the internal studs to reduce the number of members used.

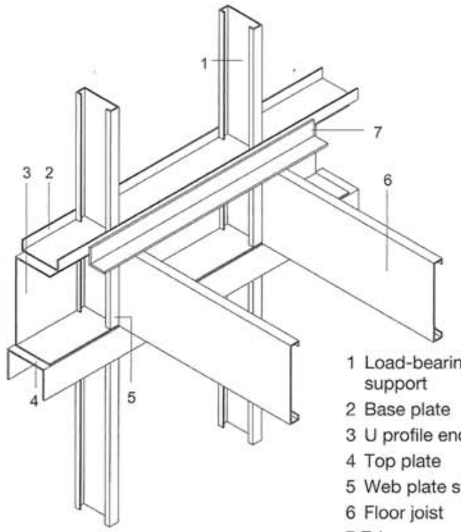


Fig. 18
Joining principle of the platform design system

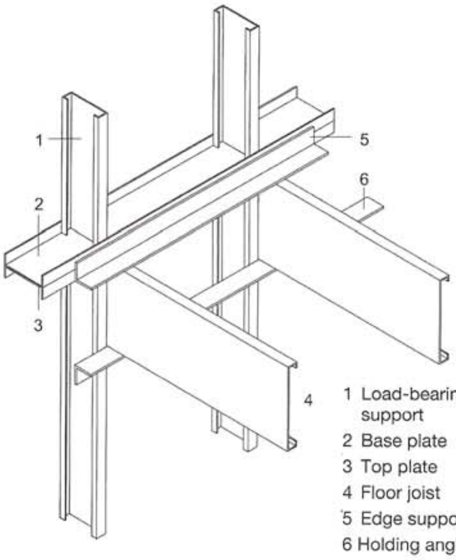


Fig. 19
Principle of jointing behind the balloon framing system

It is also possible to opt for panels in light sections for walls and to lay solid floors on a composite deck. It is also possible to use special processes using specific sections **(Fig. 23)**.

Sections in thin sheets are screwed or riveted to each other; casing plates are generally screwed onto the metal supports. A modern alternative to this fastening mode is power nailing (see chapter "Manufacturing, prefabrication and assembly").

The spacing between sections is variable but tends to be mixed with the length of the plates and takes static stress into account. An economic construction rule has adopted the spacing 62.5 cm thus reproducing the usual measurement of material plates. When the sections are thicker (1 to 2.5 mm) and the plates more rigid, the spacing of the supports go up to 125 cm. If the static loads are too high, this spacing is sometimes reduced to 31.25 cm.

In a panel for an outside wall for example, the spacing of studs may depend on the project. It makes economic sense to make them coincide with openings to avoid any variations **(Fig. 32)**. For a lintel in a large opening in a load-bearing wall or for an extremely large opening, it is possible to use reinforced or framed cold-formed sections or even hot rolled sections.

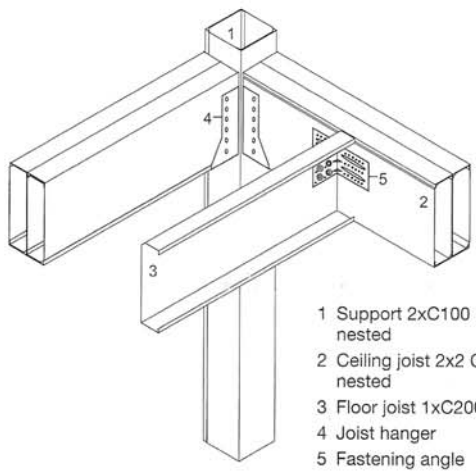


Fig. 20
Balloon framing for taking up higher loads from interlocked/ nested C profiles

Fig. 21
Combined system in light-weight steel construction
A load-bearing wall structure is added to the steel skeleton
(Rautaruukki Oyj, Finland)

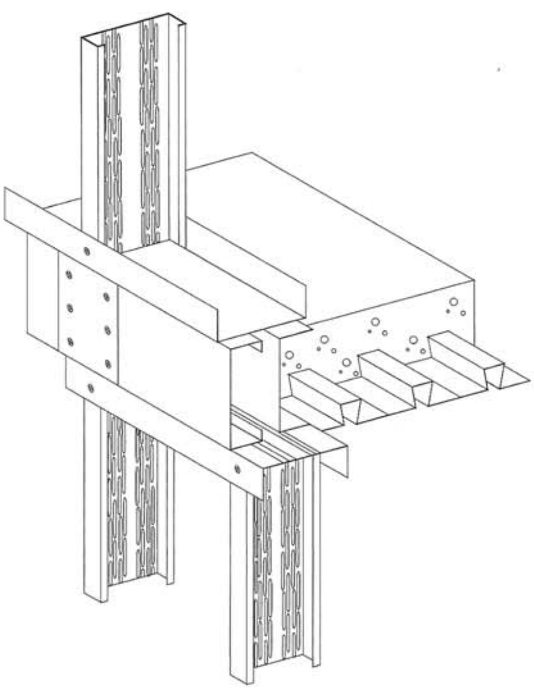
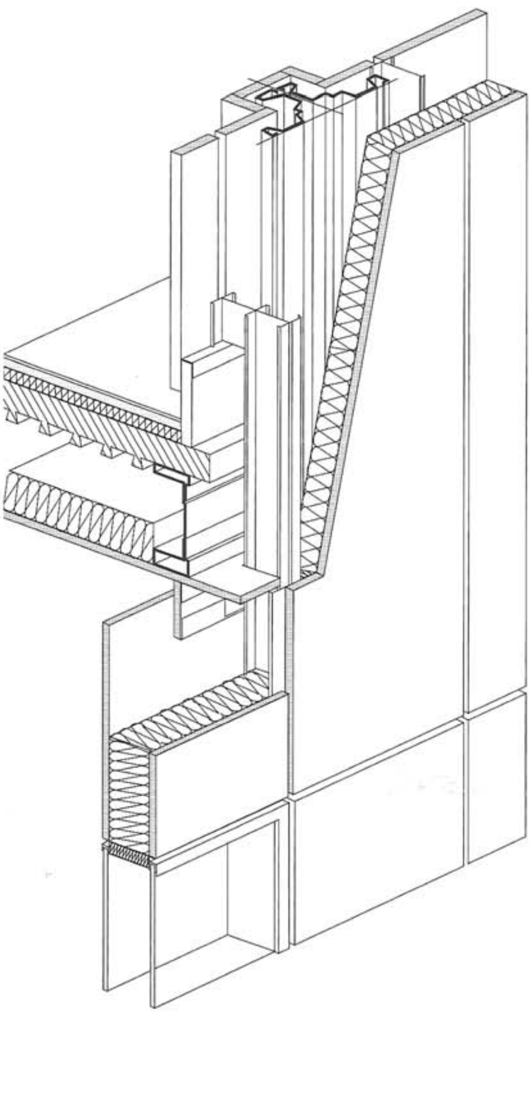
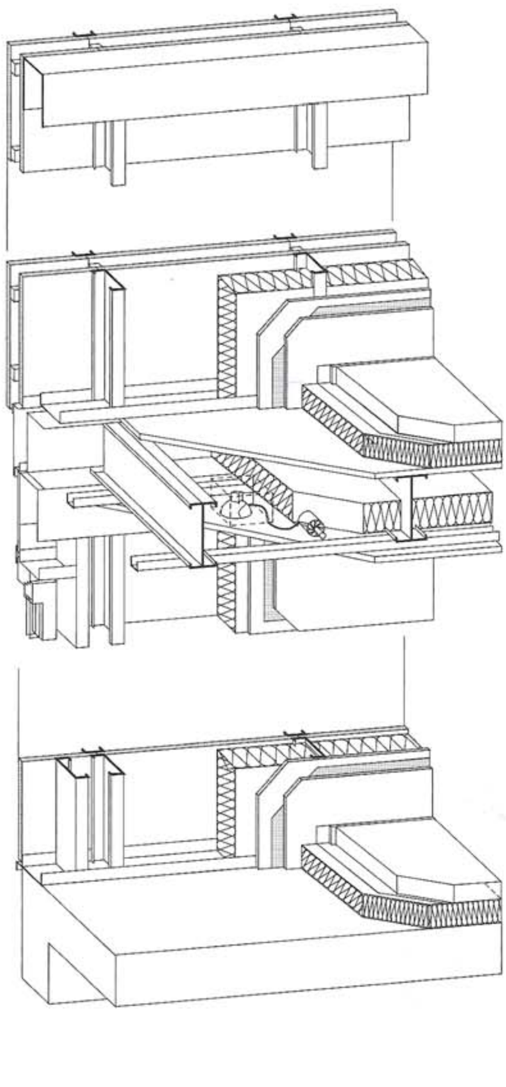


Fig. 22
Combined system as light-weight steel construction with solid ceiling as trapezoidal steel composite structure

Fig. 23 (bottom left)
Special system design consisting of purpose-made profiles

Fig. 24 (bottom right)
Structural assembly in light-weight steel construction





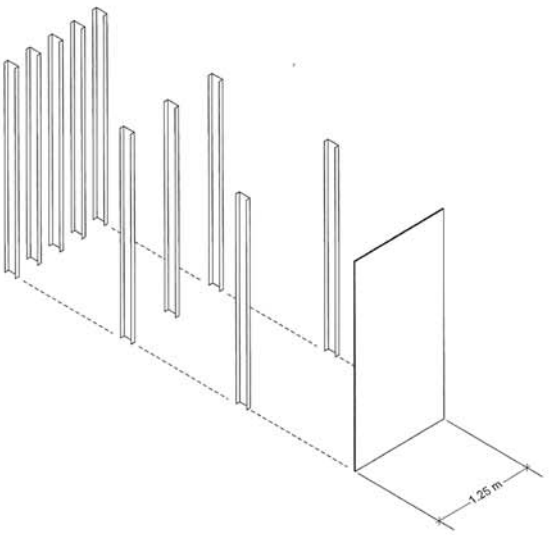


Fig. 25
Modular dimensions of the upright studs spacing depending on panel size

1 connection profile
2 upright stud profile
3 cross-frame profile
with web edging

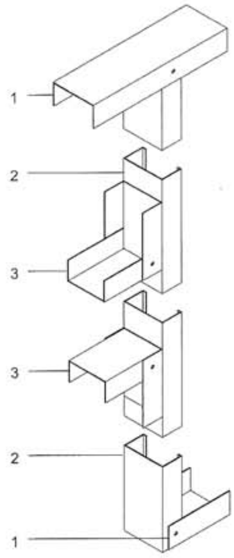


Fig. 26. Trimming to form an opening in the post-and-beam structure

The type and thickness of plates of a steel structure panel are determined by the static requirements; fire resistance and soundproofing requirements imposed on this member or the entire building (see chapters on the building physics for more details). The vacuum between the stud is filled with an insulating material as with the other dry construction processes. The type and thickness of this insulating material are determined by the energy and sound constraints of this member.

Lightweight steel structure constructions have several advantages over other traditional monolithic processes. They offer better heat and soundproofing at equal panel thicknesses.

If the different processes are compared using the same physical properties, there is increased surface for lightweight steel constructions because steel-framed panels are much thinner.

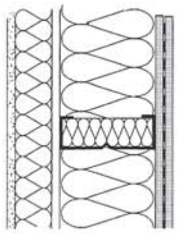
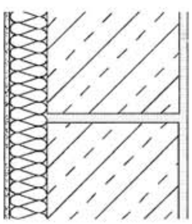
External wall construction	Layer structure	Thickness	U-value	Sound damping coefficient
	**Metal stud design** External rendering (reinforced, mineral) Mineral fiber Compound cementing material Plasterboard Metal stud, mineral wool insulation Gypsum board, vapor barrier Gypsum board, emulsion paint	**23,0 cm**	**0,25**	**51 dB**
	**Masonry with ETICS (External Thermal Insulation Composite System)** External rendering (reinforced, mineral) Mineral wool Compo Perforated brick Interior plaster	**34,5 cm**	**0,35**	**48 dB**

Fig. 27
Comparison of the structural properties of solid construction vs. lightweight construction
(cf. also Fig. 54 + 77 in the sections on building physics)

Fig. 28
Perforation of light-gauge profiles with installations in place

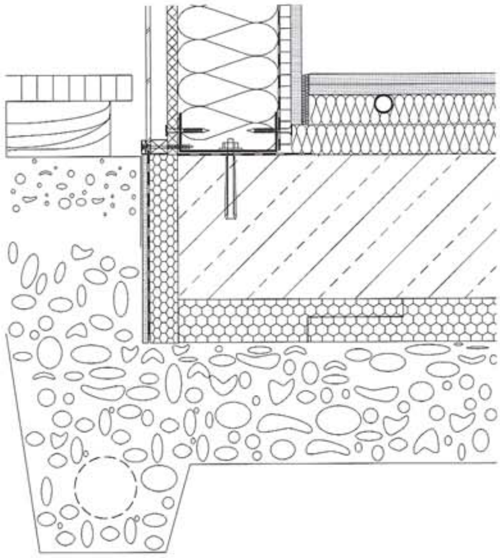


Fig. 29
Foot point of a shear wall on the bottom slab without continuous footing

For a building with a net floor area of 120 m², this gain in surface area can be as much as 5 to 10%.

The internal cavity of sandwich panels is ideal for inserting ducts, cables and sheaths and therefore makes it easy to add equipment. Sections have standard openings for routing sheaths and pipes. However, attention must be paid to acoustic problems when installing metal pipes. They must not come into contact with the studs, to avoid any sound transmission.

The lightness of the materials used in this process makes it possible, as we mentioned in the introduction, to raise buildings with a limited allowable load reserve. This advantage also has an impact on the foundations of a new construction Buildings can also be built up to two storeys without continuous footings, by erecting the walls directly on the screed.

If the reinforcement has been laid out properly, the sole plate will be solid enough to bear the loads and to distribute them on the ground. The building can thus be insulated all around because the compressive strength of the insulating material (XPS) under the slab will be enough to transmit the loads.

The edges of the slab are filled in with a gravel lining up to 1 m deep to make them frost resistant.

Fig. 30, 31 (bottom)
Building made of prefabricated panels with light-gauge steel framing (Rautaruukki Oyj, Finland)

Project organisation and design

The lightweight steel structure construction system is used to lay floors of a span of up to 6 m at low cost (see the paragraph on joists in the "Cold-formed sections" chapter, p. 17).

There is therefore large latitude in designing plans to suit all tastes. To obtain larger spans, one simply needs to fit the sections or use hot rolled sections. There's also the solution of pouring a concrete slab on composite deck floors to reach a 7 m span.

The lightweight steel-framed construction has the advantage of combining simplicity and flexibility. The most logical solution consists in adding bracing panels to the outer walls or stairways and around bathrooms.

This is what gives the designer the greatest latitude of distribution. An added advantage of this process lies in the fact that short panels 1.25 m long can be used to stiffen the unit, on condition that they are anchored correctly even if they do not support any load.

Enlargements, retrofits or separations can be easily made, depending on the plan. If for example, only the outer walls are load-bearing and bracing, the choice of distribution of the internal area is completely free and can even not be partitioned at all. The shell can then be adapted to other functionalities.

To avoid subsequent rearranging of the technical equipment for the different sections, the fact that they are always laid in a bundle must be taken into account.

There is a practically unlimited range of manufacturing modes and types of covering for self-bearing panels. Different materials are available depending on the physical and static requirements. The plates inside the building can be left in their original state or be covered with the desired covering: paint, wallpaper, coating, fabric, etc. For outdoor surfaces, all the common materials and processes can also be used: rough coat, siding, covering, etc.

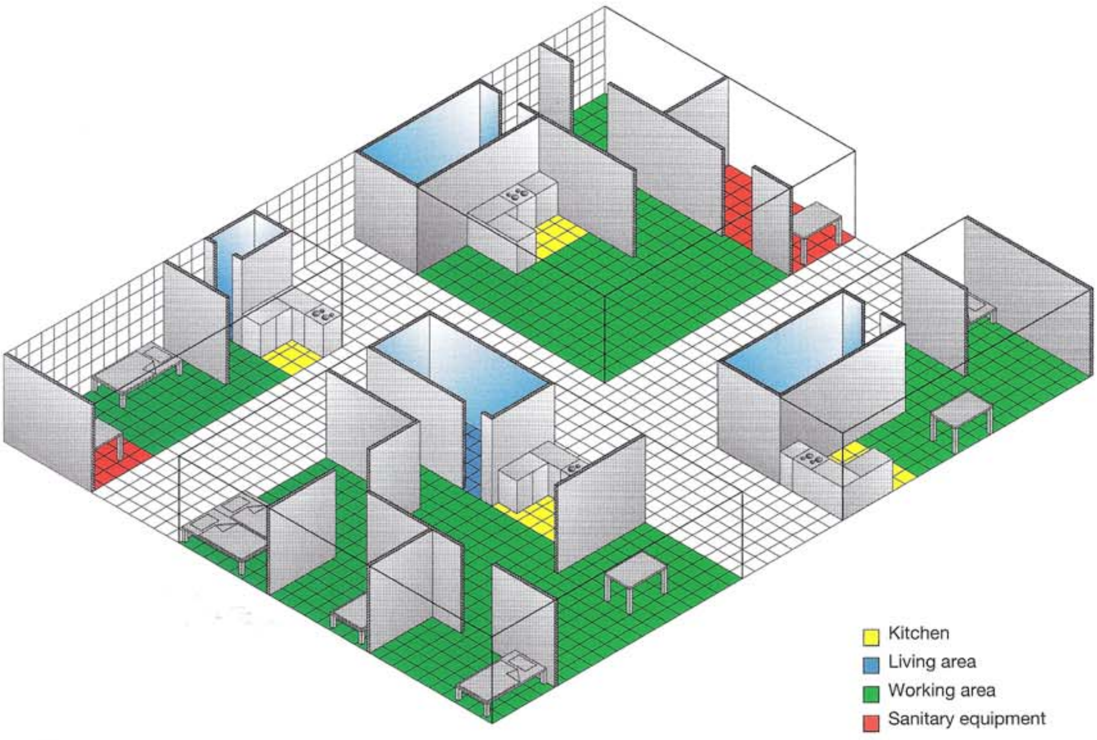


Fig. 32
Sample floor plan for flexible room layouts
Kitchen
Sanitary facilities
Living area
Working area

Cold-formed sections

Properties

Cold-formed sections are products that are manufactured from cold or hot rolled steel sheets, which may or may not be treated. They derive their form from the cold modelling of the sheet by stretching, folding and rolling on two rollers. Table 3.1 of the Eurocode EN 1993-1-3, which governs the design of cold formed sections, shows the ability of steels to be cold rolled. The yield strength of these steels is $f_y = 220$ and 500 N/mm², but most of the sheets used have a yield strength of $f_y = 320$ or 350 N/mm² and are continuously hot-dip galvanised.

As we will be seeing below, a wide range of sections are used in lightweight steel construction.

There are different light sections of standard dimension available on the market.

However, a rolling company can manufacture all the conceivable types of section, even if it does not make economic sense to manufacture a small number of a type.

There is more information on cold-rolled sections in the "Construction of residential buildings – sections manual" brochure.

The sheet thickness of the sections in illustration 33 varies between t = 1.5 and 4.0 mm; but still meet the static standards for multi-storey residential buildings.

For non-load-bearing partitions that are used in visual or soundproofing, the manufactured sections can be up to 0.6 mm thick.

Because the sheet is not very thick, its folding plays a key role in its load-bearing capacity. Folding a sheet makes the section more load resistant. The above-mentioned standards were developed to make it possible to determine the dimensions of sections depending on their use. The displacement of the resistance to stress to the more rigid longitudinal edges is taken into account in the "effective width" design mode. With the different ways of stiffening with folds **(Fig. 34)**, the allowable load of each part of a section can be increased significantly **(Fig. 35)**. It

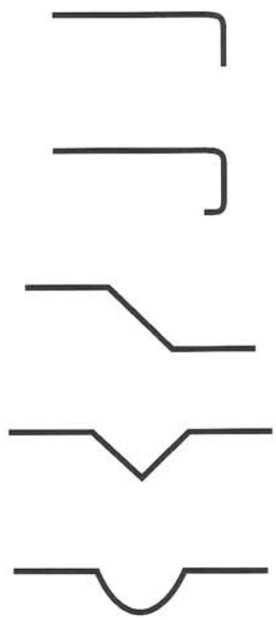


Fig. 34: Bracing options for web and flanges

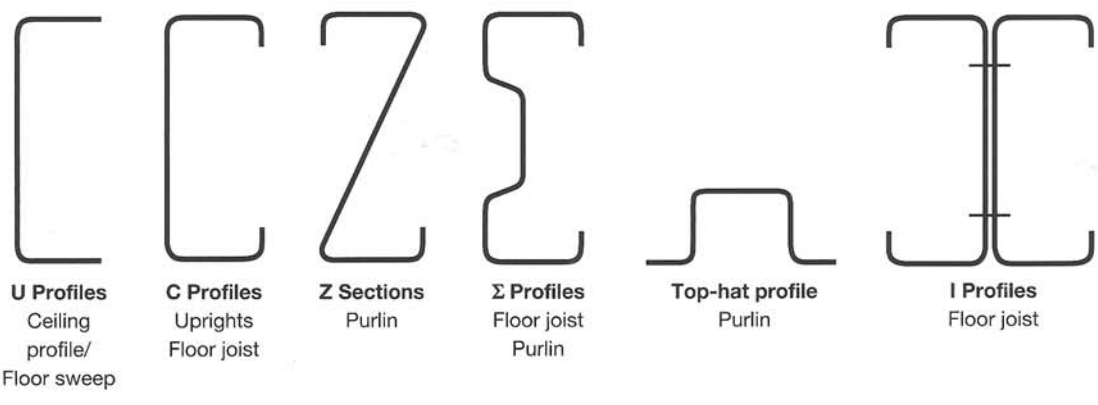
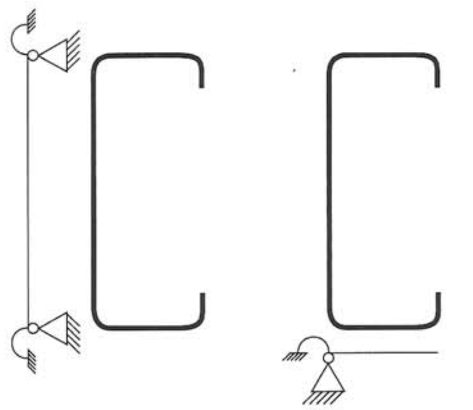


Fig. 33 Cross-sectional shapes of cold-formed profiles for residential building

Fig. 35
Partial areas of a thin-walled steel profile supported on one and two sides



Folding press   Bending press

is however important to take the following fundamental data into account:
- the flanges of a section with a wall must always have lips to make them economical to use;
- a dimple on the web of a section associated with two walls is much more effective than an upstand beam;
- since using more than two upstand beams does not improve resistance, it is not necessary to take the excess number into account in designs;
- openings must be provided for only in the web of a section and a fold must not be cut under any circumstance. American standards can be used here as an indication on the effect of these openings on the section's load-bearing capacity.

The effect of round holes drilled in the web of a section is insignificant when the ratio of the diameter of the hole and the width of the web is less than 0.38. For a section associated with two walls that has a round hole drilled in its centre and which is subjected to constant pressure, the Winter formula is completed to obtain the effective width (see Eurocode EN 1993-1-3, 5.5.2):

$$\rho = \frac{1 - 0{,}22 / \lambda'\rho}{\lambda\rho}$$

$$\lambda'\rho = \sqrt{\frac{f_{yb}}{\sigma_{cr}}}$$

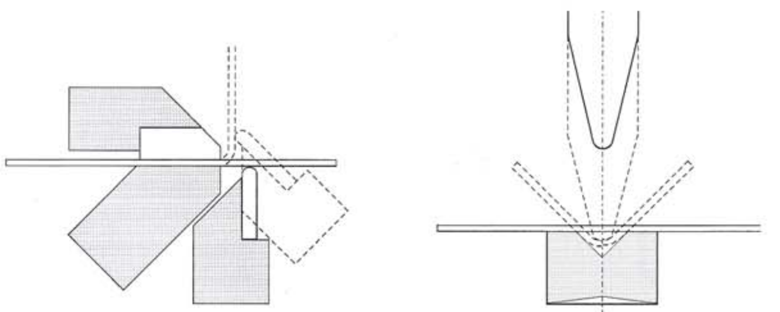
σ_{cr} = critical stress

Manufacturing

- cold rolled sections can be manufactured according to three different processes:
- drawing;
- bending;
- rolling.

Drawing, or more exactly bending by drawing or rolling, consists in pulling the strip through non-actuated rolls using jaws. The number of deforming rollers that are used successively and the deformation that they create determine the final section. Sections can be manufactured up to a length of 12 m. Drawing has the advantage of having a relatively low manufacturing cost, which makes it a process that is suited to the production of complex and very thin sections.

Fig. 36
Machine tools for champfering/edge bending



Partial area supported on two sides   Partial area supported on one side

Fig. 37. Machine functions during cold-forming of sections
Plate cross section

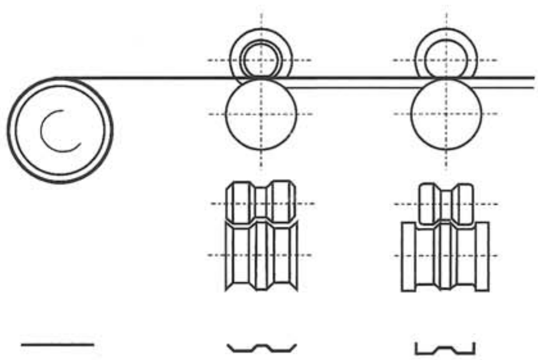


Plate cross section

Sheets are bent using brakes, benders or drop forging press. In a brake, the sheet is held tightly between two clamp frames, and then given the desired angle with an adjustable roller.

The angle of the bend can be modified by changing the roller guide **(Fig. 36)**. In a drop forging press, the sheet is forced into a V-shaped die.

Rolling is the most commonly used industrial finishing process for cold rolled sections.

The strip is given the desired form by passing it through successive actuated cylinders **(Fig. 37)**. Varying the spacing between the cylinders and their geometry makes it possible to have a positive impact on the plastic stress derived from these deformations, such as strain hardening.

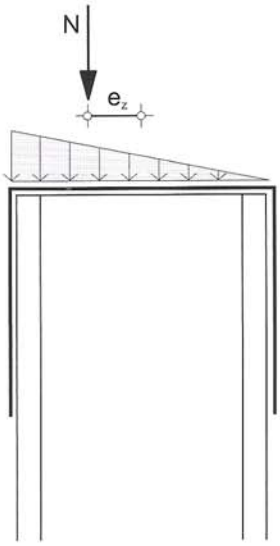


Fig. 38. Eccentric load transfer to an upright profile

Table of allowable loads of rolled sections for studs, cross beams and joists

The calculation of the values shown in the two tables below (40 and 41) follows the following rules: the limit ductility of steel is $f_{y,K} = 320$ N/mm², which corresponds to S320GD+Z according to EN 10147. The allowable loads indicated in table 40 are only valid for sandwich walls. The material used for the plates must comply with approved panel bracing standards.

Studs

The static system of studs is modelled according to pendular support rules. The dual cladding of the panel eliminates all sagging or buckling of the sections. The following lengths will be taken into account: 260 cm, 300 cm and 350 cm.

In the case of studs of outer walls, the possibility of eccentricity due to loads carried to the ground must be taken into account. If we allow for a linear distribution of stresses in the joists, this eccentricity *e* must not exceed h/6 **(Fig. 38)**. However, for internal walls that receive loads from the upper storey, it is possible to use the principle of a central load carrying to the ground. That is why the table only mentions the limit values ez = 0 and ez = h/6 with an intermediate value ez = h/12. The height of the web and the thickness of the C-section vary. To resist a thrust of the plate on the section, the footing width must not be less than 50 mm. This results in a minimum lip height of 10 mm.

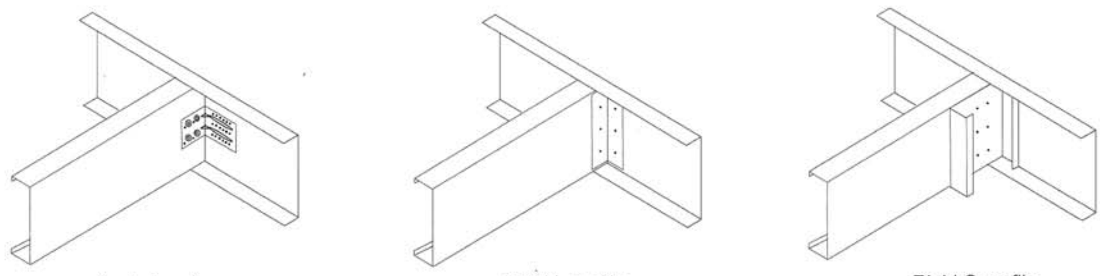
Joists

For a floor, we base our estimates on a gamma dead weight of = 1.55 kN/m² + the weight of the joists. We took a dynamic load of 2 kN/m² and 3.5 kN/m². In table 41,the limit spans of joists are followed by a plastic deformation coefficient 1, 2 or 3.

1. Sagging limit of the support $M_{y,Rd} = f_{y,kX}$ $W_{ef}/\gamma M$/gammM. There can be no plastic deformation of the support because the buckling strength is sufficient thanks to the double wall.
2. Transverse force limit $V_{z,Rd}$.
3. Use strength δ_2 L/500 subjected to dynamic loads according to table 4,1 EN 1993-1-1. Up till a span of about 5 m, oscillations and vibrations are sufficiently limited as specified in the simplified criteria of EN 1993-1-1.
   For bigger spans, oscillations have to be checked on a case by case basis.
   The load limit charge $R_{u1,Rd}$ is also indicated, with a 50 mm support width.

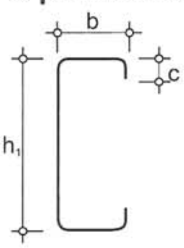
Because cold rolled sections are very sensitive to torsion on the bearing surface, this is a decisive criterion for nearly all bearers. The limit spans mentioned are therefore only valid with a sufficient reinforcement at the bearer's support point **(Fig. 39)**.

Fig. 39
Reinforcement variants for the junction of beams in the area of support



Angle junction — Rigid L profile — Rigid C profile

C profiles for Walls



Profile Labels:

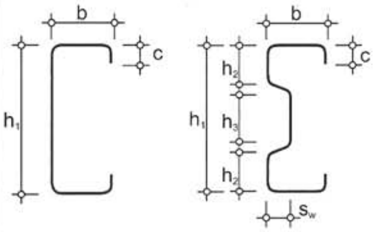
Thickness of foot face h_1
Flange width b
Lip height c
Nominal plate thickness t_n
Nominal plate thickness t

A^D_{eff} = effective cross section pressure [mm^2]
A^B_{eff} = effective cross section flexion [mm^2]
$W_{eff,y}$ = moment of resistance [cm^3]
e_{pz} = gross spacing – to effective center of gravity [mm]
l = profile length (= effective length) [cm]
e_z = eccentricity
$N_{R,d}$ = limit force [kN]

Profiles h_1 x b x c x t_n	t [mm]	A^D_{eff} [mm^2]	A^B_{eff} [mm^2]	$W_{eff,y}$ [cm^3]	e_{pz} [mm]	l [cm]	$N_{R,d}$ [kN] $e_z = 0$	$N_{R,d}$ [kN] $e_z = h/12$	$N_{R,d}$ [kN] $e = h/6$
C 100 x 50 x 10 x 1,0	0,92	106,7	163,1	4,75	7,28	260	27,2	21,9	19,9
						300	24,6	20,2	18,5
						350	21,5	17,8	16,5
C 100 x 50 x 10 x 1,5	1,42	217,4	287,4	8,74	2,71	260	54,4	43,8	39,6
						300	48,7	39,7	36,2
						350	41,8	34,5	31,9
C 100 x 50 x 10 x 2,0	1,96	338,7	397,0	12,13	2,18	260	76,4	61,5	55,6
						300	68,3	55,6	50,7
						350	58,4	48,2	44,5
C 150 x 50 x 10 x 1,0	0,92	106,7	163,4	7,35	14,67	260	31,0	24,1	21,2
						300	29,7	23,4	20,7
						350	27,9	22,3	20,0
C 150 x 50 x 10 x 1,5	1,42	220,2	338,0	14,36	5,43	260	64,1	56,2	48,8
						300	64,1	54,4	47,8
						350	64,1	51,7	46,3
C 150 x 50 x 10 x 2,0	1,96	350,0	493,2	20,80	2,96	260	101,8	86,0	74,4
						300	101,8	83,3	73,2
						350	99,1	78,6	70,2

Fig. 40. Table showing the load-bearing capacity of wall supports

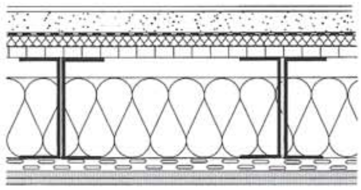
C Profiles, Σ Profiles and I Profile for ceilings



Profile Labels:

Thickness of root face h_1
Flange width b
Lip height c
Nominal plate thickness t_n
Plate thickness t

W_{eff} = Moment of resistance [cm^3]
I_{eff} = Moment of inertia [cm^4]
$M_{y,Rd}$ = Maximum moment [kNm]
$R_{u1,Rd}$ = Bearing reaction[kN]
$V_{z,Rd}$= Lateral force [kN]
p = Live load [kN/m^2]
b = Girder spacing [cm]
l_{gr} = allowable bearing distance
Failure form[1, 2, 3]
* no supporting reinforcement necessary



Floor covering, ceramic, 10 mm
Wet screed topping, 40 mm
Footfall sound insulation, 20 mm
BFU paneling [plywood], 26 mm
Furring
Sound-absorbent material, 120 mm
Suspended ceiling, 2 x 12,5 mm

Ceiling structure 1.55 kN/m²

Profile h_1 x b x c x t_n h_2 x h_3	W_{eff} [cm^3]	I_{eff} [cm^4]	$M_{y,Rd}$ [kNm]	$R_{u1,Rd}$ [kN]	$V_{z,Rd}$ [kN]	p = 2,00 b = 40 cm	p = 2,00 b = 60 cm	p = 3,50 b = 40 cm	p = 3,50 b = 60 cm
						l_{gr} [cm]	l_{gr} [cm]	l_{gr} [cm]	l_{gr} [cm]
C 150 x 50 x 10 x 1,0	7,35	71	2,14	1,69	5,58	288[1]	235[1]	240[1]	196[1]
C 150 x 50 x 10 x 1,5	14,36	120	4,18	3,50	20,5	364[3]	318[3]	302[3]	264[3]
C 150 x 50 x 10 x 2,0	20,80	165	6,05	6,06	40,1	405[3]	354[3]	336[3]	293[3]
C 200 x 50 x 10 x 1,0	10,07	134	2,93	1,69	4,18	336[1]	270[2]	281[1]	188[2]
C 200 x 50 x 10 x 1,5	19,41	228	5,65	3,50	15,4	451[3]	381[1]	374[3]	318[1]
C 200 x 50 x 10 x 2,0	30,37	326	8,84	6,06	40,1	508[3]	444[3]	422[3]	369[3]
C 250 x 50 x 10 x 1,5	24,95	378	7,26	3,50	12,3	526[1]	432[1]	440[1]	361[1]
C 250 x 50 x 10 x 2,0	37,96	549	11,04	6,06	32,4	605[3]	529[3]	502[3]	439[3]
Σ 200 x 65 x 10 x 1,5 36 x 100	29,03	314	8,45	2,17	23,3	502[3]	439[3]	416[3]	364[3]
Σ 200 x 65 x 10 x 2,0 36 x 100	42,08	434	12,24	5,33	48,3	560[3]	488[3]	464[3]	405[3]
Σ 250 x 70 x 10 x 1,5 50 x120	39,75	541	11,56	2,17	19,0	602[3]	526[3]	499[3]	436[3]
Σ 250 x 70 x 10 x 2,0 50 x 120	58,44	757	17,00	5,33	47,1	673[3]	588[3]	559[3]	488[3]
I 150 x 50 x 10 x 1,5	28,72	240	8,36	7,00	41,0	459[3] *	400[3] *	380[3] *	332[3] *
I 200 x 50 x 10 x 1,5	38,82	456	11,30	7,00	30,8	568[3] *	497[3] *	472[3] *	412[3] *
I 250 x 50 x 10 x 1,5	49,90	756	14,52	7,00	24,6	673[3] *	588[3] *	588[3] *	488[3] *

Fig. 41. Table of the limiting span lengths for floor joists

Fabrication, prefabrication and erection

Lightweight steel-framed constructions are not designed according to the same principles as high solid buildings. Furthermore, light sections can be assembled to build a frame on site or in a factory, in a prefabrication workshop.

The two possibilities require different drawings, as well as different construction and logistics practices, and their advantages and drawbacks must be examined on a case by case basis.

Construction site erection

If the structure is erected on-site using different sections, there are several possibilities depending on their level of preparation.

Fig. 42 (middle) Site assembly of individual studs to create a post-and-beam structure (Armor Steel Framing Systems, Canada)

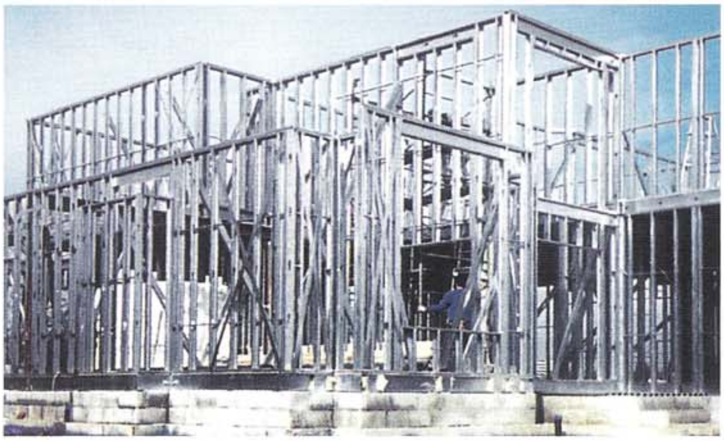


Fig. 43 (below): Installation of a set ceiling element (SwitchHaus, Bopfingen)

There can be a wide range of possibilities on the same site: uncut raw materials, sections of the right dimensions or fully-erected members (for example, roof trusses or complete panels). Depending on the system adopted, the sections are erected on the ground floor screed of (with or without a cellar). Building with lightweight steel does not require a powerful hoisting appliance. Because assembly techniques are simple, the building can even be erected by a non-professional.

Because of bad weather, builders must allow for four to six weeks of work until the completion of the wind and air tight systems are completed.

Because rain can soften everything during this period, it is essential to provide for a place for storing the materials see the chapter on "Corrosion control" p. 61).

Factory prefabrication

The intelligent use of steel in building presupposes a high level of prefabrication.

The use of modules implies using industrialised production modes.

Lightweight steel-framed constructions therefore use a lot prefabricated units. Basically, the various steel sheets and components can be assembled by welding, bolting, recess installation, riveting, clinching, stapling or tacking. However, there are more factory options than on-site possibilities. In most cases, thin sections are bolted together. Overlay plates are generally screwed onto the metal structure.

If they are factory prefabricated, the components are entirely assembled and covered with plates. It is however possible to place the sheathing plates on only one side of the panel. In the case of a single sided covering, usually on the outside, the panel is generally the most adequate means of making sure that the building is erected as quickly as possible with a skin that will protect it from bad weather.

Prefabrication of panels can be taken as far as integrating technical equipment and applying the finishing coat. These finished panels must be checked for compliance in the beginning, because it is not possible to check that all the components and layers (sheets, insulating materials, etc.) are present when they are delivered to the site.

It is also possible to manufacture three-dimensional modules that are fully finished and simply have to be installed on the site.

The assembly technique is a determining factor in the cost price of the production and erection of buildings. A technique that makes assembly and erection simple is often more economical than saving on the cost of materials. Since the cost of materials accounts for 30% of the total cost, and payroll 70%, a reduction in finishing and assembly costs largely offsets the use of more expensive materials.

New processes for fastening sheathing panels through power techniques (tacking, stapling) are being developed to be approved by engineering departments. These new processes are very economical and rationalise work even further. However, at the moment, they are mainly used in factories for prefabricated members.

As with timber constructions, the tacks or staples are driven into the steel with a powerful kinetic force. Assembly is made easy by the section folds, using clips, welding points or glue.

When they are welded or glued, the superficial layers of the assembled members are melted for a short time because of the heat released by the friction or by their being driven into each other. The fastening thus adheres firmly to the section at its intersection point.

Pneumatic fastening processes are simpler and quicker than screwing, but however present the disadvantage of making on-site assembly defects relatively expensive to repair.

The advantages of industrial prefabrication mainly lie in the guaranteed quality of members. In workshops, it is possible to work while protected from bad weather, and production is subjected to constant checks. For large panels, more high-performing tools are available and can even entail the installation of an automated chain.

Dimensions of prefabricated components vary depending on the manufacturer's production and transport possibilities, the site's ability to receive and erect them, and

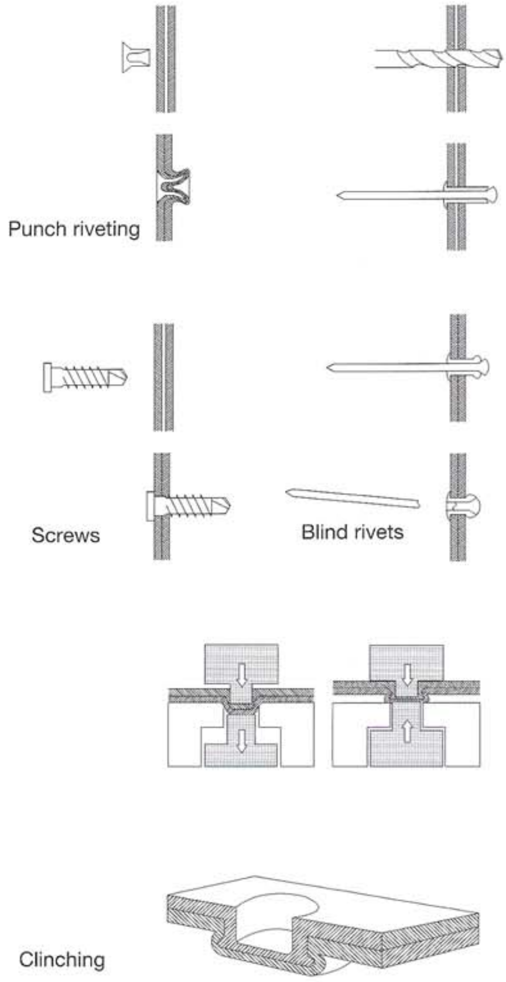


Fig. 44:
Options for joining lightweight profiles

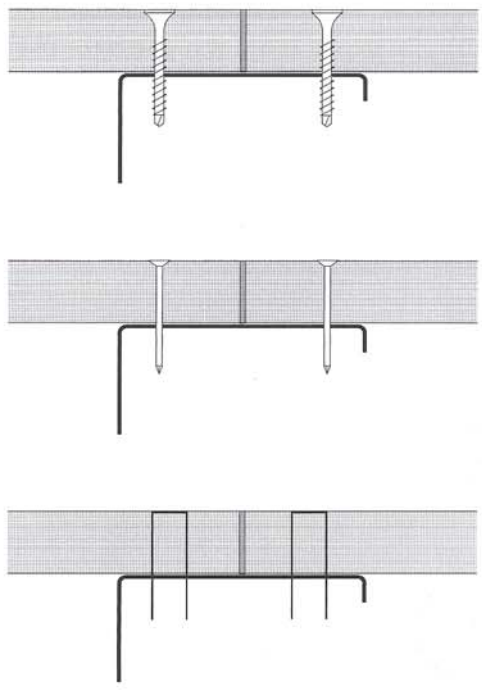


Fig. 45:
Options for joining the paneling to the metal profiles

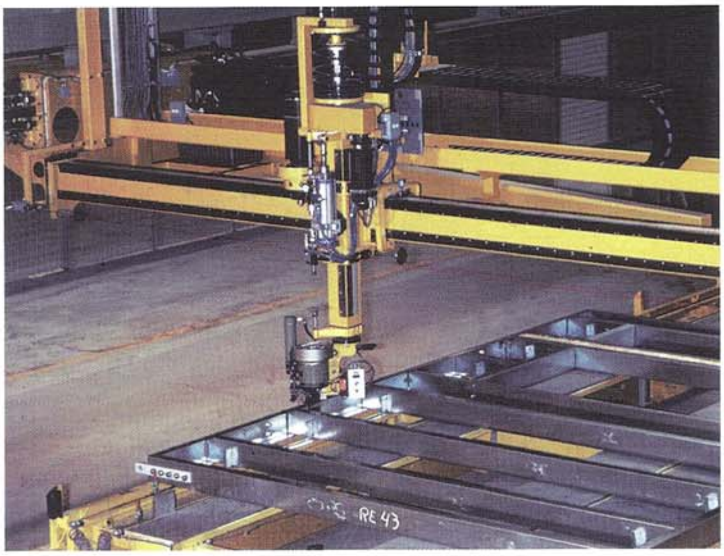


Fig. 46
Robot-controlled wall panel production at Rautaruukki Oyj (Finland)

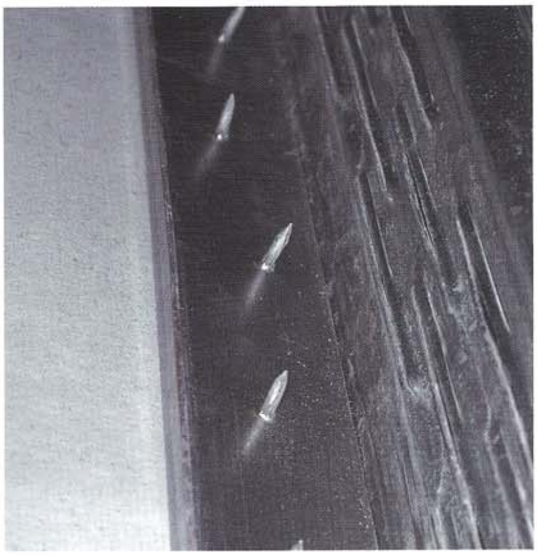


Fig. 48. Ballistic nailing into steel profiles

lastly, depending on the construction system adopted.

They are normally in the region of 3 x 8 m, and can go as far as 6 x 12 m.

Prefabrication considerably shortens construction time, because the road network, plumbing, piping and any outdoor installations can be completed on the site at the same time as the house is being built.

There is more planning and designers' tasks are different as compared with on-site work.

They do not only have to organise the position of each member, but must also plan their assembly taking the physical constraints of each section and sub-assembly into account (for example, the airtightness of the junctions between the members and sound proofing).

Fig. 47
Site assembly of pre-fabricated parts (Rautaruukki Oyj, Finland)

Depending on the degree of prefabrication, all the drawings have to be completed from the beginning of production, which means four to eight weeks before work begins on-site. Decisions concerning the details must be taken very early because modifications made after erection are always difficult and expensive.

Also, depending on the level of prefabrication chosen, the contractor may have to mount whole panels, such as walls, on site, or simply have to fasten the different members to each other or just carry out finishing work. It is always possible to personally take part in building a house, even with prefabricated members.

Members manufactured and delivered according to just- in-time methods make it possible to mount the carcass very quickly. A family home can be boxed up in three or four days so the finishing work can begin, protected from bad weather. Aside from the savings made, this eliminates the need for storage and production areas on the site and reduces waste.

During on-site erection, it is important to check the junctions between the various members because this will, to a large extent, determine the physical properties of the building. These details must be taken into strict account, and their feasibility must be ensured.

Physical constraints of residential buildings

Designing members and modules for buildings is a complex process. Often, we only think about their physical constraints late in the project. This means that they are taken into account after the fact. Consequently, because it does not have the required properties, the building may need additional work that may prove expensive, and at the same time increase the risk of poor workmanship.

We must not forget that a building or one of its members must satisfy several physical constraints at the same time. In buildings with lightweight steel structures, soundproofing and heat insulation requirements as well as fire resistance are easy to meet. It is very important to include the members that best conform with the physical characteristics of the building in the design process very early in the project in order to develop system-specific solutions.

Special care must be given to junctions — not only when the drawings are made, but also during execution, as we underlined in the chapter "Fabrication, prefabrication and erection" (p. 20). The linking of the various members must result in a unit that has the required qualities (for example, fire resistance or soundproofing). And last but not the least, the load-bearing structure must be designed in such a manner as to comply with all the physical constraints (avoiding thermal and acoustical bridges).

The pages that follow will deal with each one of the various members of a design that integrates the constraints related to the physical aspect of the building. The properties of the different types of construction will be analysed to enable their transposition.

Soundproofing and acoustic properties

People all over the world are becoming increasingly interested in the soundproofing of multi-storey buildings. This improvement costs little or even nothing.

All members with a lightweight metal structure can have excellent acoustic properties.

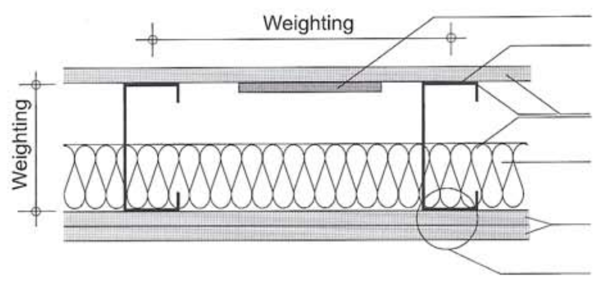


Fig. 49: Variation parameters of the basic structure of a cavity constructional element in light steel construction

Acoustic behaviour of lightweight steel-framed buildings

Double walls

For insulation from airborne sounds and impact sound and footsteps, the acoustic principles of dry, light constructions prevail. Soundproofing is not due to the mass of a material, but is also the result of a double partitioning and the application of the principle of acoustic separation.

If we consider weight, thickness and price, the soundproofing of steel frame panels, covered, for example, with plaster-board plates (gypsum plasterboard or fibre-plaster) provides very good results **(Fig. 54)**. Their acoustic properties however depend on the entire system: the material of the plates, metal uprights (type and spacing), the insulating material placed in the internal cavity and the means of fastening and assembly **(Fig. 49)**.

All these members form a complex system that constitutes a "double hull" member, from an acoustic viewpoint.

The following factors affect soundproofing the most:

- the "stiffness" of the junction between the two plates. The way the metal supports are mounted and arranged as

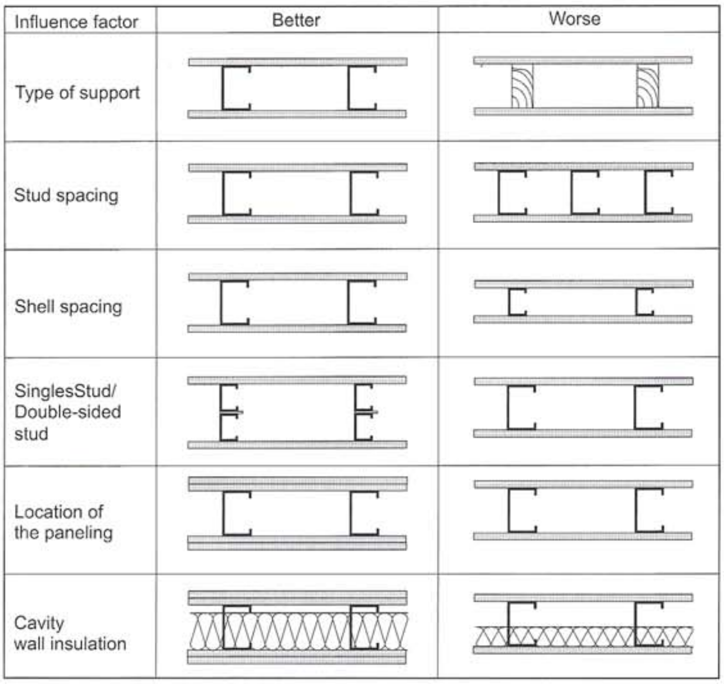
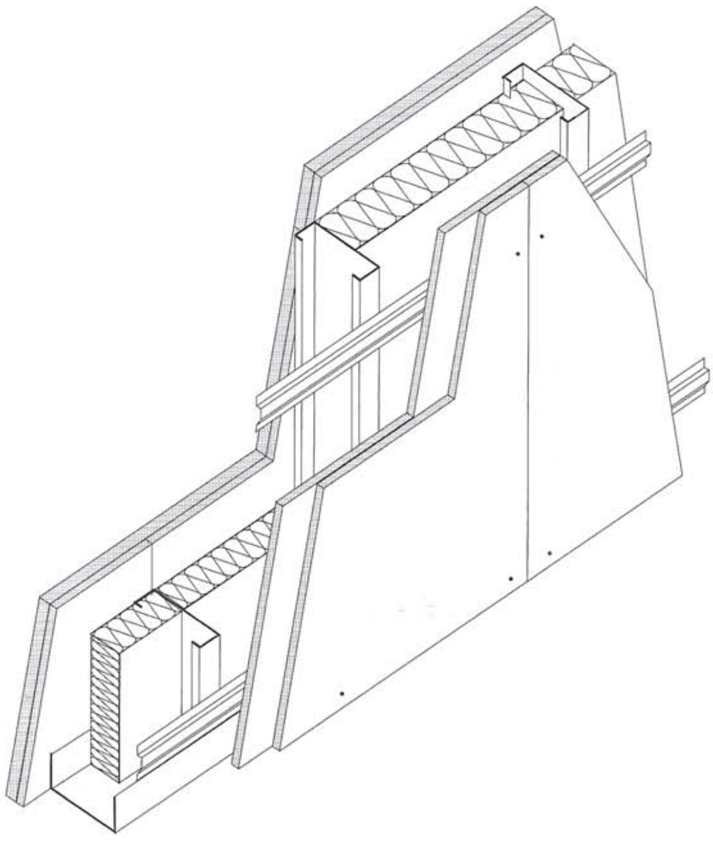


Fig. 50 (top): Influence factors on the sound-absorbent material of cavity structural components

Fig. 51 (bottom): Structure of a metal upright wall with resilient channel



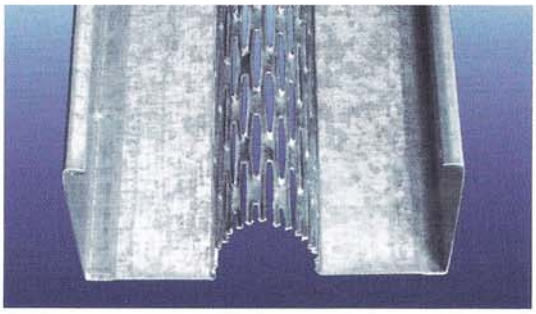
well as the way the plates are fixed on the supports, among other things, affect this factor;

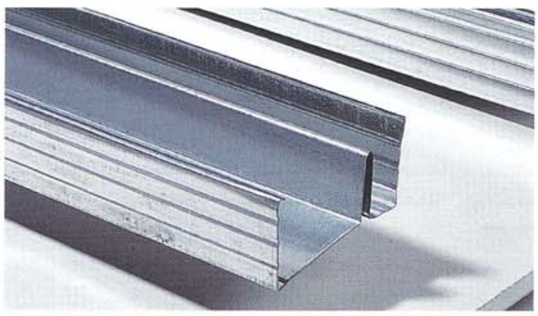
- the spacing between the plates (choice of section);
- their elasticity. This depends, among other things, on their thickness, the material used and their composition;
- their weight in relation to the surface area. This is related, among others, to the material used and the number of layers;
- the type, properties (best absorption of certain wavelengths, for example) and filling level of the insulating material.

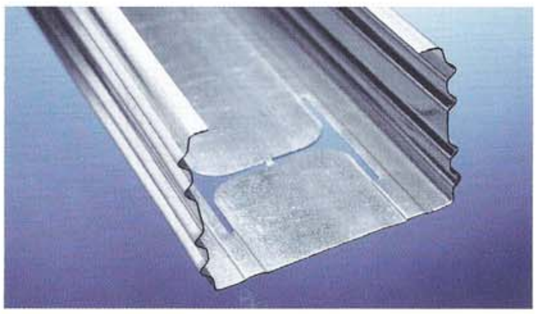
Fig. 52 (top): Acoustic profile with web separation made of expanded mesh (tread)

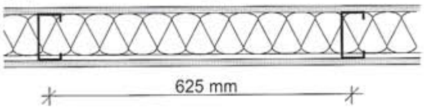
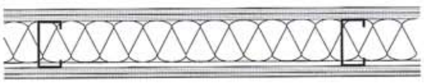
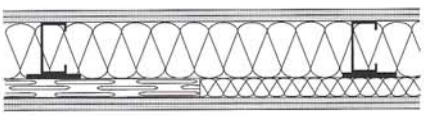
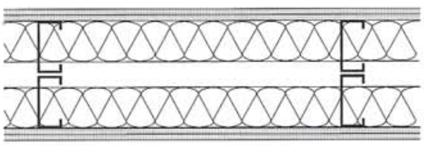
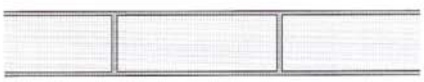
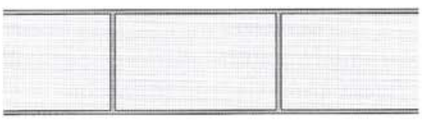
Fig. 53a (bottom middle): Acoustic profile with folded profile web, metal upright wall section (Knauf)

Fig. 53b (bottom): Acoustic profile with grooved profile flange (Knauf)







Construction	Structure Prefab. Part Thickness Surface	Weight	Airborne sound insulation index R'w	Fire protection*
Single upright wall, basic planking gypsum fiber board, gypsum board  	75 — 125 mm	35 — 45 kg/m^2	40 — 54 dB	30 min
Single upright wall, double planking with gypsum fiber board, gypsum board 	100 — 150 mm	45 — 65 kg/m^2	47 — 60 dB	60 to 90 min
Single upright wall with "Resilient Channels", double planking with gypsum fiber board, gypsum board 	ca. 155 mm	ca. 52 kg/m^2	ca. 61 dB	60 to 90 min
Double upright wall, double planking with gypsum fiber board, gypsum board 	175 — 275 mm	65 — 80 kg/m^2	59 — 65 dB	90 to 120 min
Solid brick and sandlime brick wall, 11.5 cm, plastered 	145 mm	4 200 kg/m ^{2}	42 — 47 dB	90 to 120 min
Solid brick and sandlime brick wall 24 cm, plastered 	270 mm	430 kg/m ^{2}	48 — 55 dB	180 min

* Fire protection depends on use as load-bearing or non-structural separation wall

Fig. 54: Acoustic properties of wall superstructures in light-weight steel construction compared to solid construction

Attenuation of airborne noise in a building with a lightweight steel structure

The following criteria have positive effects on the soundproofing of a sandwich panel.

Flexible sheathing with a high mass per surface unit

To obtain good soundproofing, the sheathing plate must be "flexible" from an acoustic viewpoint. This type of plate is a normal plate about 20 mm thick that may be in plaster, fibre plaster or even in wood.

The mass per unit surface of the sheathing also has a positive influence on the soundproofing of a panel. The higher the mass, the better the soundproofing of the panel.

Possible combinations

- Increase of the sheathing mass.
- Double sheathing.
- Ballasting of the sheathing.

Separation of the fastening of the two plates

The link between two plates, for example by the upright, creates an "acoustic bridge".

To obtain better soundproofing, the two sides must be as separated as possible (by adding resilient sections between the plate and the upright, for example, fig. 51) or ideally, completely independent (each side is fastened on separate uprights).

Excellent progress has been made in soundproofing performance with sections that have a deep fold in the web. Consequently, sections that allow some vibration in plates are known as "efficient soundproofing material". There are also some sections with edges that have been pinched or grooved in order to reduce the bearing section and thereby the acoustical bridge.

Possible combinations

- Larger spacing.
- Larger spaces between plates.
- Fastening of plates on insulating strips, resilient sections or springs.
- Sections that limit acoustical bridges (for example, pinched or grooved sections, MW sections).
- Separation of the two sides of the panel (double supports).

Insulation of the internal cavity

To improve acoustic performance, the space between the plates is generally filled with sound-absorbing (often fibrous) materials.

When the sound energy crosses these fibres, it is converted into heat energy. Hardened materials, such as rigid foams are not suitable for this purpose.

Possible combinations

- Filling of up to 80% of the space between the plates with a fibrous matter (to avoid creating an acoustical bridge through this material).

Lightweight steel structure floors

Floors require the same soundproofing measures as walls. However, there is another important criterion in addition to the reduction of airborne sound: the attenuation of footsteps and impact noise. This requirement is more difficult to meet for light floors than the reduction of airborne noise and therefore, a lot of thought must be given to implementing it. We can assume that if there is a good insulation from impact noise, the general acoustic performance will be necessarily good.

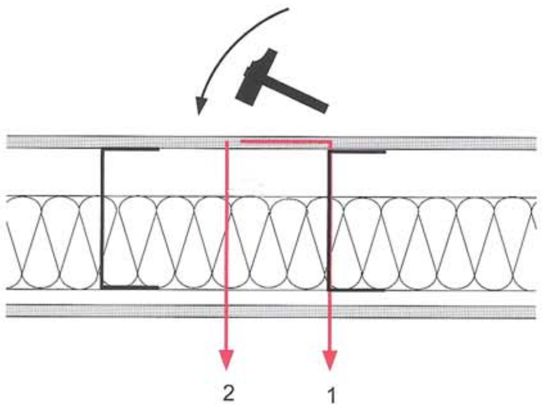


Fig. 55
Impact sound transmission in lightweight steel ceilings
1. Transmission via the beam
2. Transmission via the hollow ceiling

To obtain this insulation with a lightweight steel structure, we try to prevent the direct propagation of footsteps through the floor by separating the reception of sound on its topside as much as possible from its emission by the underside. This is achieved by separating each layer during construction. This can be solved with a floating floor because it is separated from the load-bearing frame by soundproofing layers.

The following criteria have positive effects on the soundproofing of floors:

- elasticity and high mass of the slab in relation to the surface;
- flexibility of the thick sound-insulating material (up to 50 mm thick);
- avoiding acoustic bridges near the walls and the load carrying structure;
- careful execution of junctions with walls (insulating borders);
- ballasting in the form of caulking, upholstery or stone veneer;
- elastic floor covering, for example carpet (is not included in the soundproofing design.

Dry construction systems have better acoustic performances than normal processes and also have the added advantages of less weight and the fact that they are immediately available. They also do not use water, which will then have to evaporate, thereby slowing down work.

The usual method of calculating sound proofing in solid floorboards with a floor covering is only recently being applied to light floors. Improvements, generally in the form of a floating floor, cannot be transposed to steel structure constructions. In terms of impact sound proofing, the weak points of solid wood floors are with high frequencies whereas floors made of lightweight metal structures perform less well for low frequencies. Since the effect of a floating floor is less for low frequencies than for high frequencies, we have made the following observation: classic means of insulation such as floating floors are more effective for solid floors than for thin floors.

There may be sound proofing differences depending on the dry construction system adopted.

Fig. 56 (top)
Resilent channels for attaching the suspended ceiling to the bearing profiles without affecting acoustics (Profilhaus, Ettlingen)

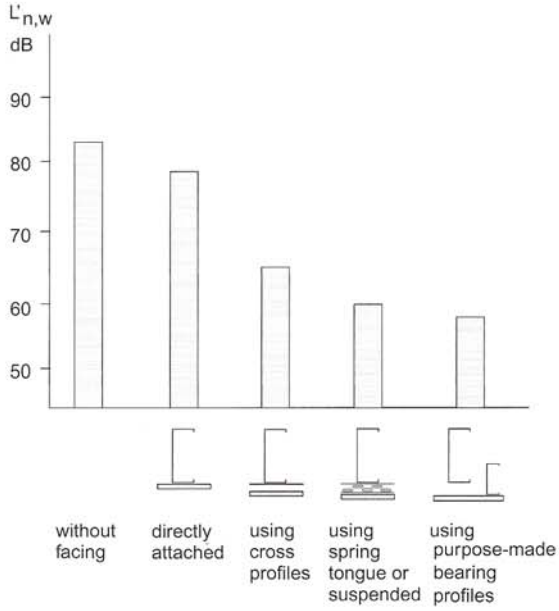


Fig. 57 (Middle)
Reduction of the standard impact sound level L'_n by releasing the connection between the lower cladding and the load-bearing profile (Estimate the values on the basis of wooden joist ceilings)

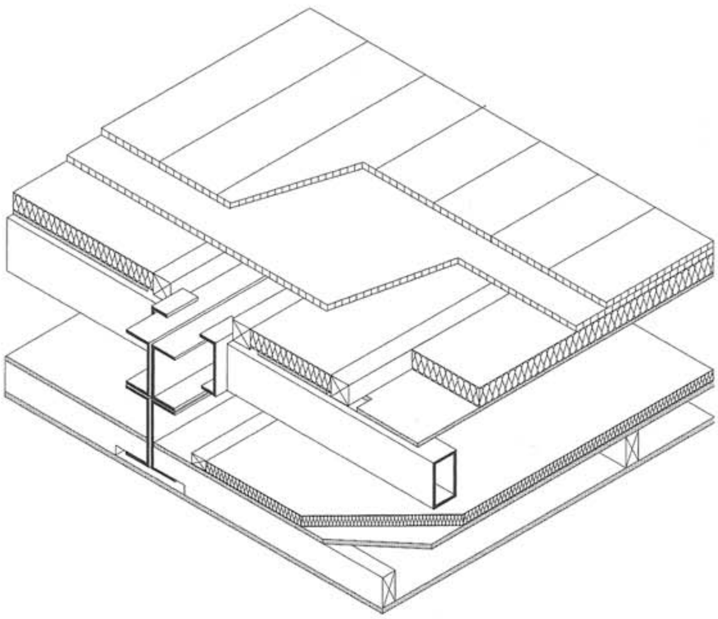
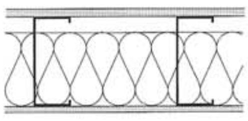
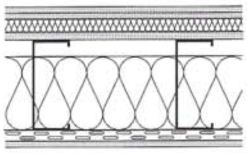
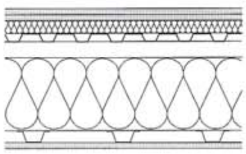
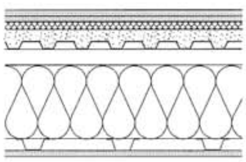
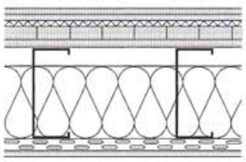
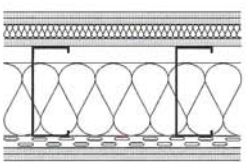
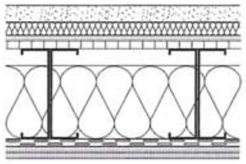
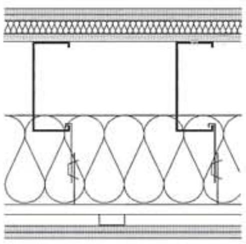


Fig. 58 (bottom)
Ceiling structure with three separate preformed sections;
Impact sound level $L_{n,w,eq,R} = 41$ dB;
Airborne sound insulation $R'_w = 70$ dB

Component structure		Sound reduction index R'_w	Impact sound level $L_{n,w,R}$
	Cement-bound fiberboard 22 mm Floor joist 200 mm Mineral fiber insulation 160 mm Gypsum plaster 12.5 mm	38 dB*	73 dB*
	Dry subfloor gypsum fiberboard 2x10 mm Impact-sound insulation 20 mm Trapezoidal sheet metal 25 mm Floor joist 200 mm Mineral fiber insulation160 mm Spring rail 25 mm Gypsum plaster 12,5 mm	52 dB*	58 dB*
	Dry subfloor gypsum fiberboard 2x10 mm Impact-sound insulation 20 mm Trapezoidal sheet metal 25 mm Floor joist 200 mm Mineral fiber insulation160 mm Spring rail 25 mm Gypsum plaster 12,5 mm	52 dB*	58 dB*
	Dry subfloor gypsum fiberboard 2x10 mm Impact-sound insulation 10 mm Weighting sand mats 34 mm Cement-bound fiberboard 22 mm Floor joist 200 mm Mineral fiber insulation 160 mm Spring rail 25 mm Gypsum plaster 12.5 mm	56 dB*	50 dB*
	Dry subfloor gypsum fiberboard 2x10 mm Impact-sound insulation 10 mm Weighting sand mats 34 mm Cement-bound fiberboard 22 mm Floor joist 200 mm Mineral fiber insulation 160 mm Spring rail 25 mm Gypsum plaster 12.5 mm	58 dB*	50 dB*
	Dry subfloor gypsum fiberboard 2x12.5 mm Impact-sound insulation 20 mm Cement-bound fiberboard 22 mm Floor joist 200 mm Mineral fiber insulation 160 mm Spring rail 25 mm Gypsum plaster 2x12.5 mm	54 dB*	53 dB*
	Concrete screed 50 mm Impact-sound insulation 30 mm Plaster building board 12.5 mm Particle board 19 mm Floor joist 200 mm Mineral fiber insulation 160 mm Spring rail 25 mm Gypsum plaster 2x12.5 mm	69 dB Acc-to-test certificate	45 dB Acc-to-test certificate
	Dry subfloor gypsum fiberboard 2x12.5 mm Impact-sound insulation 20 mm Cement-bound fiberboard 22 mm Floor joist 200 mm Mineral fiber insulation 160 mm Suspension Basic and load-bearing CD profile 2x25 mm Gypsum plaster 2x12.5 mm	53 dB*	52 dB*

* Noise protection values and ceiling structures in light-weight steel construction.

Fig. 59
Noise protection values and ceiling structures in lightweight steel construction

Consequently, measures taken to improve a particular floor will be valid only for that floor and cannot be transposed, at least in the present state of our knowledge, as is the case for solid floors. To avoid errors in interpreting the acoustical results obtained, we can compare them only when the fundamental principles of floor construction are identical, for example:

- the type of section;
- the cross-section of the section;
- the spacing;
- the type and thickness of plates;
- the type, thickness, number of layers and the fastening mode of the sheathing of these plates;
- the type and degree of filling of the material in the internal cavity;
- ballasting.

The underside of the floor is covered with a ceiling plate, which can be fastened either directly under the joists or separated in different ways.

We improve the acoustic performance of this covering by paying attention to the following points:

- elasticity and high mass in relation to the surface of the covering;
- flexible assembly, in terms of sound, of this covering under the joists using insulating strips, resilient sections, two cap sections or flexible fastenings.

To comply with minimum soundproofing standards for light floors in residential buildings built using dry construction methods, the following conditions must be met:

- > 20 mm thick dry slab;
- good quality insulating material (mineral wool) > 20 mm;
- load-carrying formwork > 19 mm thick; Filling of the internal cavity < 80%;
- resilient sections, spring links, independent fastenings;
- two wear coats < 2 x 15 mm.

It is generally not possible to comply with standards without an elastic fastening of the floor covering or with only one wear coat. The floor covering must also be as heavy and as elastic as possible; for example, a fibre-plaster plate with a thickness of between 10 to 12.5 mm or plasterboard with a thickness of 12.5 to 15 cm. With these precautions, the sound reduction index of airborne noise is approximately 60 dB and that of impact sound is approximately 51-54 dB which just complies with the standards.

If the dry floor is separated from the joists, using individual footings or insulating clips, it is possible to reach an impact sound reduction index of $L'_{n,w}$ = 51-54 dB. This can be improved further by ballasting the floor covering more.

If the resilient section is not used (elastic fastening of floor covering), the minimum requirements for flat-separating floors are (barely) reached with the floating floor.

By combining the floating floor and, either the resilient section or ballasting, a low index is attained ($L_{n,w,R}$ = 44-50 dB), that corresponds more or less to the index of the dry slab + ballasting + resilient section combination. The best index ($L_{n,w,R}$ > = 42 dB) is obtained by combining massive slab + ballasting + resilient section.

Longitudinal propagation of sound

Phonic insulation between different rooms is not due to only the acoustic performance of a divider, it is the result of all the various sound-carrying possibilities. Longitudinal propagation via adjacent members is one of the possible routes. Sound waves are carried by these members and radiate into the next room.

Lateral transmission principles in lightweight steel-framed constructions differ from those prevalent in solid constructions. Due to the rigid junction of dividers and adjacent parts, we have what is referred to as the "absorption of impact points" in solid constructions which improves the sound reduction index of the partitioning wall. In lightweight steel-framed construction, the partitioning members and the adjacent part are linked to one another by an articulation. They can therefore, oscillate independently without mutual interaction. But this does not mean that the lateral transmission of sound is weaker.

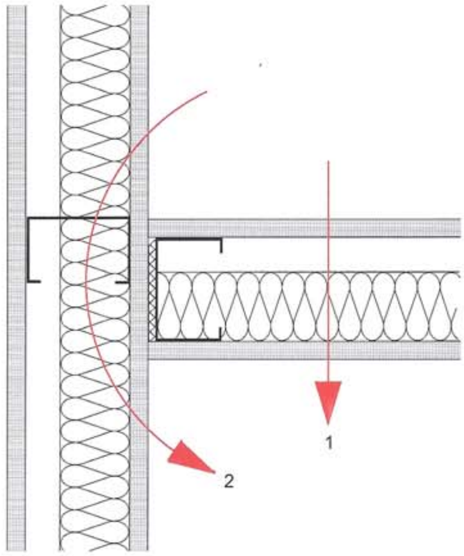
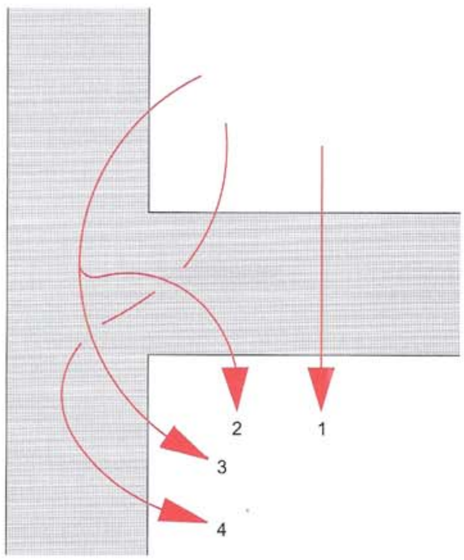


Fig. 60:
Sound transmission paths in lightweight construction

Transmission via the separating structural component and via the flanking structural component



Sound transmission paths in solid construction

Interaction between separating and flanking structural components during the sound transmission with four different transmission paths

On the contrary, with light double walls, longitudinal propagation becomes very significant and must not be neglected.

According to standard EN 12354, the longitudinal sound reduction index relating to light double walls is between 55 and 75 dB. Basically, there are two types of sound propagation paths in this type of construction, whether they are walls, ceilings or floors. First, the coating surface and second, the internal cavity.

Therefore, measures aimed at reducing longitudinal sound propagation are targeted at these two paths. Solutions for minimising sound wave propagation in the internal cavity include filling it with fibrous materials or sectioning the longitudinal plate perpendicularly to the divider. Sound propagation through a wall plate depends on how that wall was manufactured.

A stronger mass has a positive effect; for example sound is propagated less through two layers of coating than through a single one.

However, the most efficient solution entails breaking the connection between the contact surface of the partitioning member, in other words ensuring the absence of a continuous plating between two adjacent rooms. The choice of this construction process considerably reduces longitudinal noise to the point where there is practically no sound propagation through the walls.

It is therefore the most efficient method for obtaining proper soundproofing.

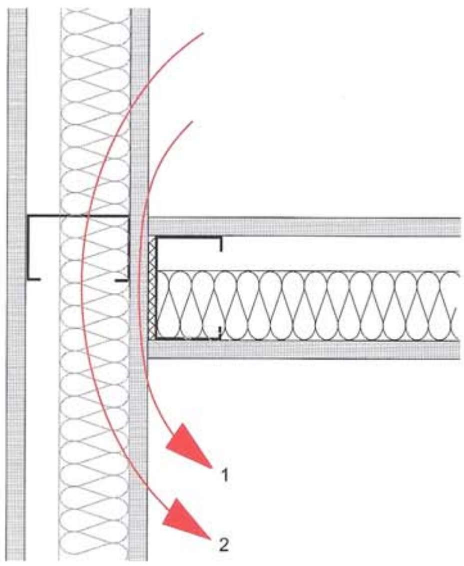


Fig. 61:
Sound transmission paths in flanking structural component

1. Transmission via the planking (e.g. top layer, wall form)
2. Transmission via the cavity

Connection between two members

The connection between flexible double partitions and adjacent parts (ceilings, floors and walls) is very important. In lightweight constructions, great attention must be paid to how these connections are made; they are in fact, critical to the optimum reduction of the longitudinal propagation of sound discussed earlier on. Furthermore, the connection of two members leaves an interstice. Hence, the importance of placing a hermetic acoustic seal in that interstice **(Fig. 62 and 63)**. Defective sealing would result in sound bridges enabling airborne noises to move from room to room without even passing through a solid body. These imperfections would be most detrimental to an efficient soundproofing.

In order to preserve the acoustic qualities of a lightweight steel-framed construction, special attention must be paid to connection jobs **(Fig. 63)** by complying with the points below:

- acoustic separation of adjacent members;
- acoustic separation of abutted members;
- installation of insulating strips, insulating material;
- use of special sections equipped with sealing joints **(Fig. 64)**;
- careful sealing of connections with a mastic sealant.

The sound reduction index of the plating of adjacent walls and its connection with the divider are indicated in standard EN 12354-1, annex E, as well as in the publications and dossiers on this topic. It would be appropriate to check that the values given are applicable to the dividing walls of apartments and are not too low. In this case, the architect must use the values measured during the tests, such as those concerning the plaster-fibre plates. By "combining" the sound reduction indices of adjacent members (wall, ceiling, floor) and the divider, we obtain a result. For this calculation, we can refer to standard EN 12354-1, part 4, or to the spreadsheets of manufacturers.

Table 68, where the principal sound propagation paths are listed, can be used as a guide to design the right acoustic insulation.

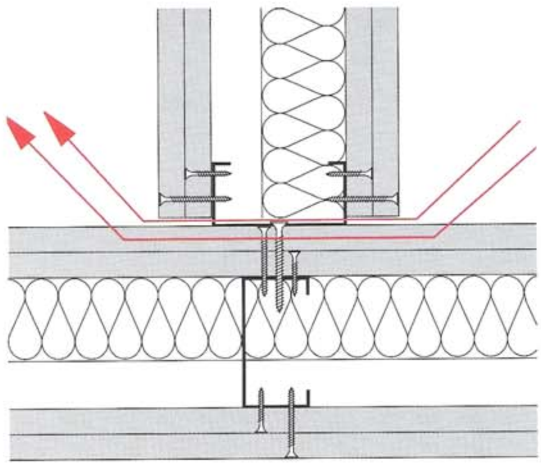


Fig. 62: Acoustic leaking and sound bridge in the vicinity of a structural component junction

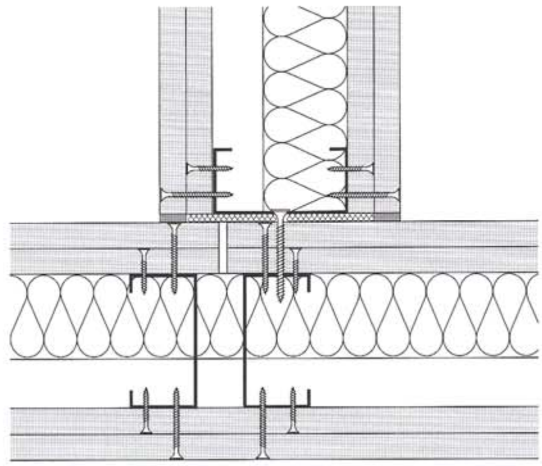


Fig. 63: Acoustically correct structural component junction with tight wall junction and separation of the flanking planking

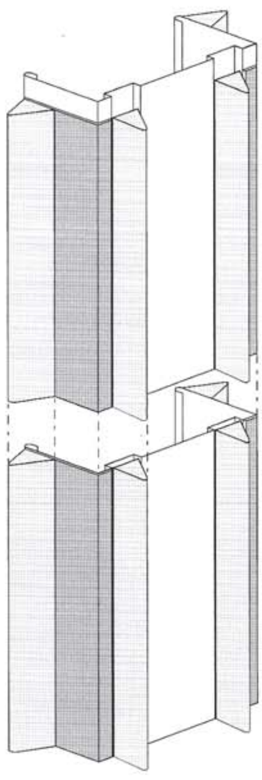
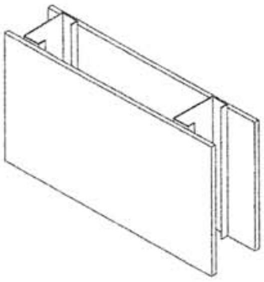
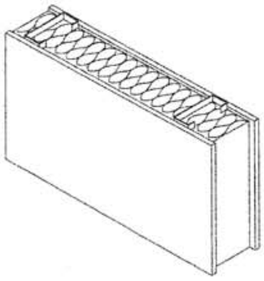
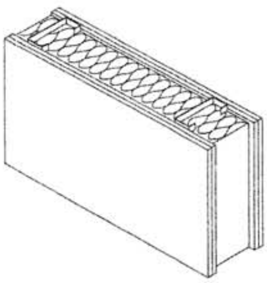
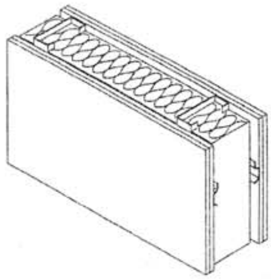
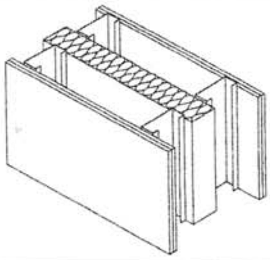


Fig. 64: Metal profile with connected dry seal

Sound insulation (indicative) and fire resistance of lighsteel wall constructions			
	Materials Specification	**Acoustic Separation D_nT_w**	**Fire Resistance**
	12.5 mm plasterboard Light steel studs 12.5 mm plasterboard	35 dB	30 min
	12.5 mm plasterboard Light steel studs with mineral wool between 12.5 mm plasterboard	45 dB	30 min
	2 layers of 12.5 mm plasterboard Light steel with mineral wool between 2 layers of 12.5 mm plasterboard	50 dB	60 min
	2 layers of 12.5 mm plasterboard Resilient bars Light steel studs with mineral wool between Resilient bars 2 layers of 12.5 mm plasterboard	58-60 dB	60 min
	2 layers of 12.5 mm plasterboard Light steel studs Clear structural cavity between studs filled with mineral wool Light steel joists 2 layers of 12.5 mm plasterboard	60-65 dB	60 min

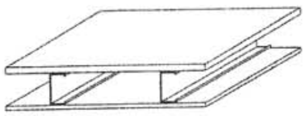
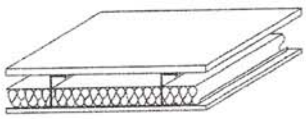
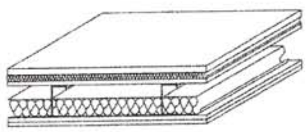
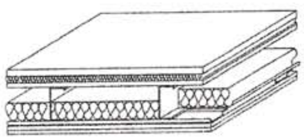
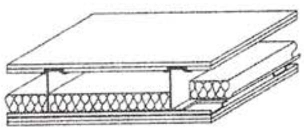
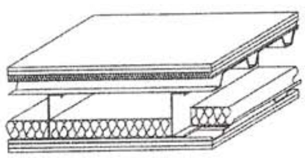
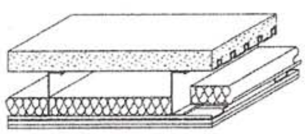
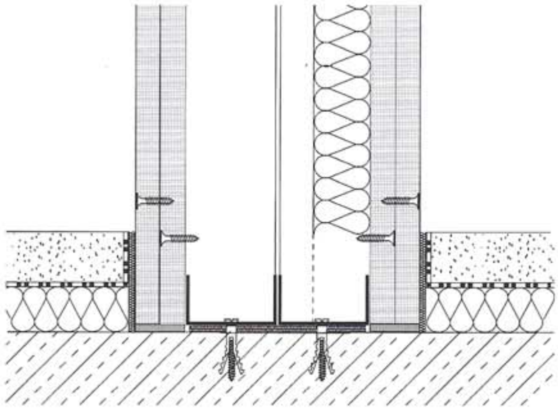
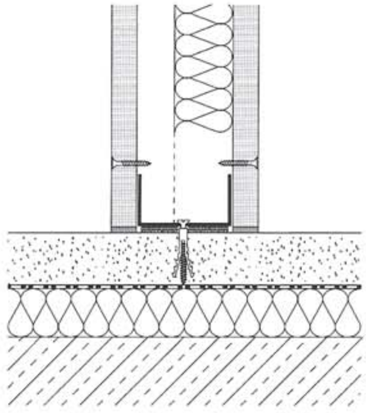
	Materials Specification	Acoustic Separation D_nT_w	Fire Resistance
	18 mm chipboard Light steel joists 12.5 mm plasterboard	$D_{nTw} = 33$ $L_{nTw} = 83$	30 min
	18 mm chipboard Light steel joists 100 mm mineral wool between joists 12.5 mm plasterboard	$D_{nTw} = 42$ $L_{nTw} = 76$	30 min
	19 mm cement particle board > 10 mm resilient layer Chipboard, OSB or plywood Light steel joists 100 mm mineral wool 2 layers of plasterboard (total thickness 30 mm)	$D_{nTw} = 52$ $L_{nTw} = 61$	60 min
	18 mm T&G chipboard 19 mm plasterboard 25-30 mm mineral wool or glass wool Chipboard, OSB or plywood base Light steel joists 100 mm mineral wool between joists Resilient bars 2 layers of plasterboard (total thickness 30 mm)	$D_{nTw} = 57\text{-}60$ $L_{nTw} = 54\text{-}57$	60 min
	18 mm T&G chipboard Proprietary top hat isolating section Plasterboard between teh top hat section Light steel joists Mineral wool between joists Resilient bars 2 layers of plasterboard (total thickness 30 mm)	$D_{nTw} = 55$ $L_{nTw} = 59$	60 min
	18 mm T&G chipboard 19 mm plasterboard 25-30 mm mineral wool or glass wool 30 mm profiled steel decking Light steel joists Mineral wool between joists 2 layers of plasterboard (total thickness 30 mm)	$D_{nTw} = 55$ $L_{nTw} = 59$	60 min
	Composite steel and concrete slab Light steel joists Mineral wool between joists Resilient bars 2 layers of plasterboard (total thickness 30 mm)	$D_{nTw} = 55\text{-}59$ $L_{nTw} = 53\text{-}59$	60 min

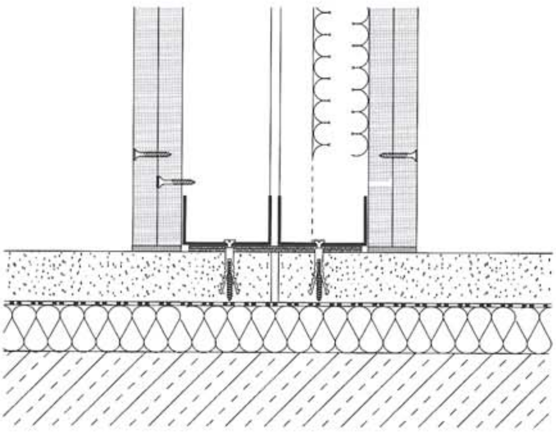
Fig. 65:
Junction details:
Partition wall on mass screed,
Partition facing Gypsum plaster,
Cement floor (floating), $R'_{w,R}$ calculated only considering partition and floor only



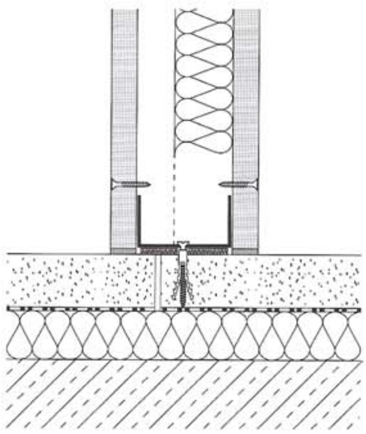
Partition $R_{w,R}$ = 60 dB
Mass screed $R_{L,w,R}$ = 70 dB
$R'_{w,R}$ = 59 dB



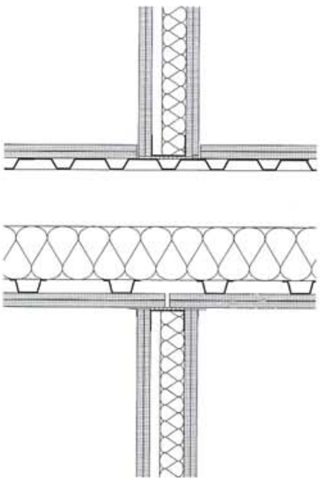
Partition $R_{w,R}$ = 41 dB
Mass screed $R_{L,w,R}$ = 38 dB
$R'_{w,R}$ = 36 dB



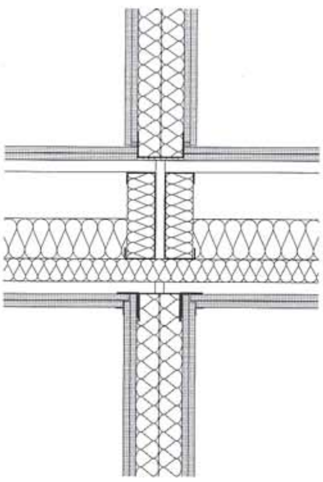
Partition $R_{w,R}$ = 60 dB
Mass screed $R_{L,w,R}$ = 55 dB
$R'_{w,R}$ = 53 dB



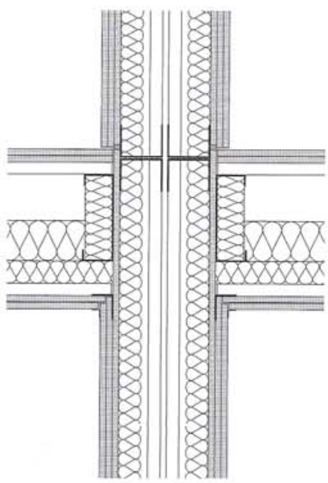
Partition $R_{w,R}$ = 41 dB
Mass screed $R_{L,w,R}$ = 55 dB
$R'_{w,R}$ = 40 dB



R'_w = 44 dB $L_{n,w,R}$ = 54-57 dB

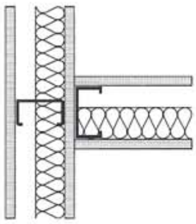
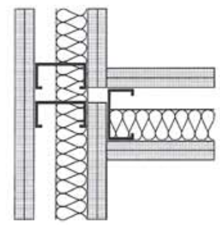
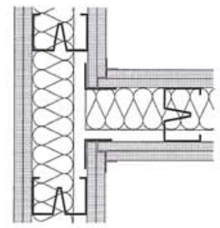
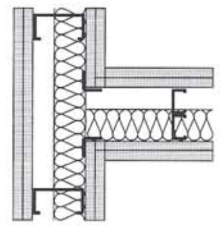
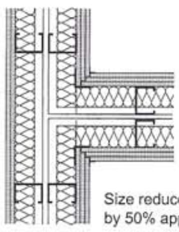
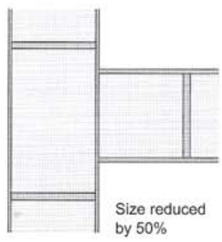


R'_w = 52 dB $L_{n,w,R}$ = 52-53 dB



R'_w =60 dB $L_{n,w,R}$=43-47 dB

Fig. 66:
Partition junction to ceilings

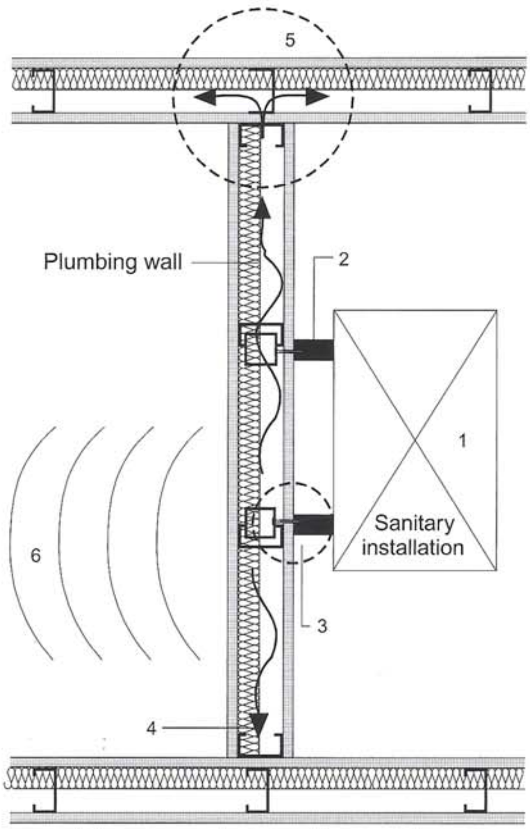
Joint of the flanking wall at the partition	Longitudinal sound transmission coefficient R of the flanking walls	Sound insulation index R of the partition $_{w,R}$	Resulting sound insulation index R' $_{w,R}$
1 	53 dB Gypsum plasterboard	42 dB Gypsum plasterboard	41 dB
	57 dB with test certificate, Gypsum fiberboard	52 dB Test certificate, Gypsum fiberboard	49 dB
2 	57 dB Gypsum plasterboard	52 dB Gypsum plasterboard	49 dB
	62 dB with test certificate, Gypsum fiberboard	57 dB Test certificate, Gypsum fiberboard	54 dB
3 	75 dB Gypsum plasterboard	54 dB Gypsum plasterboard	54 dB
	75 dB in conformity with test certificate, Gypsum fiberboard	60 dB Gypsum plasterboard	59 dB
4 	75 dB Gypsum plasterboard	60 dB Gypsum plasterboard	59 dB
	75 dB with test certificate, Gypsum fiberboard	64 dB test certificate, Gypsum fiberboard	63 dB
5  Size reduced by 50% approx.	approx. 76 dB Gypsum plasterboard	approx. 64 dB Gypsum plasterboard	63 dB
	76 dB in conformity with test certificate, Gypsum fiberboard	approx. 68 dB Gypsum fiberboard	66 dB
Comparative construction to 4  Size reduced by 50%	300 kg 17.5 cm Sandlime brick -1.8	960 kg ~ 42 cm Reinforced concrete	63 dB
	400 kg 24 cm Sandlime brick-1,8	810 kg ~ 35 cm Reinforced concrete	63 dB
	600 kg 30 cm Sandlime brick-1.8	600 kg ~ 26 cm Reinforced concrete	63 dB

1) Sound transmission via the partition and two similar flanking walls [dB] according to depiction.
2) Average for the depicted design determined during series of measurements conducted by the gypsum plaster industry for gypsum plasterboard metal framing.

Fig. 67: Measures to reduce longitudinal transmission of sound based on the example of wall T-joints

Sound transmission paths	
Transmission through the partition	- Through free openings or leaks in the surface (e.g. opposite outlets, sanitary installations) - Through weaknesses in the wall structure (e.g. shadow gaps, hidden baseboards)
Transmission in ceiling area	- Through continuous ceiling joist - Via "light" ceilings, e.g. hollow-block ceilings - Along a continuous ceiling covering or suspended ceiling - Through the ceiling cavity (between the beams)
Transmission along a flanking wall (corridor wall/external wall)	- Through the wall element - Through the connection joint - Through the door and then via the corridor - Along a continuous heat-insulating layer
Transmission along continuous structural components	- Sanitary installations - Heating pipes - Cable conduits

Fig. 68:
Sound transmission paths (after rest)



1. Reduce excitation by using low-noise sanitary installations
2. Reduce excitation of lightweight constructions by mounting sanitary installations properly
3. Reduce excitation of lightweight constructions through positive measures
4. Reduce structure-borne sound transmission in plumbing walls
5. Reduce structure-borne sound transmission from the plumbing wall to flanking structural components
6. Reduce airborne-sound propagation through the plumbing wall

Fig. 69
Measures to reduce the structure-borne sound transmission of installations

Sound insulation of sanitary equipment

Impact noises transmitted through ducts

Some noises are generated by the use of water (arrival and outflow). Water noises are transmitted by the structure just as impact noises, and circulate through the rest of the house. In general, the problem of equipment noises occurs when the sound reduction of impact noises is insufficient.

Overall, concerning impact noise attenuation, equipment noises can be divided into three:

- emission;
- transmission;
- radiation.

To obtain the best possible insulation, the three possibilities must be dealt with separately.

For controlling emission noises, silent fixtures and pipe fittings must be installed with careful attention to soundproofing.

To reduce noise transmission, it is important to separate emission zone and radiation zone, in other words, fix the noise generators (sanitary equipment, pipes, etc.) to members which do not participate in sound radiation in adjacent rooms.

This separation can be obtained by lining or sheathing the double partition supports. Radiation can also be separated by lining the adjacent rooms.

There is also the solution of installing elastic but heavy plates to reduce the radiation itself.

The design rules for reducing impact noises given above lead to lower sound distribution than in a solid construction.

The critical points to watch out for when installing sanitary facilities in a lightweight steel-framed house are the following:

- soundproofing fasteners for ducts on the structure by using rubber covered flanges **(Fig. 72)**. If clamps are used, an insulating material must be placed between the clamp and the pipe and between the clamp and the wall;
- avoid any rigid fasteners for sanitary fixtures on the walls or on the floor:
  – insulating fastener for basins, bowl and flushing, and bearers on the structure by inserting elastic seals,
  – install the bathtub and related accessories on an insulant (a resin

pedestal, for instance) or on a floating slab,
– insulate the bathtub and the area near the walls with a flexible strip; use insulating sections for the bathtub edges,
– insulate the pipe fittings (against the tiles, for example) by inserting flexible seals or by using plastic fittings,
– bore holes and floors by sheathing the pipes;

- use noise-reducing special pipes, in particularly sensitive places; be careful to give them a larger exterior diameter (120 mm instead of 100 for a drainage duct);
- avoid contact (pipes and fittings) between incoming pipes and water flow (acoustical bridges);
- fill remaining internal cavity in the double partitions and the formworks with insulating material **(Fig. 74)**;
- surround all pipes with a flexible material (insulating sleeve, felt sleeve, etc., no hard resin foam);
- use type I pipes (sound insulant) and reduce water pressure;
- install silent water flushing system;
- preferably choose the most complete prefabricated wall, for the wall receiving the equipment or different members, to avoid as much as possible erection faults; have job performed by tradesmen skilled in insulation techniques.

The recommendation to fix the shower tray or the bathtub on a floating slab may be problematic due to the compressibility of the insulating layer and the resulting sagging of the seal around the basin, if this sag is higher than 1 mm. Therefore, a sufficiently rigid material must be used for this insulating layer.

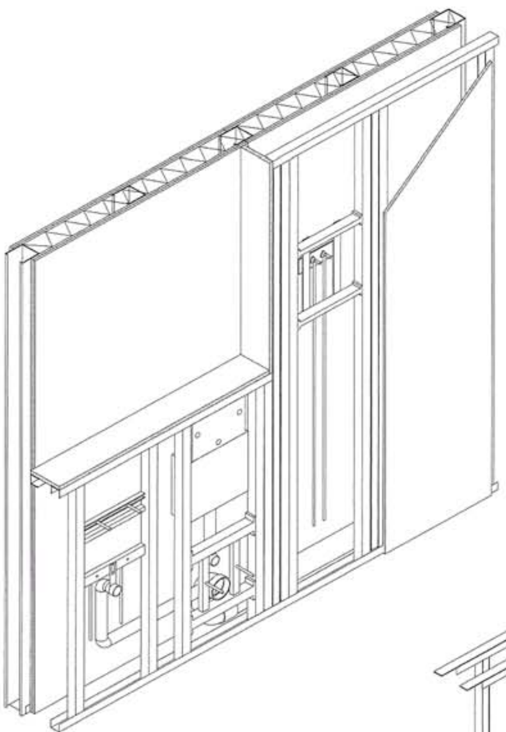


Fig. 70 (bottom left): Installations on wall for sanitary equipment (medium high and room high)

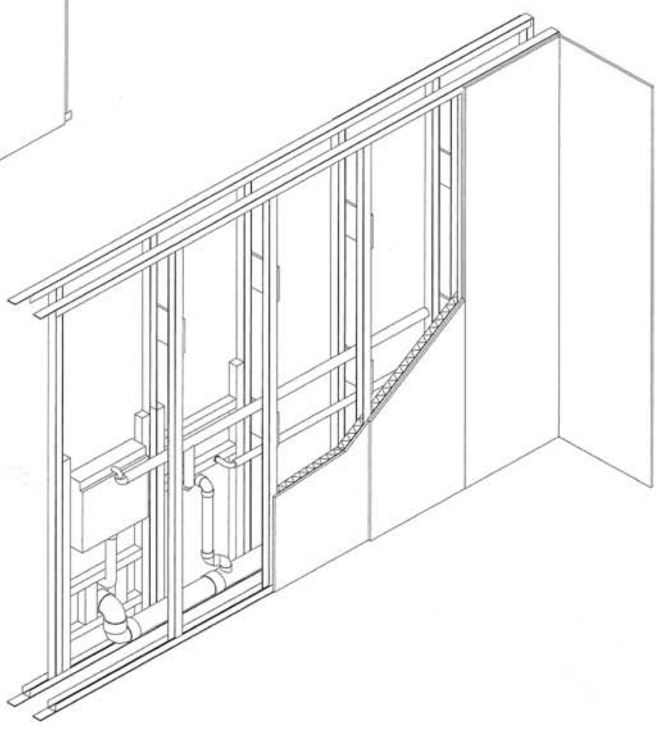


Fig. 71 (bottom right): Double column plumbing wall. The studs are joined by plate strips

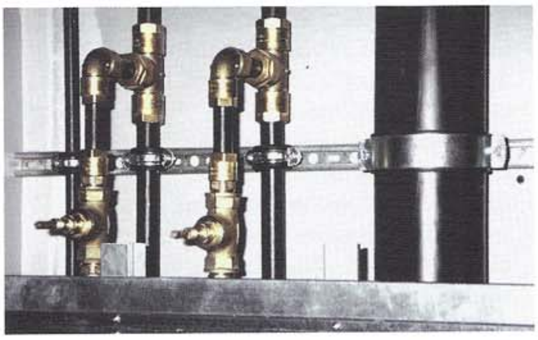


Fig. 72:
Structure-borne sound absorbing mounting of plumbing lines in a dry wall

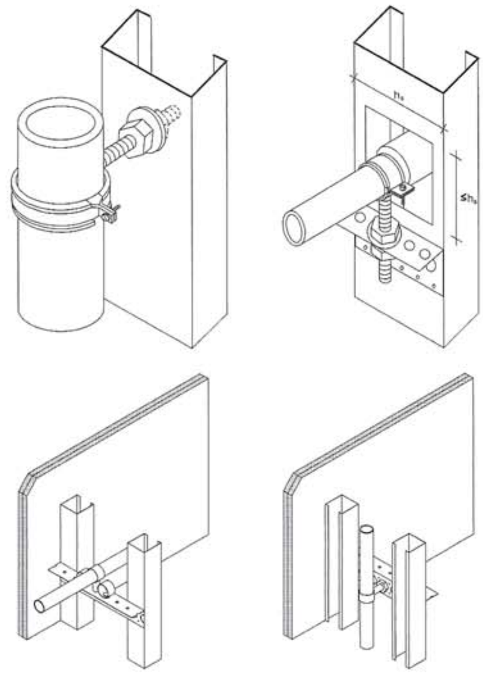


Fig. 73:
Acoustic isolation with resilient insulating layer for horizontal and vertical cable runs in single upright walls and double column walls

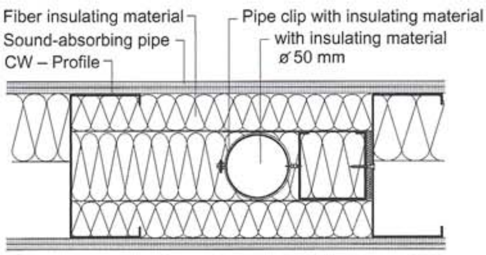


Fig. 74:
Sound-absorbing pipe in a single upright wall

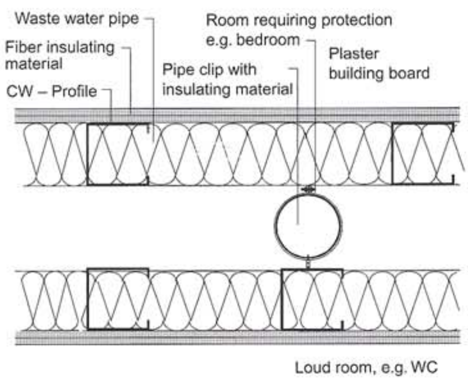


Fig. 75:
Sound-absorbing pipe in a double-column wall

Soundproofing may become less efficient over time due to the gradual hardening of certain elastomers, such as silicon and acrylate when used as sealing joints.

Lining is preferable when the equipment is placed against a dividing wall. However, the internal cavity of lightweight steel structure panels can practically serve as formwork for inserting ducts. Sections quite often have spaces and openings for passing the ducts through. Built-in equipment can also provide good acoustic performance levels provided the instructions below are complied with:

- sheathed pipes must not be mounted on surfaces marked for plating but on the other side of the formwork or on distinct parts (separate upright, floor, ceiling);
- for double surfaces, ducts must be fixed to the noisy side or to distinct members (separate upright, floor, ceiling, fig. 75);
- keep the surfaces separate from each other. There must be no linking (acoustic bridge) between the plating and the ducts. Insert a continuous fibrous insulating material between the equipment and this plating. The formwork depth or the partition width must be suitable for the duct with the largest diameter;
- place a continuous layer of fibrous insulating material (= 40 mm) between the water ducts and the room to be protected;
- double plating;
- fill the formwork with insulating material without compressing it **(Fig. 74)**;
- in case of double upright panels, place the insulating material on the side the noisy room as well **(Fig. 75)**;
- an additional liner must be used if the wall divides two flats. If there are noisy rooms on both sides of a dividing wall between two flats (bathrooms), the equipment can be mounted on that wall, on condition that the insulating requirements are complied with (Fig. 75).

Protection against heat and moisture

Winter thermal insulation

In the external walls of lightweight steel-framed constructions, the primary insulating layer is integrated, in other words, it is situated between the load-bearing uprights. Consequently, the choice of the section depends not only on the physical stress applied to it but also to the desired energy properties. The vacuum separating these uprights must be entirely filled with insulating material in order to avoid thermal bridges and convection flows. The insulating layer is completed, in most cases, by an additional layer installed outside or inside to attenuate the thermal bridge effect due to the steel uprights.

Requirements for low energy houses are almost always achieved in the cases of lightweight steel-framed constructions. And it takes just an additional thermal insulation, such as an external coating for example, for them to meet the requirements of passive houses, then there is no need at all for installing a heating system.

With the same thermal inertia properties, lightweight steel-framed constructions present, thanks to thinner walls, a surface gain of nearly 5 – 10% in relation to a classic, monolithic system. The use of the right door frames helps to optimize the residential surface area **(Fig. 77)**.

Avoiding thermal bridges

The thermal inertia of a lightweight steel-framed building is provided by an external insulating coating as well as the meticulous execution of joints.

To eliminate the risk of heat losses and cold surfaces promoting condensation during heating periods, thermal bridges must be absolutely avoided. Thermal bridges form in corners and at joints (geometric thermal bridges), next to the fasteners and high heat loss members (thermal bridges due to the material, by conduction) as well as the location of sealing faults (convection thermal bridges) in the external coating.

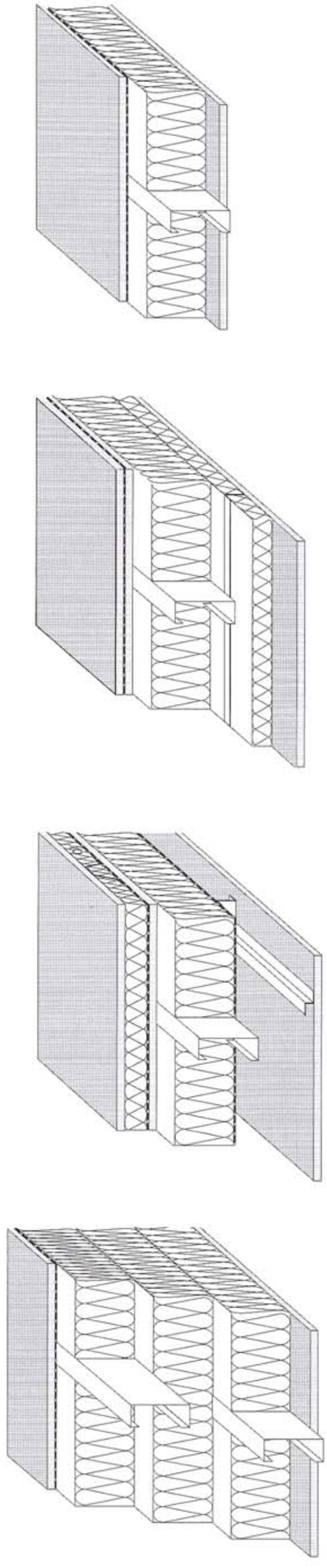


Fig. 76: Structural principles of exterior walls in light-weight steel construction

Fig. 77 (Part 1):

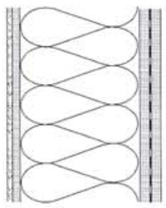
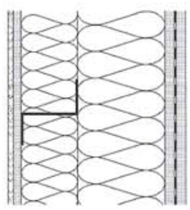
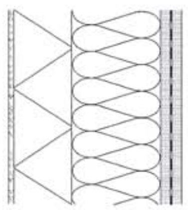
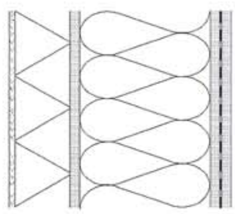
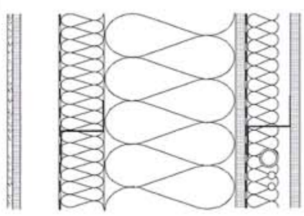
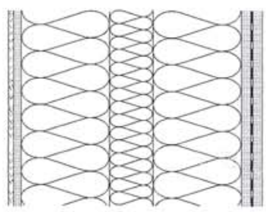
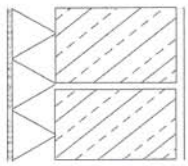
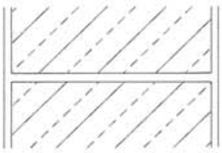
Structural components	Metal profile t = 1,5 mm, unkpunched a = 0.625 m Mineral wool insulation 40 Kg/m² (Thermal conductivity class)	Vapor barrier [mm]	U-value [W/m²K]	Fire protection
	External rendering (reinforced, mineral) Plaster base Metal upright/Mineral wool insulation Vapor barrier Internal cladding fireproof plasterboard, double	10 15 150 - 2 x 12,5 **200**	0,48	30 min
	External rendering (reinforced, mineral) Plaster base Metal profile/Mineral wool insulation Metal upright/Mineral wool insulation Vapor barrier Internal cladding fireproof plasterboard, double	10 15 80 100 - 2 x 12,5 **230**	0,25	30 min
	External rendering (reinforced, mineral) Wooden soft fiberboard Metal upright/Mineral wool insulation Vapor barrier Internal cladding fireproof plasterboard, double	10 80 100 - 2 x 12,5 **215**	0,29	30 min
	External rendering (reinforced, mineral) ETICS (External Thermal Insulation Composite System) Mineral fiber Plaster base Metal upright/Mineral wool insulation Vapor barrier Internal cladding fireproof plasterboard, double	15 80 15 150 - 2 x 12,5 **285**	0,22	30 min
	External rendering (reinforced, mineral) Plaster base Metal profile, double/insulation Wind-tight layer Metal upright/Mineral wool insulation Gypsum fiberboard Vapor barrier Installation plane/Insulation (40 mm) Gypsum fiberboard	10 15 2 x 60 - 150 10 - 60 12,5 **377,5**	0,19	30 min
	External rendering (reinforced, mineral) Plaster base Metal upright, Mineral wool Mineral wool Metal upright Mineral wool (staggered) Vapor barrier Internal cladding fireproof plasterboard, double	10 15 100 50 100 - 2 x 12,5 **300**	0,18	30 min

Fig. 77 (Part 2):
U-values
of external wall
superstructures

Structural components		Thickness [mm]	U-value [W/m²K]	Fire protection
	External rendering (reinforced, mineral) Mineral wool Compo Sandlime brick cored blocks Interior plaster	10 80 175 15 **285**	0,39	120 mn
	External rendering, mineral Cellular concrete block GWP 2/0.5 Interior plaster	20 365 15 **400**	0,37	120 mn

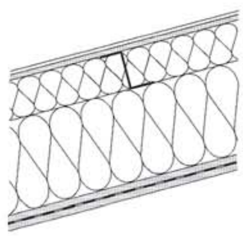
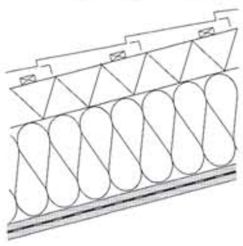
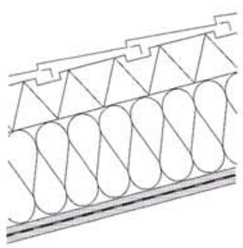
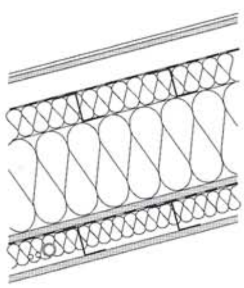
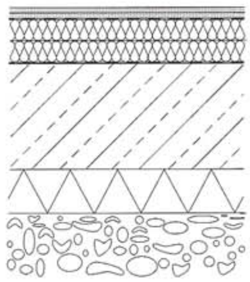
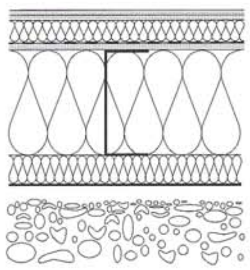
Structural component	Metal profile t = 2.0 mm, unpunched a = 0.40 m Mineral wool insulation 40 Kg/ m³	Thickness [mm]	U-value [W/m²K]	Fire protection
	Roof covering, metal Formwork Metal profile/Insulation Load-bearing profile/Insulation Moisture barrier Internal cladding fireproof plasterboard, double	1,5 22 80 200 - 2 x 12,5 **328,5**	0,21	30 mn
	Roof covering, tile Roof battening Wooden soft fiberboard, impregnated Load-bearing profile/Insulation Vapor barrier Internal cladding fireproof plasterboard, double	40 30 80 200 - 2 x 12,5 **375**	0,27	30 mn
	Roof covering, tile Insulation EPS Load-bearing profile/Insulation Moisture barrier Internal cladding fireproof plasterboard, double	40 80 200 - 2 x 12,5 **345**	0,21	30 mn
	Roof covering, metal Formwork Metal profile (Ventilation) Trusses with sag rods Load-bearing profile/Insulation Cladding gypsum fiberboard Vapor barrier Internal cladding fireproof plasterboard Metal profile/Insulation (40 mm) Metal profile/Insulation	1 22 60 - 60 200 12,5 - 60 12,5 **380,5**	0,19	30 mn

Fig. 78:
U-values from roof
structures

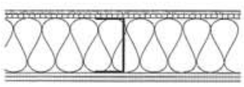
Fig. 79:
U-values of floor slabs and ceilings

Structural component		Thickness [mm]	U-value [W/m²K]	Fire protection
	Gypsum fiberboard, two-layer Moisture barrier Impact-sound/Heat insulation Separation layer Floor slab Insulation XPS Dry area without requirement	2 x 10 - 80 - 200 80 - **380**	0,23	Without requirement
	Gypsum fiberboard, two-layer Impact-sound insulation Moisture barrier Cement-bound fiberboard Insulation/Underlay a = 0.40 m Insulation/Metal profile a = 0.40 m Galvanized sheet Air space Base	2 x 10 40 - 20 200 60 1 **341**	0,19	60 mn

Thermal bridge effects depend directly on the heat loss factors of adjacent zones. The smaller the conductivity of a full panel, the greater the loss via a thermal bridge and the more its negative influence will be felt.

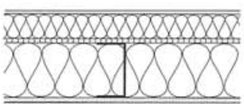
Because steel is a high conductor of heat, one must be extremely careful to insulate the sections in the external members: roof beams or steel fasteners, are all potential thermal bridges.

Fig. 80:
Material thermal bridge; Influence of the metal upright on the surface temperature of the inside



Structural component construction A

Heat-insulating plaster, 10 mm
Particle board V100, 13 mm
Heat insulation, 100 mm
Gypsum fiberboard, 2 x 12.5 mm

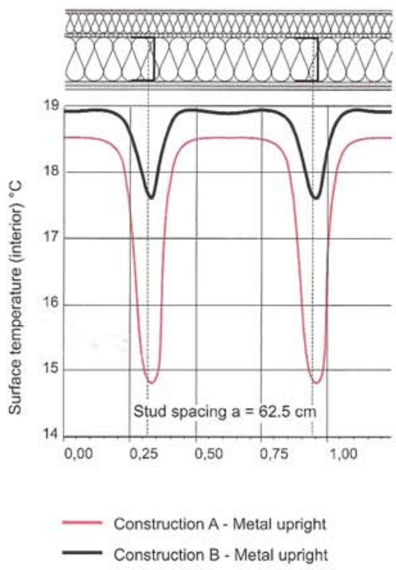


Structural component construction B

Heat-insulating composite system 60 mm

Particle board V100, 13 mm
Heat insulation, 100 mm
Gypsum fiberboard, 2 x 12,5 mm

Metal stud
60 mm x 100 mm x 0.6 mm



Cross steel members must absolutely be avoided.

Next to sections, the temperature of the interior coating can fall below dew point. Mechanical fasteners such as screws tying plates to uprights, also cause lower surface temperatures. By carrying out a thermovision of the exterior wall, we observe exterior temperatures that are higher at the intersection of steel structures than in the rest of the wall **(Fig. 81)**. In the presented example, the difference is around 1 °C.

Illustration 82 shows the technically correct way to avoid the conjunction of geometric thermal bridges and conduction thermal bridges.

Heat resistance and the average coefficient of thermal transmission of the building's components and walls can be calculated in accordance with standard EN ISO 6946 standard. This standard is valid for homogenous walls and gives a trial load method applicable to heterogeneous layers, with the exception of cases where the insulation layer is penetrated by a steel member. Thermal bridges can be calculated by a 3D finite element method defined in standard EN ISO 10211. In practice, this calculation is only possible if the ratio of conductivity coefficients between the steel sections and the insulating material used to fill the internal cavity is not greater than 1/5, which is quite easy to obtain by lining the walls and installing an external insulation.

Table 85 shows the effects of thermal bridges caused by the steel sections on the actual coefficient of conductivity of a wall by comparing different structures and different insulating thicknesses. By using thermal bridge breakage fasteners with a composite insulation system, thermal bridges caused by steel uprights are so limited that the actual conductivity index is barely higher than that of a timber frame structure process.

We can therefore admit as a basic principle that with an additional external insulation which is more than > 60 mm thick and conductivity of 0.04 W/m²K, structural thermal bridges are sufficiently reduced to exclude interior dew points.

Several insulation layers as well as thermal bridge breakage sections can be installed to obtain an extremely high insulation level.

The web plates of these sections, exposed to less mechanical stress, are bored with longitudinal holes to reduce conductivity. The staggered openings reduce direct conduction. According to the layout of these slits and the width of web plates, the path taken by the heat can be multiplied by three **(Fig. 84)**. This significantly reduces propagation. This ingenious example clearly proves that the properties of a construction member can be improved with very little equipment and raw material.

Air and wind tightness

The air and wind tightness of buildings or of their skin is a critical construction property with far-reaching consequences: room atmosphere, absence of construction fault, inside air quality and energy balance.

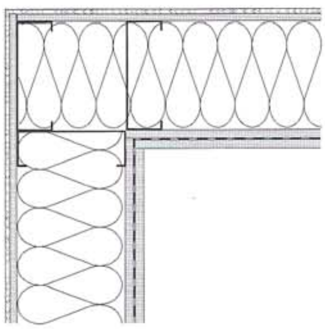
By air tightness, we mean protection against all convection flows due to a pressure difference, the penetration of air in a construction member (from inside to outside or vice-versa, as applicable). As a general rule, waterproof membranes are installed on the inner side of external coatings.

We speak of wind tightness when outside air is prevented from penetrating into the thermal insulation layer or into the internal cavity and, therefore, has no

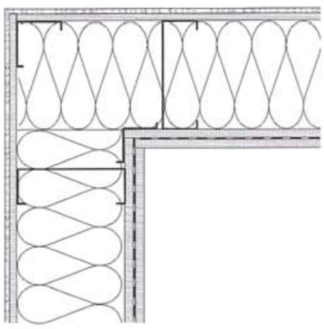
Fig. 81 (top):
Thermovision photo of a building in lightweight steel construction

Fig. 82 (Middle):
Superposition of a material heat bridge with a geometrical thermal bridge in lightweight steel construction

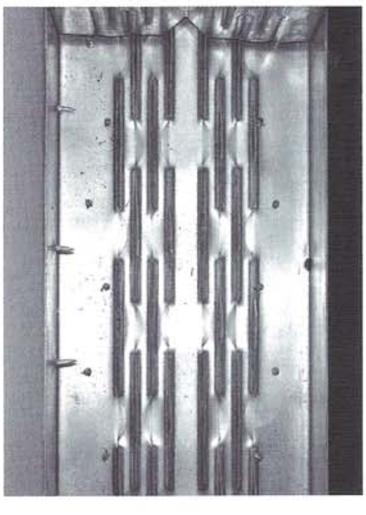
Fig. 83, 84 (below):
Web of a "thermal profile" and heat flux through the cross section

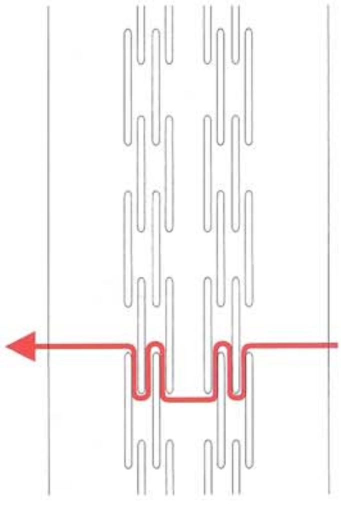


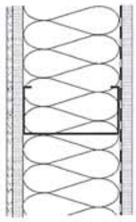
Greater heat transfer
due to additional metal stud



Better structure
due to separate metal stud construction



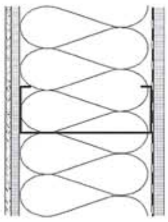




$U_{Gefach} = 0{,}24\ W/m^2K$

$U_{actual} = 0{,}44\ W/m^2K$

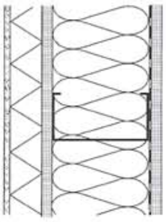
Plaster building board	20 mm
Mineral wool $40 kg/m^3$ / Steel section	150 mm
Particle board	19 mm
Plaster	15 mm



$U_{Gefach} = 0{,}19\ W/m^2K$

$U_{actual} = 0{,}38\ W/m^2K$

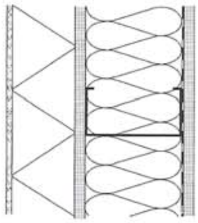
Plaster building board	20 mm
Mineral wool $40 kg/m^3$ / Steel section	200 mm
Particle board	19 mm
Plaster	15 mm



$U_{Gefach} = 0{,}18\ W/m^2K$

$U_{actual} = 0{,}24\ W/m^2K$

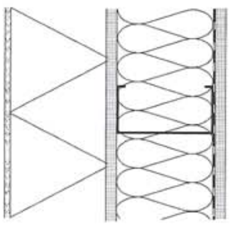
Plaster building board	20 mm
Mineral wool $40 kg/m^3$ / Steel section	150 mm
Particle board	19 mm
EPS $40 kg/m^3$	60 mm
Plaster	15 mm



$U_{Gefach} = 0{,}15\ W/m^2K$

$U_{actual} = 0{,}19\ W/m^2K$

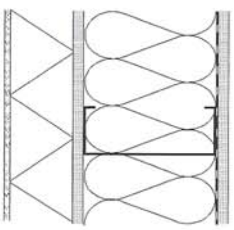
Plaster building board	20 mm
Mineral wool $40 kg/m^3$ / Steel section	150 mm
Particle board	19 mm
EPS $40 kg/m^3$	100 mm
Plaster	15 mm



$U_{Gefach} = 0{,}13\ W/m^2K$

$U_{actual} = 0{,}15\ W/m^2K$

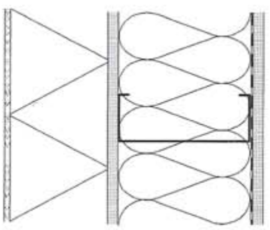
Plaster building board	20 mm
Mineral wool $40 kg/m^3$ / Steel section	150 mm
Particle board	19 mm
EPS $40 kg/m^3$	150 mm
Plaster	15 mm



$U_{Gefach} = 0{,}13\ W/m^2K$

$U_{actual} = 0{,}18\ W/m^2K$

Plaster building board	20 mm
Mineral wool $40 kg/m^3$ / Steel section	200 mm
Particle board	19 mm
EPS $40 kg/m^3$	100 mm
Plaster	15 mm



$U_{Gefach} = 0{,}11\ W/m^2K$

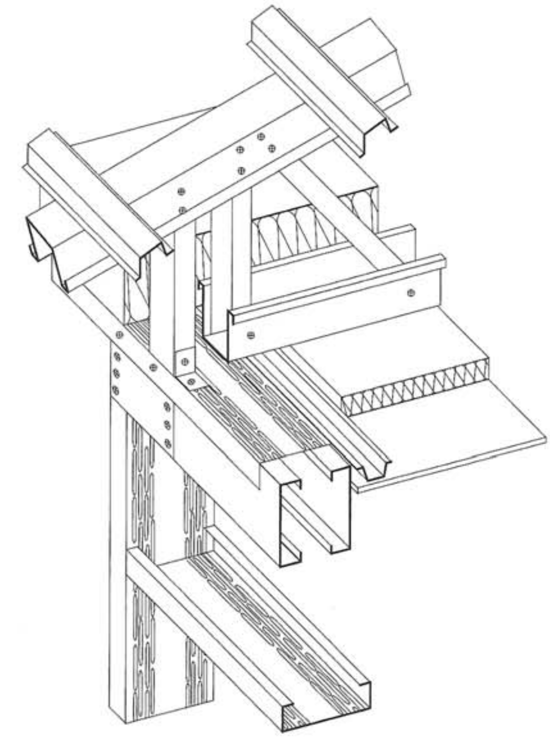
$U_{actual} = 0{,}14\ W/m^2K$

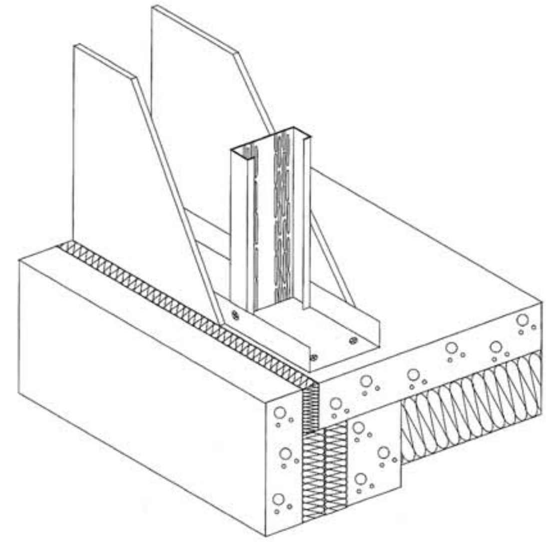
Plaster building board	20 mm
Mineral wool $40 kg/m^3$ / Steel section	200 mm
Particle board	19 mm
EPS $40 kg/m^3$	150 mm
Plaster	15 mm

Fig. 85 (left):
U value comparison of different insulating material thicknesses and structures with regard to the thermal bridge impact on the metal upright profiles (a = 62.5 cm)

Fig. 86 (bottom):
Roof flashing with thermal profiles

Fig. 87 (very bottom):
Base joint with thermal profiles





negative effect on the thermal performances of a construction member.

The inner side of external coatings are lined with wind-tight insulation membranes **(Fig. 88)**.

The lack of tightness against the penetration of outside air inside the building's skin can result in unpleasant draughts. The cold air gathers at floor level, cools the feet and results in huge temperature differences between the top and the bottom of a room.

An apartment with a tight casing is the key condition for enjoying an excellent inside atmosphere. Indeed, it helps to prevent the intrusion of unpleasant scents from adjacent apartments and, possibly, dank air from the basement, fine dust particles and other disturbing emissions from inside the building.

Energy savings

Panel constructions incorporated onto lightweight steel-frames necessarily show structural connections on their outer surface. The insulating materials installed in plates or rolls in the internal cavity of double partitions, carpets, wall paper widths or fillings are generally not air tight. These defective joints (thermal bridge by convection) in the surface connections result in the uncontrolled exchange of air between the inside and outside. Absence of sealing in the interior plating or connection between two members can communicate with a defective joint of the exterior plating via the internal cavity of the walls. The inside hot air can then flow out and cause a significant loss of energy. To avoid this, the interior side of the construction must be equipped with an airtight membrane. A draught of air from outside can also penetrate the vacuum in the double wall. If the membrane installed on the external coating is not totally wind tight, cold air penetrates through that point and spreads to the adjacent members.

The fibrous insulating materials are then ventilated and their insulating effect is reduced.

A better solution is the application of thermal insulation to the entire exterior of a building, because heat losses due to defective joints are more significant, proportionally; the energy balance is considerably affected. In order to minimise these losses as much as possible, joints and connections must be carefully executed **(Fig. 89-93)**.

One must ensure that a defective joint observed inside the building has no direct link with an external flow and vice-versa. Solid air-tightness is just as important as sufficient thermal insulation. Low-energy houses and passive houses only confirm predicted qualities if they are sufficiently airtight.

It is also the basic condition for installing controlled ventilation guaranteeing for hygienic reasons, air renewal in well insulated buildings. In panel constructions incorporated on a framing, it is very easy to integrate air ducts in the walls, floors and ceiling.

Damage caused by moisture

If the interior coating is not sufficiently tight, hot air and vapour can penetrate the building's exterior members through convection. The resulting humidity reduces that member's thermal insulating power and can further cause damages such as corrosion, proliferation of fungus, frost, unsightly physical aspect, etc. Condensation within construction members must be absolutely avoided, because its effects and damages remain visible for a long time. The intensity of humidification by convection is significantly higher than by diffusion because the steam quantities carried through the air are significantly higher.

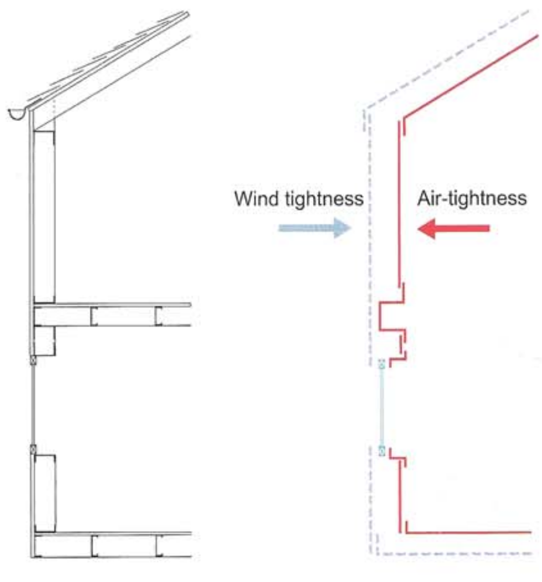
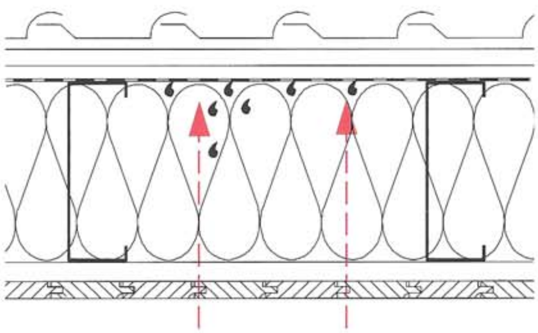
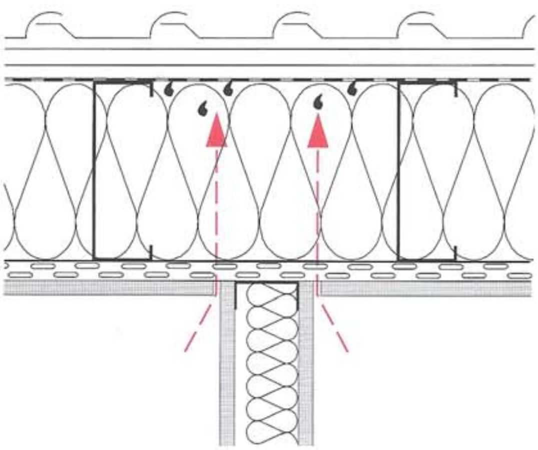


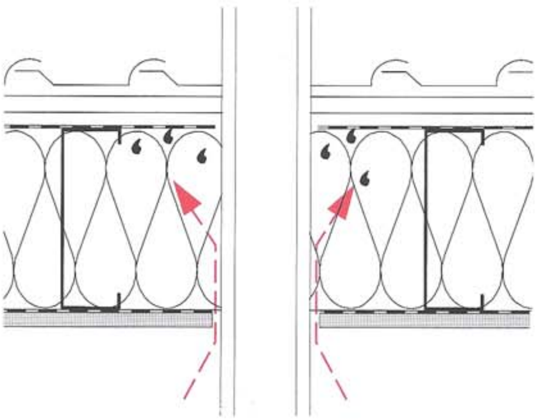
Fig. 88: Differentiation between air-tightness and wind-tightness



a) air-permeable lower cladding



b) untight connection at partition



c) untight connection at roof opening

Fig. 89:
Convective thermal bridges due to leaks in exterior structural components with the resulting formation of condensate

Design and implementation of air and wind tightness of lightweight steel-framed constructions

To obtain a perfectly tight exterior member at the best price, certain steps must be taken right from the project's early design stages. The tightness factor must be taken into account in the assembly of the different members as well as in the load-bearing structure. Cross members must be avoided because they are expensive and their technically-correct erection is time consuming. Concerning detail drawings, all connections must be examined and drawn with the utmost attention.

In practical terms, insufficient tightness due to poor design is expensive and difficult to repair permanently.

Tightness can be obtained, first, on the plating level, by carefully coating all the connections or, second, by installing a membrane on the inner side of the outside coating; in most cases, this membrane also serves as a moisture barrier.

Since the joints of plates are generally located on uprights and cross beams, they can be easily sealed with a coat.

Furthermore, in most cases, the plates can be glued to each other **(Fig. 90)**. A connection to an adjacent construction member can only be durable if it is made with a flexible material **(Fig. 91)**; and this can be achieved if it is covered with a coating, a double facing for example.

Installing gypsum plasterboards is a good way of permanently preventing the formation of cracks. Compared to wood panels, this material has the advantage of minimal shrinking and expansion indices below 0.02% of the length by unit of moisture change. With this in mind, the installation of a stable first coat is very important for obtaining air and wind tightness.

If we use membranes to provide this tightness, several job factors must be taken into account.

To avoid cross connections, the width of the membrane must exceed the height of the corresponding member. On the roofing, the membrane must be continuous and go under the rafters from the top to the eaves gutter.

The different widths must overlap by at least 100 mm and must be carefully bonded **(Fig. 92)**.

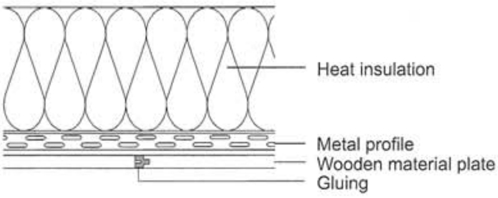
For this operation, a special bond or two or single sided adhesive strips adapted to the membrane fabric must be used. Overlapping widths must be laid as a subcoat (under the rafters or the supports) to be compressed by the plating or the lower lathing. With rigid thermal insulants or more solid membranes, one can use floating bonds, or cross widths provided that the right adhesive strips are used and sufficient pressure can be exercised on the joint.

At adjacent members, a sufficient covering must be glued or compressed by the sections (or the lathing) on the entire length **(Fig. 93)**. To avoid rough surfaces, one must place a flexible sticky strip or an elastic joint in the compression zone between the overlapping membranes.

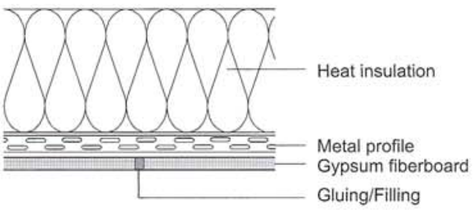
In addition to the attention paid to these intersections, special care must be taken in installing power outlets and switches, pipe fittings, heating devices and door frames. In sandwich board constructions, the electrical or sanitary equipment (switches for example), independently of the job quality, penetrates the sealed surface and establishes a link with the internal cavity. It must therefore be surrounded by a hermetic seal. The measures below result in solid airtightness in dry constructions with lightweight steel structures:

- adapting the construction to the principle of air and wind tightness, by avoiding for example air penetration

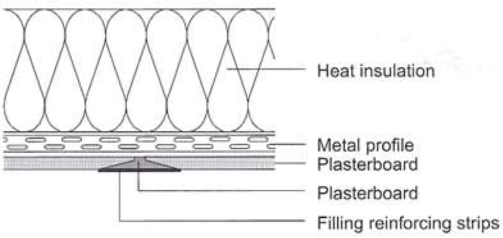
Fig. 90:
Creation of an airtight plane with slab materials



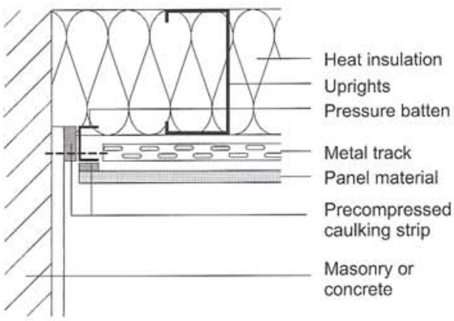
Sealing the joint by gluing

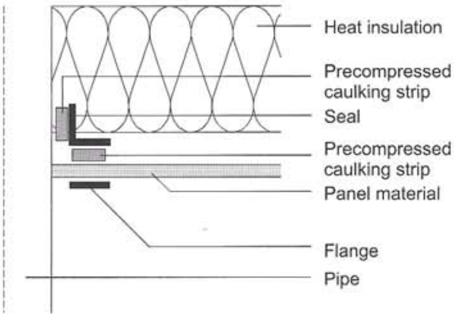


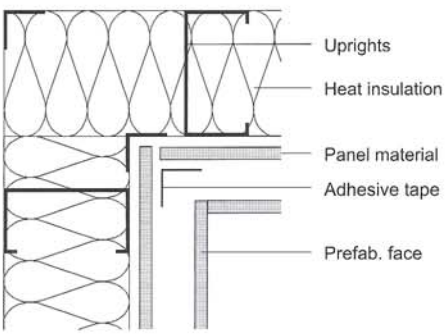
Sealing of the joint through gluing or filling



Sealing the joint by filling with reinforcing strips







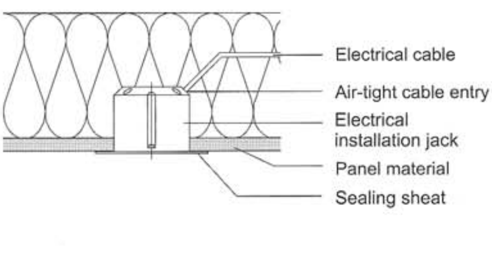


Fig. 91:
Junction of slab materials to neighboring structural components to create an airtight plane/installation of an airtight outlet

into the external skin, by separating certain parts (balconies, for example), etc.;

- installing an impermeable coating, by gluing the plates or widths of a membrane and overlapping them by at least 100 mm **(Fig. 92)**;
- installing broad membrane widths to minimise the number of connections;
- meticulous execution of holes, for pipes, for example, through the waterproof membrane of the member in question. Possible installation of sleeve connectors **(Fig. 91 and 93)**;
- use of members especially designed for sandwich board constructions, such as roof windows with connections for the waterproof membrane or for the electrical installations **(Fig. 91)**;
- distinction between the sealed volume and closed volume by installing a lining; a simple, trustworthy way of preventing damage to the waterproof membrane **(Fig. 94)**.

If the volume to be sealed contains too many holes from penetration by corbelled joists (such as balconies and arcades),

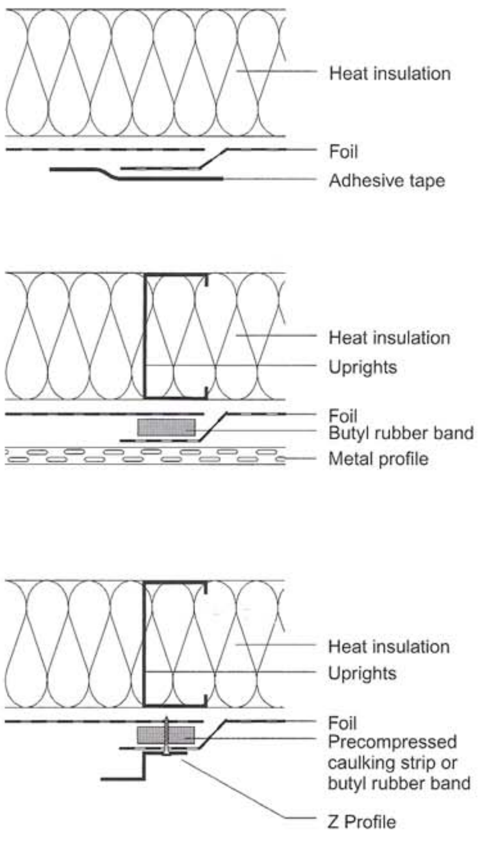
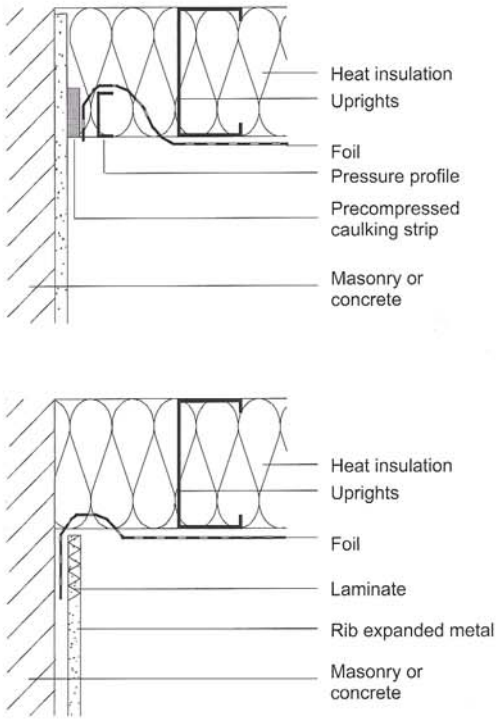


Fig. 92:
Formation of air-tight foil joints components



Junction of foil to a gable of masonry or concrete

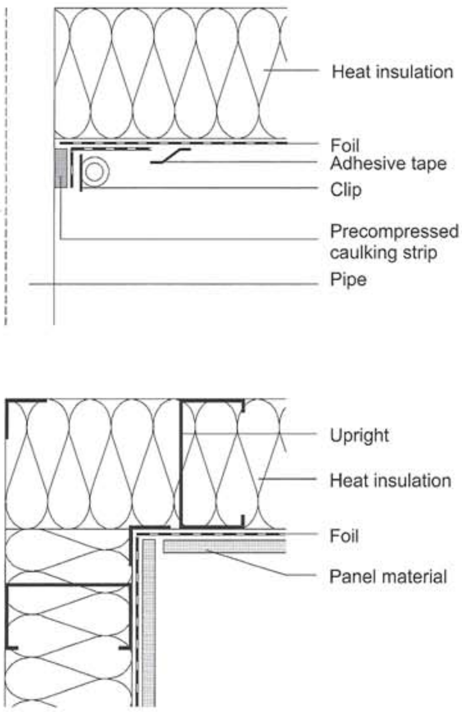


Fig. 93:
Airtight junction of foils to neighboring structural

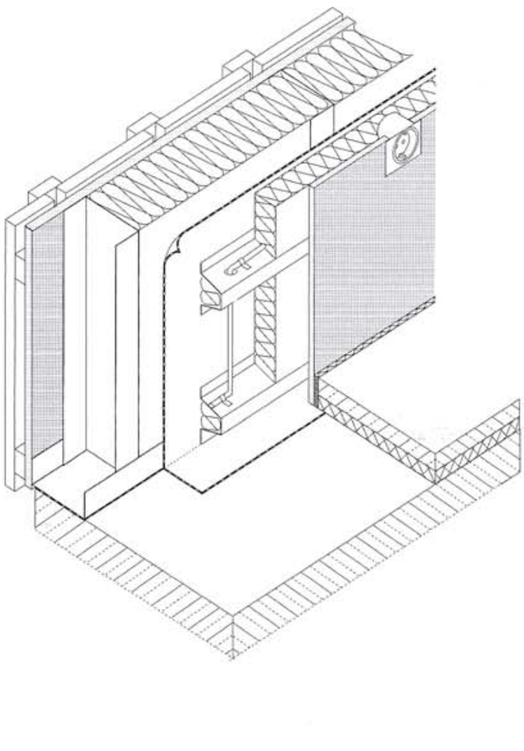
projecting tie beams or rafters, then it becomes difficult to carry out a durable, state-of-the-art waterproofing job.

That is why this type of "traditional" construction is not ideal with a lightweight steel structure: in such cases it is better to replace this process by a more advantageous variant from a thermal viewpoint (see chapter "Protection against heat and moisture"). If factory prefabricated members are being used and erected in place, the building or the part of the building erected in this way will present a larger number of connections than a traditional monolithic building. The vertical connections between the different members must be included in the plans; designed to be air and wind tight, they must be faultlessly installed.

A waterproof construction can be obtained at reasonable cost if the different constraints of connections and joints are factored in right from the design stage.

Damp-proof barrier

In lightweight steel-framed buildings, contrary to monolithic buildings, particular attention must be paid to air circulation through the exterior members due to the presence of very different materials. Each layer's vapour barrier must be installed from the interior towards the exterior in order to prevent fogging.



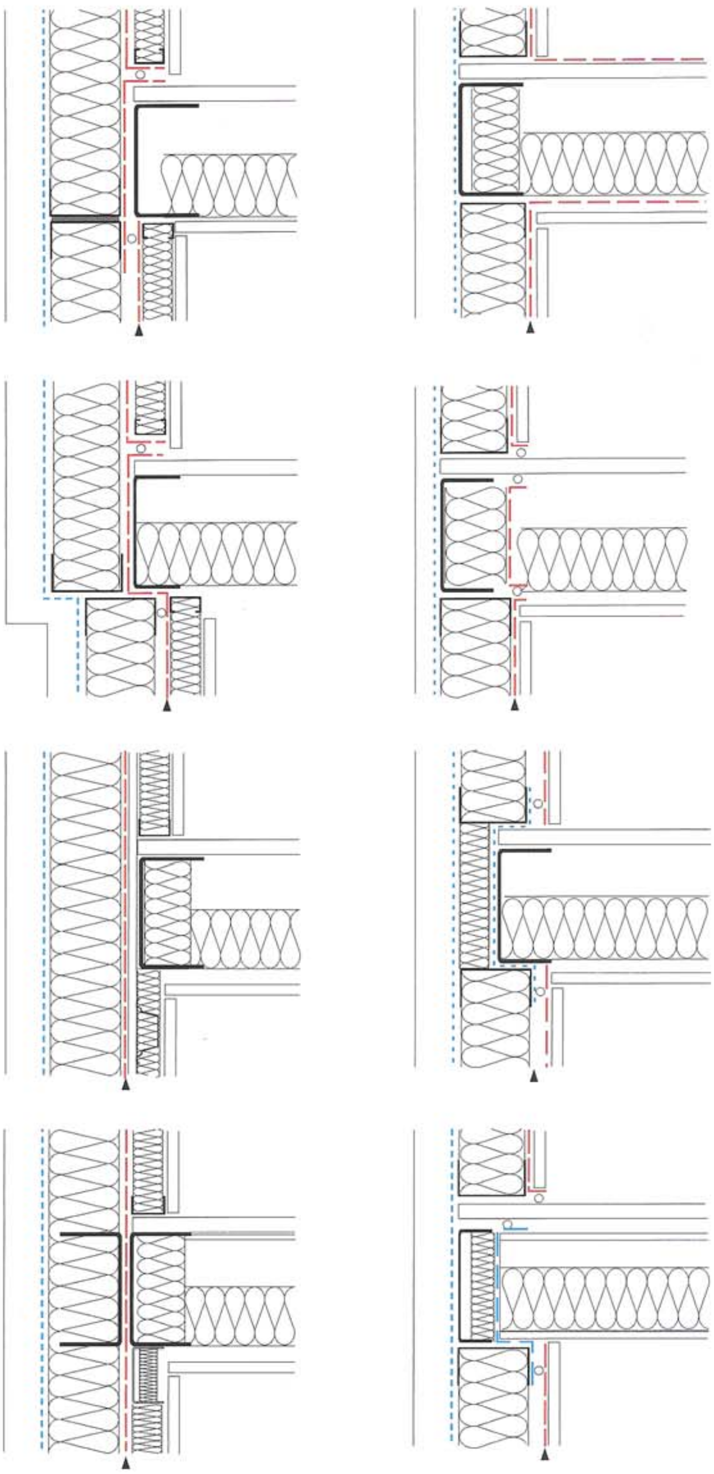


Fig. 94 (left):
Structure of an inside installation plane with undisturbed airtight plane

Fig. 95 (top):
Variants of the junction of the floor to the external wall in balloon and platform framing. Rendering of an airtight plane inside and of the wind-tight plane outside.
The red foil is a vapor barrier, the blue foil allows diffusion

Formation of condensation on a member surface

An absorbent interior covering such as plaster or wood can be used to prevent condensation forming inside a house when the moisture level rises abruptly. To maintain the absorbent qualities of these coverings, they must be covered exclusively with micro-porous materials. The instantaneous appearance of condensation on these surfaces is unthinkable because by their very composition, these materials soak up the atmospheric moisture and only render it in the long term.

To avoid condensation on inner walls, it is advisable to ensure a minimum temperature of 13 °C on the surface of walls under normal climatic conditions. According to standard EN ISO 13788, the moisture level on the interior surface of a building must not be greater than 80%. A practical recommendation for preventing the appearance of shadows on the upper part of framings is to ensure that the temperature difference between the surface on this level of the framing and the other parts does not exceed 5 °C.

Formation of condensation inside a member – vapour circulation

For these members, it is generally necessary to have either a design-based performance certificate or a manufacturer's certificate. The calculations can be made according to the Glaser method.

If these calculations reveal a condensation risk, the construction must be modified as follows:

- ventilation of the layer threatened by condensation;
- installation of a vapour barrier on the "hot" side of the member (interior).

Generally, in the exterior panels (steel structure, for example), there can be no condensation if the points below are complied with:

- sufficient thermal insulation;
- sufficient diffusional strength of the interior layer (for example, vapour barrier) with simultaneous ventilation of the exterior covering.

Summer thermal insulation

When designing a building, one must take the summer heat into account, regardless of the construction procedure, in order to avoid an unpleasant temperature due to

Strong solar radiation and outside temperature. Good summer thermal insulation

is one of the achievements of the current technique.

Stable temperature in a house is often linked to a strong heat storage capacity. This is a misconception, at least concerning properly insulated buildings.

Causes

A building obtains heat through solar energy. This is true for solid constructions as well as for lightweight constructions. Sun-rays go through transparent members such as windows and are transformed into heat energy. They are therefore the primary source of air temperature rise in a room. But even without direct radiation, construction members can store large quantities of heat by diffusion or by reflection. It is therefore possible to have high interior temperatures due to insufficient insulation, a lack of waterproofing in the construction, absence or inadequate solar screen in front of windows as well as defective ventilation.

High air temperature rises in a building are caused by the following reasons:

- the heat permeability index of the glass (value g);
- size and orientation of the window;
- interior or exterior protection of the bay against the sun (blind, shutter or insulating glass);
- possibilities of airing the room, especially night-time ventilation;
- thermal inertia of members (also inside the building);
- heat loss index of the materials of the outside members;
- inhibiting behaviour of the external members.

In properly insulated houses, the difference in temperature between night and day is minimal. Therefore, storage possibilities are limited and are often underestimated when we include the house's fittings (furniture, stairs, and wall coverings, etc.) into the calculations. Large wardrobes, thick rugs or insulated false ceilings can significantly reduce the heat storage capacity of the solid construction members they cover. thermal inertia, less in lightweight steel structure construction than in a solid construction, can be partly compensated by better insulation. Regarding the efficiency of this inertia, we must take account of the fact that, in the massive walls, only a layer of 6 to 10 cm is active during the night-day alternation, and with temperature differences diminishing from the surface towards the inside of the wall **(Fig. 96)**. The principal causes of heating in a room are its glass surface and its orientation. One must prevent the heat energy from penetrating and when it has penetrated, it must be evacuated.

Standard EN 832 annex G proposes data for solar contributions, through a method for calculating the quantity of energy to provide, in order to maintain a specified temperature over the year.

The German standard DIN 4108 2nd part § 8 (3/2001) gives more precise recommendations for summer thermal insulation and makes it dependent on the following factors:

1. percentage of glass surfaces (f);
2. the heat permeability index of the glass (g index);
3. screen effect (F_c index).

Solar penetration index (S) is calculated as follows from the factors that we have just mentioned:

$S = f \times g \times F_c \times F_f / 0{,}7$;

F_f: reduction factor due to door frames.

Without specific indications, we can assume that $F_f = 0{,}8$.

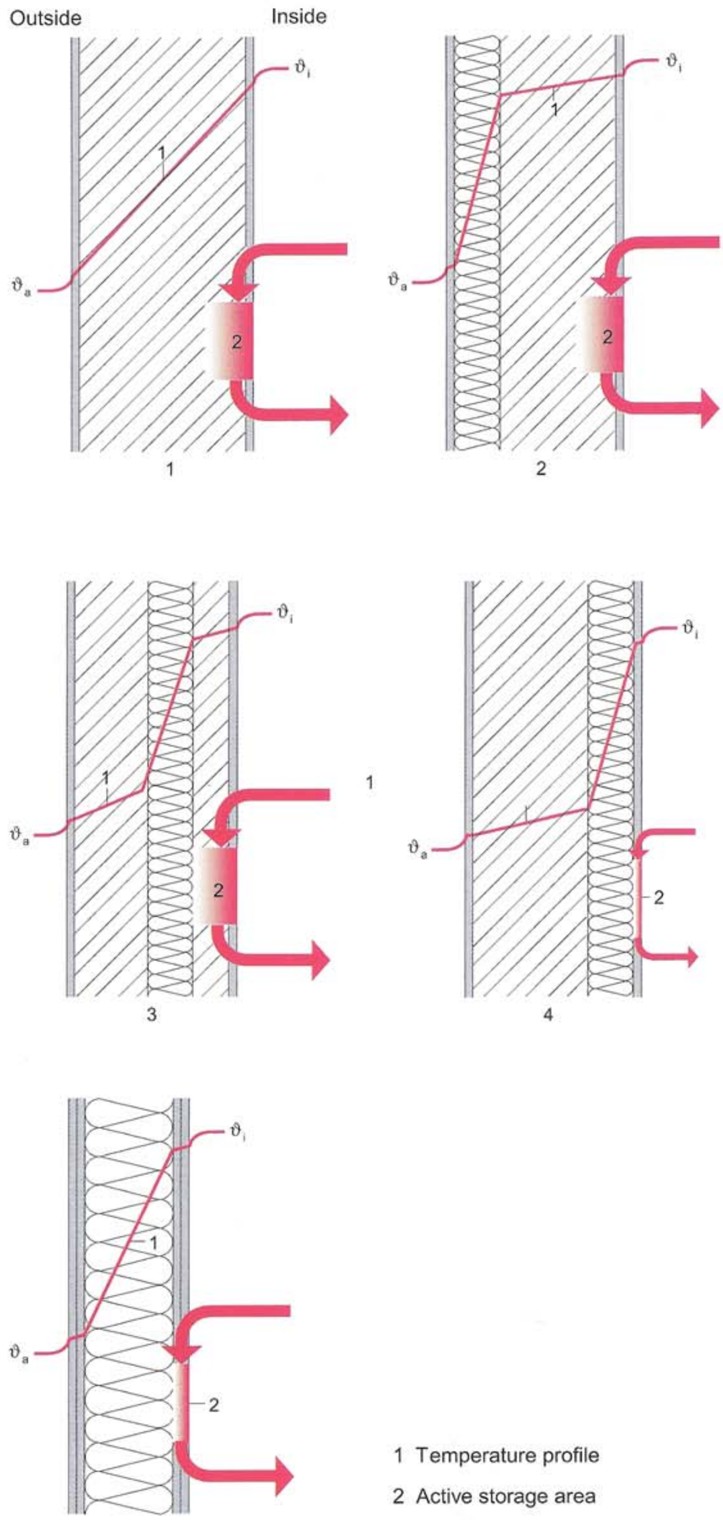


Fig. 96:
Different storage behavior of building materials
1. Monolithic insulated wall: the heat storage abilities of a monolithic wall are limited to the first 8-10 cm. The theoretical storage capacity cannot be used
2. Wall insulated from outside
3. Core-insulated wall: The wall's ability to store heat is decisively determined by the location of the insulating layer. Only the area in front of the insulating plane actively stores heat
4. Wall insulated from the inside: insulating layers on the room side limit the ability of the wall to store heat in the cladding layer on the room side, but allow the room to reach the desired temperature rapidly
5. Panel insulated wall: The ability of these walls to store heat is largely determined by the panel materials used on the room side and on the uprights (material and number of uprights)

Line	Building location or structure		Aggregate value Δs_x
1	Region with high summer stress[a]		-0,04
2	Style		
2.1	Light style: wooden upright construction, suspended ceilings		-0,03
2.2	2.2 Extremely lightweight style: primarily inside insulation, large corridor, virtually no room enclosing surfaces		-0,10
3	Anti-sun glass, g < 0,4 [b]		+0,04
4	Frequent night airing during second half of night $n > 1{,}5\ h^{-1}$	With easy design	+0,03
5		With heavy design	+0,05
6	Percentage of window area f > 65%		-0,04
7	Inclined window alignment: inclination up to 60° vis-à-vis the horizontal		-0,12 x f
8	Façade with north, northeast, northwest aspect		+0,10

a Regions with average monthly outdoor temperatures above 18 °C

b sun-protection device is considered an equivalent measure to reduce diffuse radiation permanently at g<0.4

Fig. 97:
Aggregate values for index of summer thermal protection

Fig. 98:
Sample calculations of the interaction of various boundary conditions for summer heat protection

Percentage of window area f	Glass g	Shading F_c	Highest value S_{ma}
40%	0,80	1,00	0,36
40%	0,65	1,00	0,30
Line 2.1 -0,03 Line 4 +0,03		Total 0,00	S = 0,18

Despite frequent night airing (allotment line 4), **proof has not been provided** by the selection of a better g-value of the glass.

60%	0,80	1,00	0,48
60%	0,80	0,25	0,13
Line 2.1 -0,03 Line 4 +0,03		Total 0,00	S = 0,18

Proof is provided by effective shading measures and frequent airing.

80%	0,80	1,00	0,64
80%	0,40	0,50	0,18
Line 2.1 -0,03 Line 3 +0,04 Line 4 +0,03 Line 6 -0,04		Total 0,00	S = 0,18

Despite the greater window area, **proof is provided** by the combination of appropriate glass and a low g value and shading measures.

The value of S must not exceed the maximal value S_{max}
$S_{max} = S_O + \Sigma\Delta Sx$ (formula 6)

For S_O, we assume a basic value of 0.18 **(Fig. 97)**.

The construction process has no impact on calculating the index of solar penetration (S). If one then examines the weighting of each factor of table 8, we notice that the construction process only plays a secondary role.

The difference of 0.02 between lightweight and solid construction in the calculation of nocturnal aeration on line 4 is so small that it can be compensated without any problem, for example by changing the size of the glass surface or by using glass with higher insulating properties.

We have added calculation examples **(Fig. 98)** which clearly show that these factors are not linked to the construction process.

Construction recommendations

These observations have shown us that the construction process and therefore thermal inertia have no decisive impact on the quality of summer insulation. Therefore, at design, one must monitor the factors below given by order of priority:

- reduce the intensity of solar radiation through glass surfaces (design, orientation, room geometry, installation of screens, properties of the glass);
- guarantee thermal insulation and tightness of the external members;
- optimise the size of heat and cold sources in each room (reduce the interior causes of heat in summer, install a combination system producing heat or cold);
- tailor the ventilation power to the outside air and inside-outside climatic exchanges (cross ventilation and especially nocturnal ventilation);
- optimise the permeability index and thermal inertia linked to the temperature of radiation through each member.

The basic criterion is to prevent as much as possible the penetration of heat energy and evacuate the heat that manages to enter.

Natural ventilation is enhanced by a

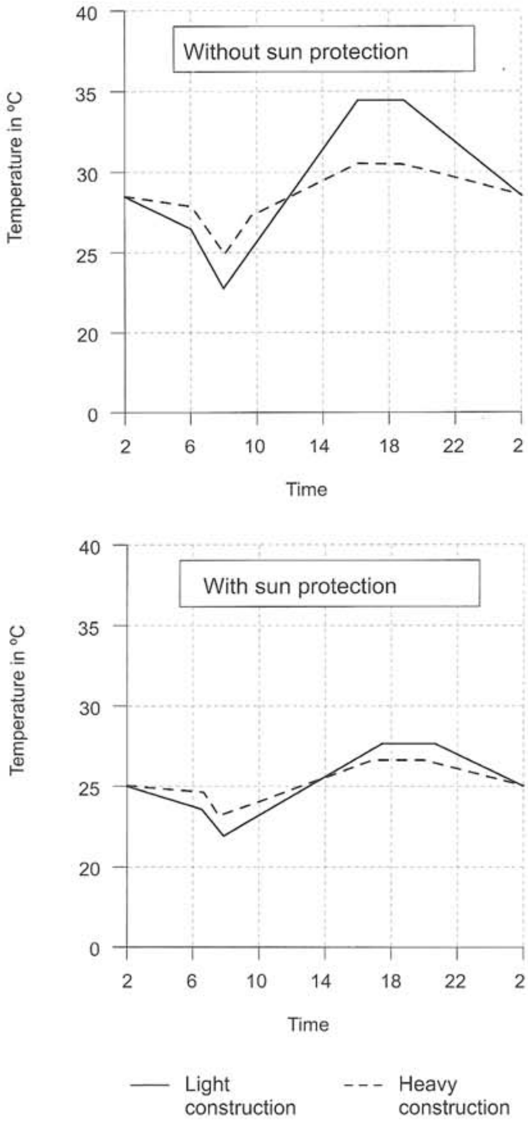


Fig. 99:
Influence of shading of window areas on the heating up behavior of buildings

device which allows cross aeration. As human beings tend to be hot during the day but have the possibility of cooling down at night, an efficient natural night-time ventilation is highly important. By complying with these rules, lightweight steel-framed constructions also offer excellent climatic conditions.

On average, their temperatures will be 0.5 to 1.0 K above that of solid construction buildings, but the installation of screens reduces the temperature by 16 to 19 K **(Fig. 99)**.

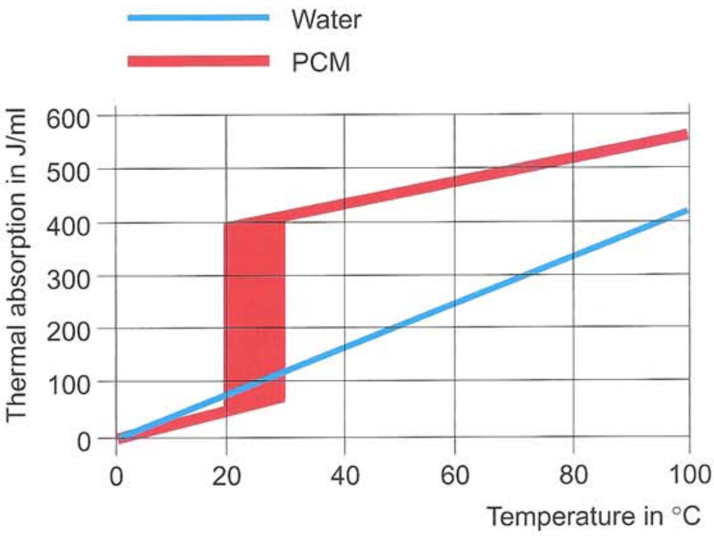


Fig. 100:
Thermal absorption in J/ml
Energy absorption of a "Phase Changing Material" (PCM) compared to water

Therefore, when choosing between solid or lightweight construction, the problem of summer thermal insulation plays no role. Latest research to improve comfort in in lightweight constructions resort to "latent heat storage systems". About 20% of a compound of microscopic paraffin balls is added to plasterboards. This material is known as PCM or Phase Change Material. To change phase (from solid phase to liquid phase), the paraffin requires a lot of heat, then stored in the material. In a reverse process, the "latent heat" is expelled when the ambient temperature falls.

In this way, a member composed of this material can store heat quantity equivalent to that of a 11.5 cm thick sand-lime brick wall.

Lightweight steel structure constructions assembled with this kind of plates have an interior comfort quality that is superior to traditional solid constructions.

Fire protection

Objectives

The load-bearing capacity of steel (strength and ductility) falls linearly when the temperature rises above 500 °C. Steel members are incombustible (Class A material) but, although, they are particularly used in thin walls or in lightweight frames, they have no fire resistant properties themselves, they must be protected against the effects of high temperatures during a fire. It is the only way of preventing serious plastic deformations and consequently, the static failure of the construction member.

In lightweight steel-framed constructions, sections are often integrated in closed members, in a confined space, for example in fire-proof doors. It is therefore the panel sheathing which provides fire protection. It acts as a kind of thermal sheathing for the steel members.

Fire performances of different materials used in lightweight steel-framed construction

Members which meet fire resistance standards are the result of the proper combination of certain materials with certain members **(Fig.101)**.

As we mentioned earlier on, the thin sections must be covered with a sheathing to prevent them from being ravaged by fire.

Plates composed of the materials below have been approved as anti-fire materials and can therefore be used for sheathing:

Fig. 101:
Fire protection classification of the materials used in lightweight steel construction

		Potential euroclasse not mentioning smoke and droplets
Load-bearing structure / Furring	Metal profiles (cold-formed profiles and hot-rolled beams and supports)	A1
Panel materials, Facing / Planking materials	Plaster building boards (gypsum fiber, gypsum plaster, and gypsum glass fiber mats)	A1 to B
	Panels made of mineral-bound fibers	A1
	Cement glass fiber panels	A1
	Wooden material panels	C to E
Insulation	Mineral wool insulation	A1, A2
	Organic insulation	C to F
Joint sealing material	Caulking tape – mineral fiber strips	A1
	Mineral fillers	A1

- plaster;
- plaster-fibre;
- plaster on glass-fibre;
- sand-limestone.

These incombustible materials are fit to protect combustible, load-bearing members from the direct effects of the fire and therefore to serve as wall, floor and ceiling coverings.

In Fig.102, we have compiled the heating time of various materials by different manufactures. The results can serve as useful indication and information on the fire resistance of steel member coverings. Tests have proved that plaster-fibre boards presented the same level of fire performance as GKF gypsum boards (reinforced fire insulation plasterboard).

When placing an insulant in the internal cavity of panels, it is important to know if it is a load-bearing member or not.

In a non load-bearing member, the insulant can improve the fire resistance of the construction. We resort to mineral fibrous insulating material which have a melting temperature of > 1000 °C. Thanks to them, the heat which is communicated to the opposite side of the fire is reduced and, once the fire side covering is destroyed, this insulant slows down the propagation of the fire to the other side of the wall.

In a load-bearing wall, the decisive time for its load-bearing capacity is when the temperature reaches 500 °C, a critical temperature for steel. The installation of an insulant reduces heat convection in the internal cavity: the side of the wall on the fire side will therefore heat up faster and will reach the critical temperature more rapidly without an insulant **(Fig. 103)**.

If, from the fire protection viewpoint, insulation is not necessary or can even be harmful, it can nevertheless turn out to be essential from a thermal or sound viewpoint. One must therefore weigh the advantages and disadvantages for each individual case. If an insulant is installed for acoustic or thermal reasons, it must therefore belong to class B2 and be approved, because its presence can have negative effects on the fire performances of a member.

In lightweight steel-framed constructions, the installation of a vapour barrier or wind and air tight membranes are not detrimental to fire protection.

Classification and approval of different categories of fire resistant members

To prevent fire propagation into adjacent rooms or on other floors, "fire-stop" members, such as walls and floors must meet the requirements below concerning the length of their fire resistance:
- prevent the propagation of fire;
- tightness against inflammable gas;
- limitation of the temperature of the surface opposite the fire surface.

Additional constraints for load-bearing members must be taken into account, namely keep the load-bearing capacity as a load factor. Therefore during testing, the load strength of dividing walls must be checked.

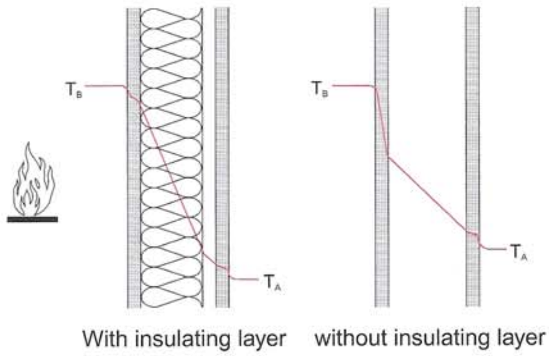


Fig. 103: March of temperature in a partition with and without insulation with a one-sided fire load

The fire performances of constructions and lightweight steel structure members are determined by the factors below:
- fire stress (fire on a single side, if it is a wall, on all sides, if it is a stud);
- dimensions of the member;
- construction process (of each member and of the whole);
- static system;
- allowable dynamic load for the member;
- building materials;
- location of the fire protection coating.

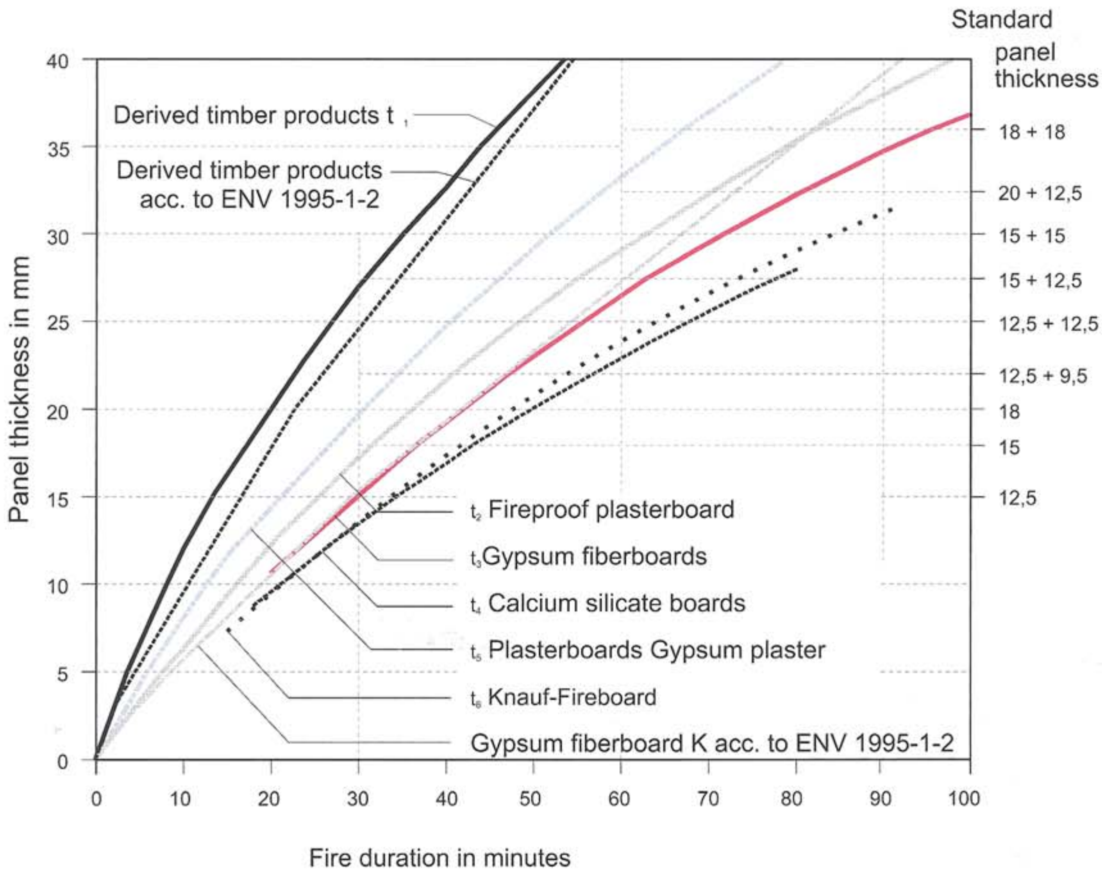


Fig. 102: Characteristic burn-through times of different panel materials

Each component of a lightweight steel structure construction and its location determines the category of the whole member's fire resistance category.

The spacing of plates, the thickness and the number of coating layers as well as the width of the insulant are decisive for the member's classification. The highest requirements can be met by adding up several layers of fire-retardant coatings.

The classification of fire-protection coatings are generally based on the U/A (U = 2 section heights + 2 section widths; and A = section nominal surface) of the section. In the absence of a specific standard for thin sections, the fire classification is supplied by an authorization or an engineering department certificate. Thus, we can classify lightweight steel-framed members according to the manufacturing certificates of sheathing boards; either they have test certificates when it relates to special materials (Knauf-Fireboard, for example), or they are assimilated to another member that has received approval (shaft lining for example). The key criterion for this type of test is the increase temperature (140 K) in average and180 k locally on the opposite side to the fire. If this condition is fulfilled, the member can serve as a lining for steel sections; indeed, the critical temperature of steel (500 °C) is therefore not reached during the duration of the test and the section maintains its full load-bearing capacity.

Fire performances of walls

Load-bearing walls and dividers

In terms of fire protection, it doesn't matter if a wall is load-bearing or not. What determines the length of its fire resistance is the type and the thickness of the covering as well as those of the insulating material placed in the internal cavity.

A non-load bearing wall must prevent the propagation of fire to the next room during a certain time (length of fire resistance).

A load-bearing wall or diaphragm plate must additionally, maintain its load-bearing capacity. This means that all load-bearing members must be cased to be insulated from the effects of the fire. This concerns steel uprights and cross-beams as well as bracing members such as rails or steel cables or plates **(Fig. 106)**.

Fire walls

Firewalls may be load-bearing walls or simple partitions. A firewall is made up of different members whose fire performances have been tested. In addition to being fire-resistant (90 min), a firewall also has a greater resistance to thrust. This result can be obtained by inserting between the different covering layers, a continuous layer in sheet metal to ensure surface stability **(Fig. 105)**.

Firewalls can be divided into three categories: load resistant, load-bearing and non-load-bearing. In the event of fire, load resistant walls must not receive more than the allowable maximum load (kN/m). This is given by the manufacturer and indicated in the certificate. Their permissible load must be checked and must not be less than the probable load of the floor. The dimensions of load-bearing firewalls are calculated according to the loads applied to them. First of all, this concerns the structure (steel sections). Static control, plus commissioning control.

When installing fire partitions (non Load-bearing), the appropriate measures must be taken to prevent that in case of fire they do not receive any unexpected load, due to a sagging floor for example. If a floor is expected to slump by more than 10 mm, then a a slip joint must be installed at the partition/ceiling junction **(Fig. 107)**, the execution of this joint is different from that of the standard joint.

In addition, care must be taken to ensure that all the stiffening members completing a firewall such as walls and adjacent floors have the same level of fire resistance. To design lightweight steel structure walls compliant with fire protection standards, all the connections with adjacent members must be compliant. This means more stringent requirements in the execution of the joints described in the chapter on page 61 "Fire performances of different materials".

In addition to state-of-the-art assembly, particular attention must be paid to the points below:

- horizontal and vertical stresses on these walls;
- connections with the walls and the adjacent floors;
- installation of glass surfaces;
- installation of window frames;
- equipment routing.

Electrical installations in walls with uprights and cross beams

Enclosures for hollow walls can be installed anywhere in a wall regardless of whether it is load-bearing or not. One must simply comply with the installation restrictions described in fig. 108. Equipment can also be routed through them. The only constraints to comply with are detailed in the next chapter "Floors", in fig. 111 and in the chapter on "Fire performances of different composite materials".

If the directives below are not complied with, then an overall technical control must be carried out.

- Electrical outlets or switches can be installed opposite each other in the dividing walls **(Fig. 108,1)**, they must be located in the different compartments **(Fig. 108.3)**.
- Electrical enclosures facing each other in a double upright wall, where plates' spacing is < 600 mm, must be separated by a fireproof plasterboard 600 mm x 600 mm reinforced insulation board as thick as the covering **(Fig. 108.2)**.
- The fire insulation material around an electrical enclosure in a double partition must be at least 30 mm thick **(Fig. 108.3)**.
- In walls not fitted with fire insulant (without any insulant or with a no fireproof insulant), the electrical enclosures must be surrounded by > 20 mm thick plaster. Fire resistant constraints must be complied with, in other words the thickness must be the same as that of the covering **(Fig. 108.4 – 108.6)**.

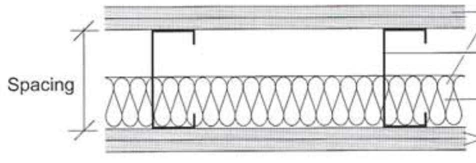


Fig. 104:
Ways in which metal framing can improve fire protection

Fire insulation constraints of steel-joisted floors

The classification of fire performances of lightweight steel structure floors follow the same principle as the walls. However, a floor must be considered as a whole. The steel joists are protected, underneath, by fireproofed ceiling coverings and above, by slabs equally compliant with fire standards. The fire protection criteria are the same as for dry constructions.

A floor classification, for example in 90 min, is based on categories to which the its key parts as well as those of the ceiling belong. The key parts are all load-bearing or stiffening members which contribute to its stability. This is true for the ceilings (directly under joists) and for false ceilings (or suspended ceilings).

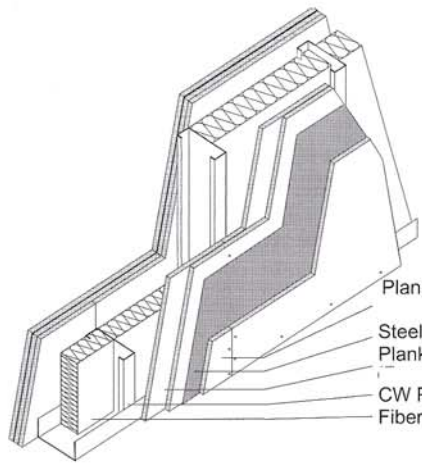
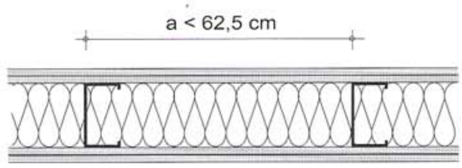
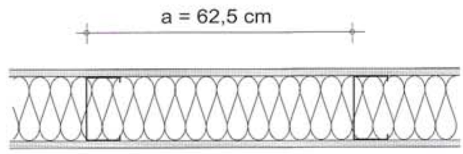


Fig. 105:
Firewall in light-weight steel construction

Fig. 106: Structure of the cladding of load-bearing and nonstructural walls with the resulting fire resistance durations

	Upright wall, load-bearing			Upright wall, non structural		
						
	Planking insulation on both sides	Thickness [mm]	Density [kg/m³]	Planking insulation on both sides	Thickness [mm]	Density [kg/m³]
30 min	2 x 12,5 mm fireproof plasterboard	Not required		2 x 12,5 mm Gypsum plaster	40	30
	10 + 12,5 mm gypsum fiberboard	Not required		12,5 mm fireproof plasterboard	Not required	
	20 mm Fireboard	Not required		12,5 mm gypsum fiberboard	40	20
60 min	2 x 15 mm gypsum fiberboard	Not required		2 x 12,5 mm fireproof plasterboard	40	40
	2 x 15 mm Fireboard	Not required		25 mm fireproof plasterboard	40	40
90 min	2 x 25 mm fireproof plasterboard	Not required		2 x 12,5 mm fireproof plasterboard	40	
	2 x 20 mm Fireboard	Not required		2 x 12,5 mm gypsum fiberboard	50	50
	3 x 12,5 mm gypsum fiberboard	Not required		25 mm fireproof plasterboard	60	50
				a = 31,25 cm 20 mm Fireboard	100	40
90 min Fire wall	25 mm fireproof plaster-board metal sheet 25 mm fireproof plasterboard	Not required		2 x 12,5 mm fireproof Metal sheet plasterboard 12,5 mm fireproof plasterboard	Not required	
	20 mm Fireboard Metal sheet 20 mm Fireboard	Not required		2 x 12,5 mm gypsum fiberboard Metal sheet 12,5 mm gypsum fiberboard	Not required	
	2 x 12,5 mm gypsum metal sheet fiberboard 12,5 mm gypsum fiberboard	Not required		15 mm Fireboard Metal sheet 15 mm Fireboard	Not required	

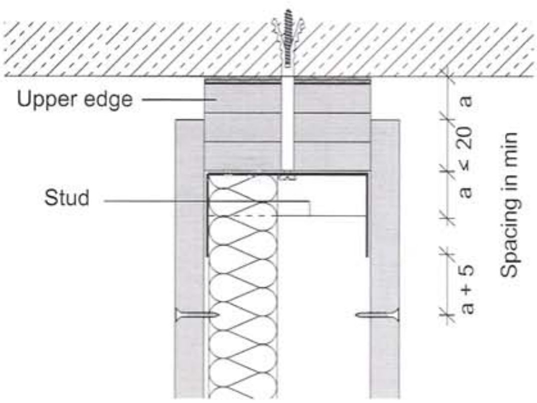


Fig. 107: Sliding ceiling junction of a nonstructural wall with fire protection requirements

Fire fighting from the underside

As there are no fire standards for floors or for lightweight steel-framed walls, one must resort to certificates and approvals of the different materials to obtain the fire resistance of floors. But this mainly applies to the structure, the only one in question to offer the required protection in case of fire fighting from beneath.

Ceiling supports must be installed perpendicularly to the joists with a spacing determined by the load. In lightweight steel-framed floors, joists can play the same role, but a manufacturer's certificate is required.

Some ceilings **(Fig. 109)** can be directly fastened to the floor without any independent structure. But in this case, the spacing between the joists must not be higher than 40 cm and an authorization is required from the competent authorities.

Fire fighting from the topside

For lightweight steel structure floors with an 30 min fire resistant category, a floating slab or dry slab is mandatory. It protects the plating on the joists and prevents the latter from rapid deformation and the floor from collapsing. The fire resistance of a floor depends on the type and thickness of its structure as well as those of its insulation.

A mortar, plaster or asphalt slab as well as floor plating in plasterboard, plaster-fibre or pressed wood can be accepted up to 60 min fire resistance category. A dry floor in fibre-plaster can serve as a floating slab after it has been certified by an inspection.

For category 90 min floors, we can also use plasterboard or fibre-plaster after inspection or appraisal by an expert.

Roofs

Roofing whose construction system is identical to that of independent ceilings are treated in a similar way in matters of fire performance.

Therefore, logically, the requirements mentioned for fire fighting from beneath are valid here.

As a general rule, for fire fighting from outside, a roof must be compliant with the requirements of a "hard roof".

This means that the roof must offer sufficient resistance to fire surges and heat release. "Flexible roof cladding", such

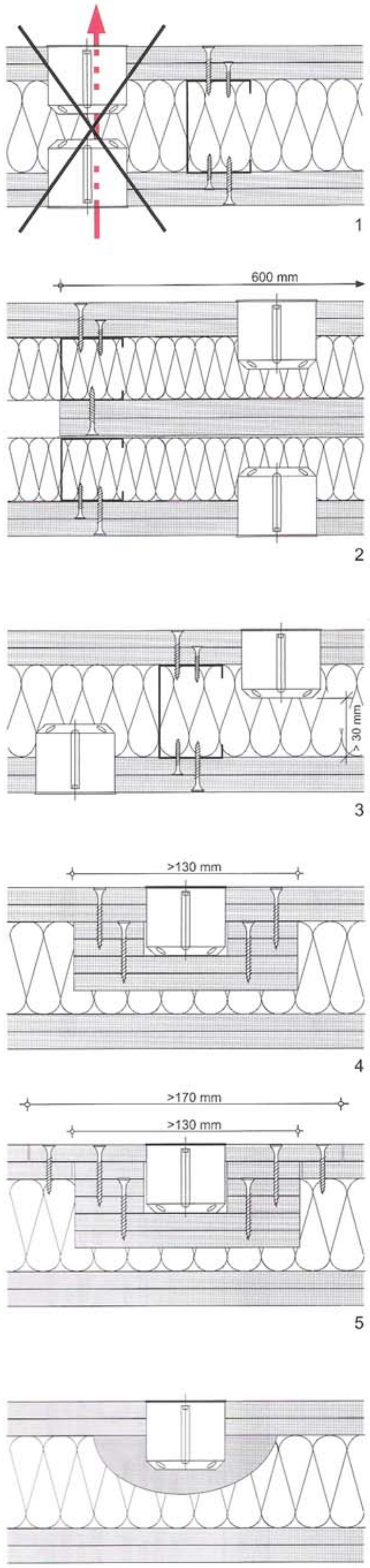
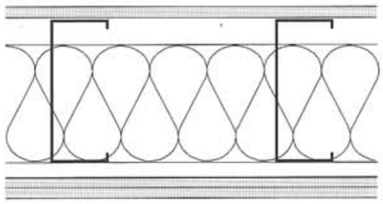


Fig. 108: Installation rules for electrical installation outlets in a wall with fire protection requirements



	Underside ceiling covering
30 min	2 x 12,5 mm fireproof plasterboard 2 x 10 mm gypsum fiberboard* 20 mm Fireboard*
60 min	18 + 15 mm fireproof plasterboard 2 x 15 mm gypsum fiberboard* 2 x 15 mm Fireboard*
90 min	2 x 20 mm fireproof plasterboard 25 + 18 mm fireproof plasterboard 2 x 20 mm Fireboard* 4 x 10 mm gypsum fiberboard* 1 x 15 mm + 2 x 12,5 mm gypsum fiberboard*
Furring for the ceiling covering * These constructions can also be attached directly to the supporting structure after approval from the fire protection authority if the distance between the floor joists does not exceed 40 cm.	

Fig. 109:
Underside ceiling covering in lightweight steel construction as self-supporting suspended ceiling to meet fire protection requirements

as waterproof foils, are authorized when the buildings are sufficiently apart, among other reasons, to reduce the risk of propagation of the fire.

Equipment in the roofs

Some electric wires can be routed through the eaves without it affecting their fire resistance if they are pointed, with coating for example. Vertical ducts must be very carefully installed if they pass through the ceiling. A bundle of ducts with a diameter of at least 50 mm can go through the false ceiling without any particular arrangements. The drilled hole must be lined with very compact mineral wool (melting point > 1000 °C) and coating.

Fire protection for load-bearing and stiffening members

If, in a lightweight steel-framed construction, studs and beams which are not integrated in the walls or floors are used, the appropriate steps must be taken to achieve the required level of fire resistance, in other words so that the steel's load-bearing capacity and strength are constant for the required period of time. Covering these steel members with fire-retardant panels is an economic solution. They can also be covered with rough coat or insulant layers. Steel members may require a covering even when they are partially protected by a false ceiling or by a wall.

To guarantee fire resistance for the desired period, the following criteria must be complied with:

- constraint of the member (30 min, ... 180 min);
- fire stress on the member (fire on 1, 2, 3 or 4 sides);
- geometry of the section, form factor (U/A ratio);
- choice of the covering material (plaster-board, plaster-fibre, sand-limestone, vermiculite or rock-wool) inspected by the engineering departments or with a general control certificate;
- determination of the required thickness for the covering;
- surface fit to receive a covering;
- protection of covering in the parts where it is likely to be damaged (edges, for example).

We usually use steel sections with a U/A ratio of > 300 m^{-1}. In the absence of specific standards, one must refer to the manufacturer's certificate of usage possibilities. In accordance with indications above, checking criterion of 140 K is key to guaranteeing the load-bearing capacity of a member.

If we use steel sections with a U/A ratio of < 300 m^{-1}, we can still refer to the German standard DIN 4102 4th part which gives the covering thickness required for each type of material. Plaster-fibre boards are equivalent to GDK boards from the viewpoint of fire performances.

The plating materials below are not classified by fire-proof standards:

- plaster-fibre, plaster on special supports, on glass-fibre, for example ;

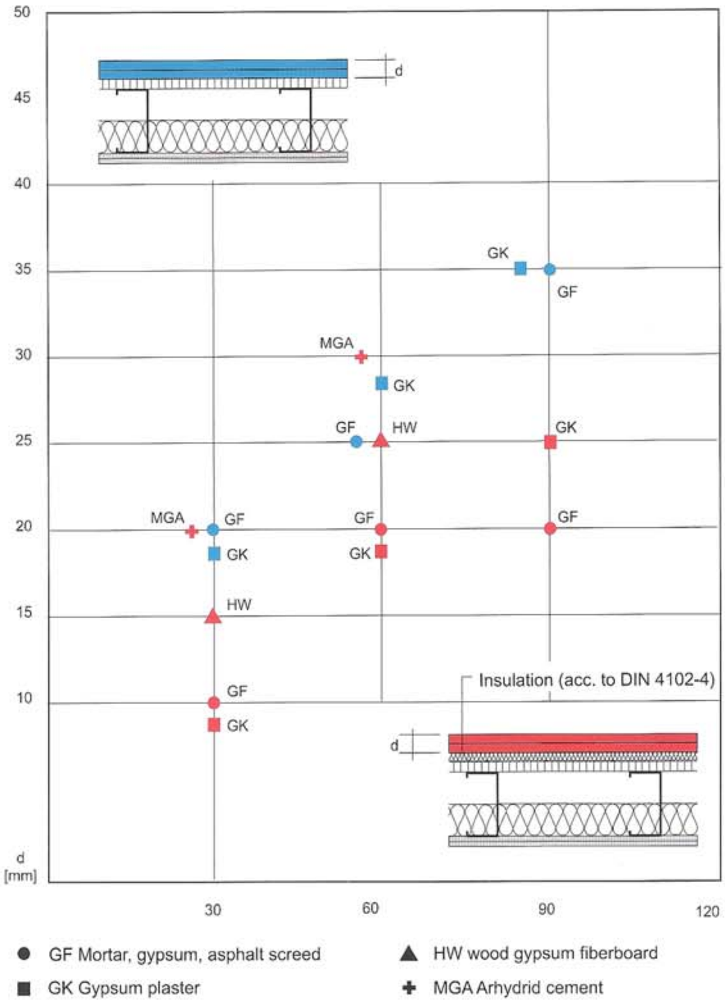


Fig. 110:
Fire resistance of lightweight steel ceilings with screed systems and a fire load from the top [mm]

- composite cement;
- sand-limestone;
- vermiculite;
- mineral fibres.

The method used to fasten a covering is very important: it prevents it from peeling off the surface in the event of fire **(Fig. 114)**. There are many off-the-shelf coverings made with approved materials which because of their mechanical strength, can be joined to each other just by their edge thanks to mechanical fixtures (screw or staple) without any other auxiliary element.

Fig. 111 (left): The correct execution of openings and penetrations in lightweight steel ceilings to prevent fires

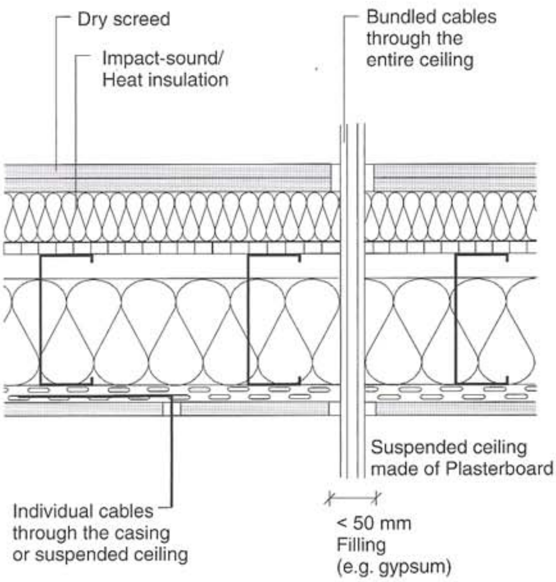
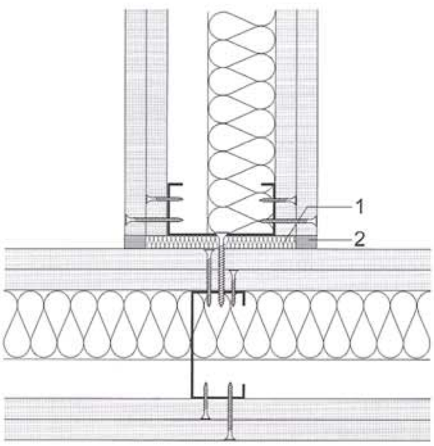


Fig. 112 (middle left): Effective structural component junction for preventing fire using the example of a wall T-junction



1 Connecting strips made of mineral wool 10 mm Melting point > 1000 °C
2 Density Filling

Fig. 113 (far right): Detailed junctions to be considered during planning to prevent smoke and the fire from spreading in hollow structures

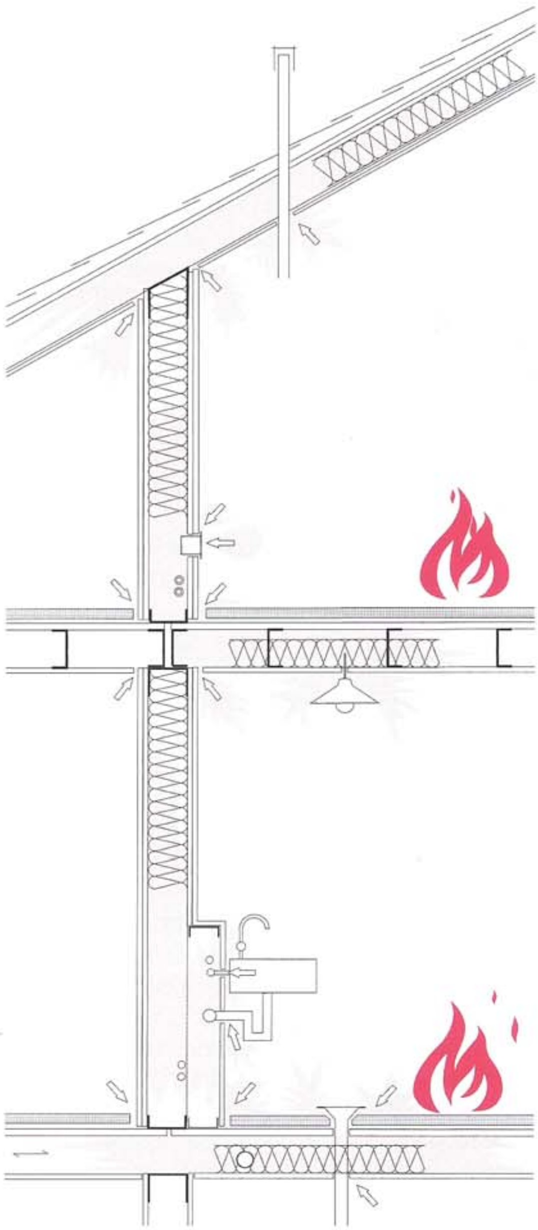
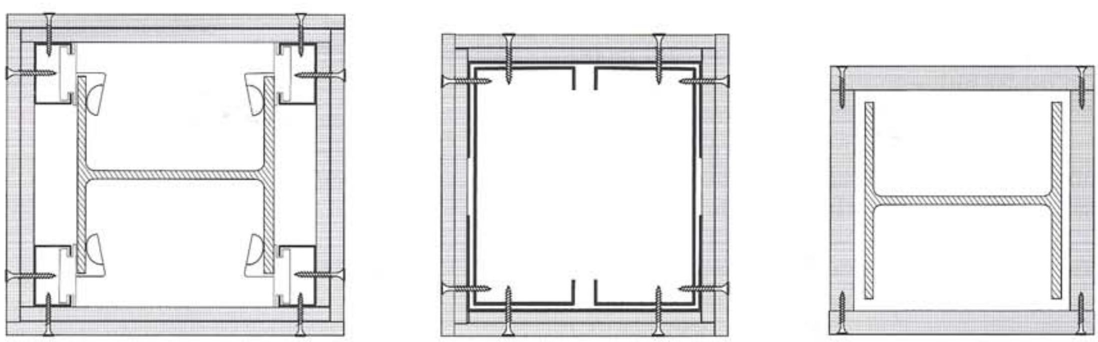


Fig. 114: Facing of steel sections with gypsum material plates for fire protection



Fire performances of composite panels

Lightweight steel-framed constructions are made up of "composite panels". Fire can therefore spread in the internal cavity and harmful gases flow into parts of the building not affected by the fire.

To prevent the propagation of fire and ensure the smoke proof connections between the different members, the following points must be monitored **(Fig. 113)**.

Connection of members and equipment routing

First of all, particular attention must be paid to the tightness of horizontal and vertical connections between the different members. They must be lined with incombustible mineral wool strips, mastic or expanded foam, and completed by a careful final coat **(Fig. 112)**.

This observation especially applies to intersections and drillings for routing equipment. These are the weak points in the tightness of a fireproof covering which may allow the fire to reach the internal cavity **(Fig. 113)**. When any equipment bores a hole into a construction member, in addition to ensuring that the member's fireproof properties are intact, we must also ensure that the fire cannot spread through the power outlet, for example. Openings > 50 mm (for pipes) must be sheathed unless it is an incombustible pipe corresponding to the same standards as the wall.

Corrosion control

Cold rolled shapes are manufactured with hot-dip galvanized iron strips. They are covered with a zinc layer of 20 µm. which corresponds to a weight of 275 g/m². Galvanization is a good way of controlling corrosion on parts for a period equal to the building's service life, on condition, however, that the construction details and the different coverings have been correctly designed and implemented. The primary damage to this protection layer occurs during shipping and storage. That is why maximum possible care must be taken to ensure that their packaging prevents any mechanical damage. The shapes must be stored in such a way that neither water nor dirt can accumulate on them.

In normal climatic conditions outside a building, around 0.1 g/m² of zinc disintegrates every year due to corrosion : the protective layer therefore has a life span that is much longer than that of a building. Zinc also has the property of "self healing" its damaged parts by cathodic reaction. If moisture comes into contact with a bare steel surface, it generates a galvanic substance. The less noble zinc particles form "soluble" anodes which settle on the steel and provoke a "cathodic" reaction. The result is an "anodic" zinc layer which then protects the steel from corroding.

That is why cut-out galvanised sections do not require any additional treatment.

Products initially coated with zinc have a shiny aspect which goes away within a few weeks to form a matte grey coating.

This "passivation" is the result of the zinc's interaction with water, oxygen and carbon dioxide. The basic zinc carbonate, insoluble in water, which forms on the surface provides an excellent protection against any additional corrosion. Therefore, this reaction must not be prevented by inappropriate warehousing, which means that the steel sections must be stored in a cool, dry place. If right after manufacture, the sections interact with moisture, a white rust forms on the surface due to the insufficient oxygen and carbon dioxide.

This white and flaky hydroxide is very voluminous. When it can be removed without leaving any visible traces, the protection control is not damaged. But if serious alterations are observed on the base layer, then the efficiency must be checked. A well-ventilated storage room prevents the formation of this white rust **(Fig. 115)**.

If high corrosion is predicted in buildings exposed to marine environments for example, and sections are left without protective sheathing, it is possible to treat them organically in addition to the galvanisation. Then we talk of "duplex system". The paint coating prevents the slow erosion of the passivated coating. The zinc coating in turn prevents the steel corrosion, its transformation into rust. (The latter may appear in places which have received only single treatment and which have suffered a shock or which show signs of aging).

Due to the synergy of the two treatments, the protection period of the duplex system is about 1.8 to 2.5 times higher than the sum of the two. The thin steel sheet used for cold sections can be treated continuously, in other words receive right after galvanization an organic bath (paint or polymer) or a protective film. In this way we achieve a quality clearly higher than what can be obtained by applying this layer with a roller or a brush. We use sections treated in this way when a strong corrosion control or a special paint are required. As moisture speeds up corrosion, open sections must be fitted with downward sloped openings, in the web for example. In this way, rainwater is prevented from accumulating during construction and causing corrosion. Voids in between junctions must be built in such a way as to allow water to run out. When choosing the material of fasteners, care must be taken to avoid contact corrosion. That can result from lectrochemical reaction when two different metals come into contact. Therefore, preferably, galvanised members must be fastened with galvanised steel parts, if possible. Outside, in case of exposure to bad weather or when condensation is a threat, stainless steel screws must be used. Inside, it is possible to use phosphated screws, but in that case, there must be no moisture at all.

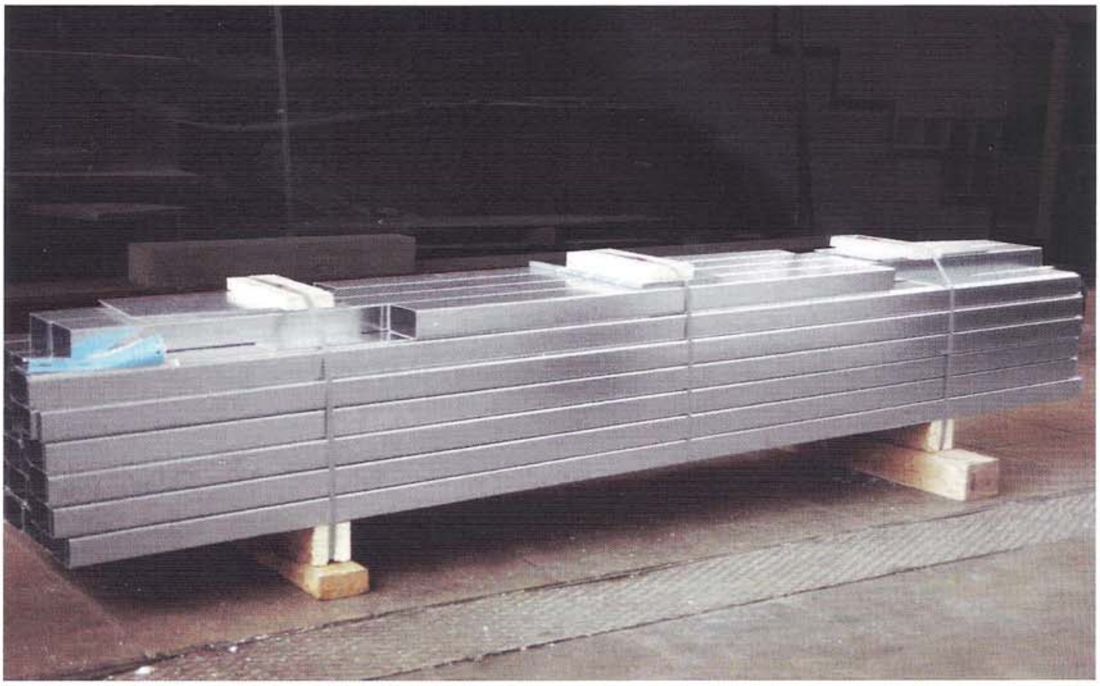


Fig. 115: Slightly inclined seating of profiles to ensure protection from corrosion

Development possibilities for lightweight steel-framed construction

Lightweight steel frame panels have the advantage of lightness, high load-bearing capacity and a wide range of possible uses. Main contractors prefer dry constructions for fitting out offices, warehouses or production premises. At very little cost, the plans of hotels, day-care centres and hospitals can be changed if certain parts are assigned new roles. This system also allows the cost effective construction of multi-storey residential buildings. It is therefore very popular with architects, main contractors, developers, and project owners.

In recent years, the steel industry has been developing at a steady pace and today it offers an incredible choice of innovative products that can be used for a host of applications in buildings. A new generation of sections has emerged, with optimised shapes enabling the assembly of streamlined lightweight structures. The traditional fastening methods requiring welding, rivets and screws have given way to new processes such as clinching and power nailing. Special steels or stainless steels, new treatments such as the duplex system provide excellent corrosion resistance. Project owners are looking for simple, fast solutions which do not require an army of working tradesmen. Next to construction costs, the costs of fixtures and the stability of real estate prices are the most important factors. And these aspects are determined by the long lifespan and quality of construction. Quality is primarily the business of builders, architects are responsible for design, engineers for technical issues, trades people for assembly and finishing. Optimal quality can only be guaranteed if the greater part of assembly is carried out in always identical conditions, in the workshop. That is why the greater part of a builder's work has increasingly become the work of specialists who manufacture increasingly complete members and modules in the factory. This has resulted in the availability of low-cost produced, superior quality prefabricated members with galvanised steel sections. They have a long life span, are easy to dismantle, separate and recycle. The lightweight steel-framed constructions presented in this brochure represent a first step towards smart, contemporary housing. Henceforth, the rationalisation processes used in the automobile industry will be applied to buildings. Tomorrow's construction industry will operate with electronically-controlled assembly chains. **(fig. 116)**.

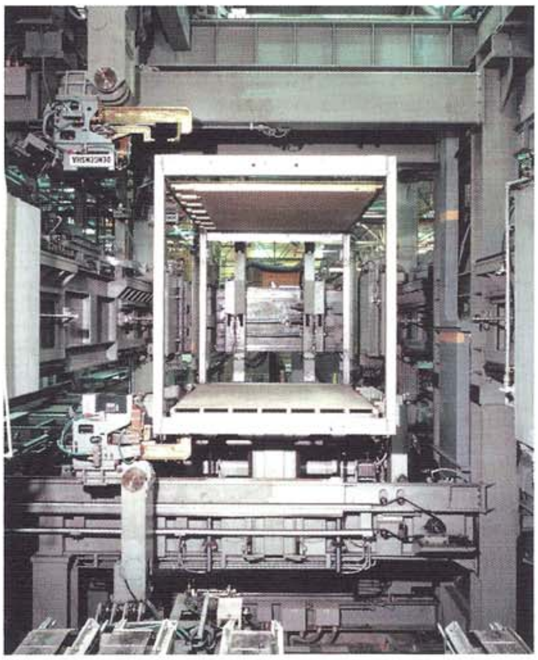


Fig. 116: Industrial production line for steel box units (Sekisui Heim, Japan) compared to an automobile assembly line (DaimlerChrysler)

Fastening

Fastening is one of the primary issues relates to the competitiveness of light frame steel housing.

On average, the installed costs for light frame steel home construction are not as competitive as the methods used with conventional building materials such as wood framing. To compensate the differences must be offset by lower material costs or reduced labor costs associated with connections and fastening materials. Two approaches are typically employed to improve the fastening efficiency for light frame steel housing:

- development of efficient connection details, and
- development of improved fastening methods.

More efficient connections could include reducing the number of connections and, therefore, the number of fasteners required, or developing completely different connection details. This can be achieved through testing, development of efficient analytical engineering approaches, more efficient framing systems, and integrating materials to minimize the need for labor-intensive activities.

Choosing a fastening method

Many connection and fastener types exist for light gauge structural framing, although not all are widely used. Often, a satisfactory connection can be obtained with fastening possibilities, and if the designer is aware of all these options, efficient and economical solutions can be achieved. The specific choice of a fastener will depend on:

- loading conditions,
- type and thickness of connected materials,
- required strength of connection
- configuration of material
- availability of fasteners and tools
- where assembled (on site or prefabricated in a shop)
- cost
- builders experience
- durability requirements, and
- code acceptance.

The labor involved in steel-to-steel fastening is a key contributor to the overall cost of light-frame steel housing, and lower cost is necessary to approach the productivity of fastening competitive material framing (such as wood). For example, typical fastening methods for light-gauge steel can take 75% longer than pneumatically nailed wood connections.

Fig. 117
Table of the most common fasteners

FRAMING CONNECTION	MOST COMMON FASTENERS
Rim joist to masonry foundation	Masonry Screws, Powder actuated pins
Joist to rim joist	Self Drilling Screws
Plywood subfloor to joists	Screws (with reamer tips), Pins
Wall track to floor deck	Self Drilling Screws
Wall stud to floor and roof track	Self Drilling Screws, Rivets, Clinching, Welds
Blocking to floor joists	Self Drilling Screws
Header to wall studs	Self Drilling Screws
Floor joists to structural steel beam	Welds, Powder actuated pins, Bolts
Structural sheathing to wall studs	Screws, Pins, Adhesives
Exterior foam board sheathing to wall studs	Screws, Adhesives
Gypsum board to wall studs	Screws, Pins, Adhesives
Truss joint connections	Screws, Proprietary connectors
Roof truss to top track	Self Drilling Screws
Roof sheathing to roof trusses	Screws (with reamer tips), Pins
Gypsum to roof truss	Screws

Using a screw gun rather than a hammer or pneumatic nailer, is an ergonomic adjustment. The process of fastening steel members includes two steps – clamping the assembly, and then driving the screw. Using a drill gun that requires a driving force by the installer can slow the process and cause worker fatigue.

Automatic feed screw guns, screw gun extension attachments, pneumatic pin nailers, and portable plasma troches are some of the tools that have been developed to help advance light-gauge steel framing.

A major consideration of steel fastening systems is the environment where the fastener is assembled. Therefore choosing the proper fastener depends on the steel framing system. In general, steel-framing systems can be grouped into two major categories: site-built construction, industrialized fabrication.

Fig. 118: Typical screws for light frame steel housing

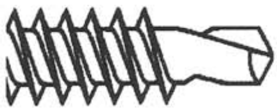


Fig. 119: Self-Drilling Tapping Screw

Fig. 120: Self-Piercing Screw

Screws

Screws are the most common fasteners used in framing cold-formed steel members and are typically applied with a positive-clutch electric screw gun. Screws used for light frame steel housing are self-drilling tapping screws or self-piercing screw. The first category is the most prevalent. The biggest advantage screws have in the light steel framing market is that they are widely available, standardized, and the tools are low cost. Proper installation requires little training, and mistakes can usually be fixed relatively easily since the screws can be backed out. In addition, screwed connections have been recognized and included in most building codes and industry standards. Screws are typically designated by the diameter, thread, head style, point type, and length.

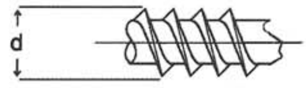
Screws are available in sizes ranging from No. 6 to No. 14, with No. 6 to No. 10 being the most common. Lengths vary from 12.7 mm to 76 mm depending on the application. Screws are generally 9.5 mm to 12.7 mm longer than the thickness of the connected materials so that a minimum of three threads extends beyond the connected material. It is important that the drill point be as long as the material thickness being fastened to, to drill effectively.

Screw point type

- Self-drilling tapping screws are externally threaded fasteners with ability to drill their own hole and form or cut their own internal mating threads into which they are driven without deforming their own thread and without breaking during assembly. Self-drilling screws are high-strength, one-piece, one-side-installation fasteners. These screws are typically used with 0.8 mm steel or

Fig. 121: Screw body diameter

Screw Number Designation	Nominal Diameter, d, (mm)
6	3,5052
7	3,8354
8	4,1656
10	4,826
12	5,4864
14	6,35



thicker. They are also used when fastening two or more pieces of steel of any thickness. Self-drilling point style are listed as #2, #3, #4, #5. The higher the number, the thicker material the screw is designed to drill. The self-drilling point style requires more consideration due to the variety of thicknesses and possibility of multiple layers being joined.

- Self-piercing screws are externally threaded fasteners with the ability to self-pierce metallic material and "tap" their own mating threads when driven. Self-piercing screws are high-strength, one-piece, one-side-installation fasteners, with sharp point angles under 30. The self-piercing point style is recommended for connections of less than 0.84 mm steel.

The body diameter of a screw is related to the nominal screw size as shown in Fig. 121. Most connections are made with No 8 or No 10 screws, except when attaching gypsum wallboard where No. 6 screw is typically used.

Screw length

The length of the screw is measured from the bearing surface of the head to the end of the point. The length of self-drilling screws may require special consideration since some designs have an unthreaded pilot section or reamer with wings between the threads and the drill point.

Threads

Self-piercing and self-drilling screws intended for cold-formed steel applications generally have a coarse thread. There are also many self-drilling screws that have fine threads for use in thicker steel.

Head styles

Common head styles include flat, oval, wafer, truss, modified truss, hex washer head, pan, bugle, round washer, and pancake. Specialty features may also be on the head, styles one of which is cutting nibs under the head of a flat head design. Hex head screws are typically used for heavier structural connections, round washer screws are typically used for general framing connections, low profile heads are used on surfaces to be finished with gypsum board, and bugle head screws are typically used to attach sheathing products.

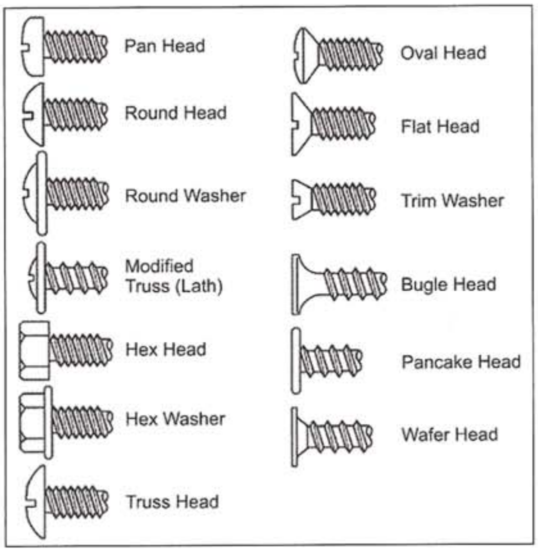


Fig. 122:
Head styles

Screw Body

The body of the screw includes the threads and any designed special feature, such as a shank slot.

Drive type

Drive types are usually determined by availability and preference.

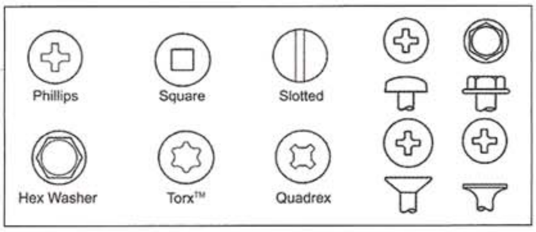


Fig. 123:
Drive types

Drill capacity

Drill capacity is defined as the total thickness the screw is designed to drill. The drive type and head style is typically related to individual preference, but may be a consideration for each application.

Pins

Pins fasteners are fairly new to the cold-formed steel framing industry. They employ techniques similar to nail guns for wood construction and are commonly used for attaching sheating panels to steel. Pins are available with mechanical or electro-zinc plating or with polymer coating depending on corrosion resistance requirements. Head diameters range from 0.100 to 0.236 inch (2.5 to 6 mm) and length from 1/2 to 8 inches (13 to 203 mm).

Pins are usually installed with air-driven tools similar to pneumatic nail guns. These fasteners can be easily installed in a one step process. Pneumatic driven pins can be used for attaching wood, cement, and gypsum panels to steel framing to construct roof and floor diaphragms, and shear walls. The most common pin diameters are 0.100 inch (2.5 mm), 0.105 inch (2.7 mm), 0.120 inch (3 mm), and 0.144 inch (3.7 mm). The shanks of the pins can be knurled to better grip the steel framing. Lengths must be sufficient to penetrate 1/4 inch (6 mm) beyond the steel sheet after driving.

Pins can be installed up to 10 times faster than screws. However, on one-to-one basis, screws usually offer greater holding strength than pins when withdrawal strength is measured, but for most applications, the installation of a few more pins, allow a pinned assembly to carry the same loads as an assembly built with screws.

Loose pins can create annoying squeaks in floor systems. The cost of the pins is also a major factor. Pins typically cost approximately 5 times the cost of screws. Pins are rarely used in steel trusses due to the potential for loosening. Vibrations in the delivery and erection phase, and cyclic axial loads in service can cause pins to loosen or back out.

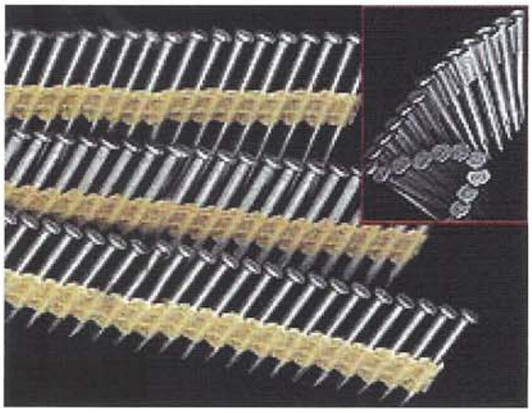


Fig. 124:
Collated pins

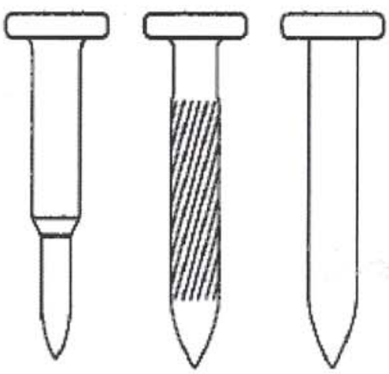


Fig. 125:
Step-down, knurled, and smooth pins

Clinching

Clinching is a method for joining sheet material and profiles without rivets, screws, or other added fasteners. The clinching tools are able to make an incredibly strong connection without the use of a fastener. In this process, one part of the steel is pressed into the adjacent steel, in a button or stitch configuration.

Many of the clinching tools are limited to use in a warehouse or factory environment. However, hand-held clinching tools are being developed that could be valuable for field use.

They have been used successfully in some truss and panel shops. In these settings, where tools can be suspended and tight tolerances can be achieved, clinching tools have proven to be faster than screw or weld connections.

Clinching has one characteristic that sets it apart from all the others; it does not involve the introduction of a consumable in the fastening process. Clinching eliminates the need for separate fasteners such as screws, rivets and pins. A clinched connection can be made in less than one second and workers can easily be trained to operate clinching tools. Integrated clamping results in a connection with no gap, no deformation, and no burrs. A clinched connection leaves a relatively flat surface, which helps prevent cracks in gypsum. The risk of hand injuries from sharp screws and metal burrs is reduced. There are no toxic fumes or loud noises and clinching does not burn away the zinc coating as in welded connections. Clinched connections are less susceptible to loosening over time than other types of connections. Costs per clinch have been reported to be a fraction of a screw connection.

Fig. 126:
Clinching process

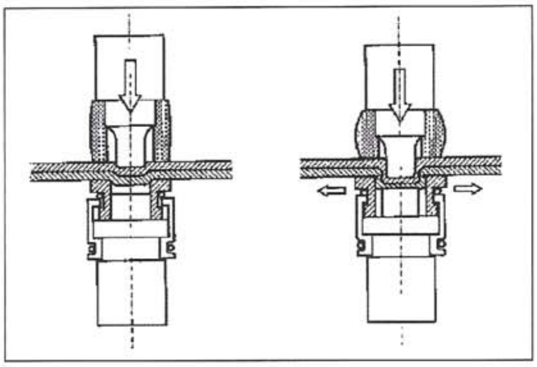
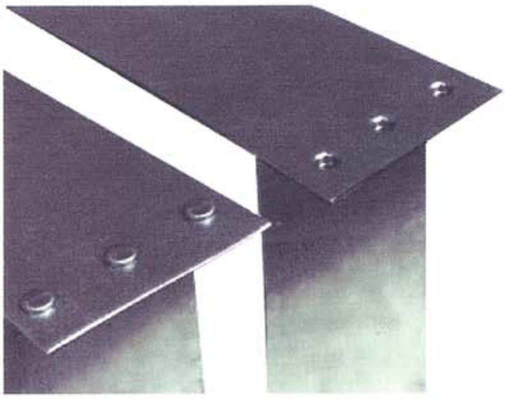


Fig. 127:
Clinched connection



Clinching tools are specialized and can be very costly. They can be bulky, and a field framer would have a difficult time lugging the tools and required compressor around on a job site. Also, if a clinch is made in the wrong place or the steel is not aligned properly, the connection has to be drilled or cut out. There is no easy way to remove the connection or pull the members back apart without destroying the metal.

Rivets

Rivets are dowel-type fasteners that rely on the deformation of the fastener rather than threads to secure it in place. Some rivets consist of two pieces: the rivet itself, which is a flanged metal sleeve about the diameter of a typical metal screw, and a mandrel. The mandrel is pre installed in the steel sleeve and has a bulged head on one end. The mandrel is used to deform the driven end of the rivet and is typically broken off and discarded after the rivet has been installed.

There are two main types of rivets, which are classified by their installation methods. Blind rivets that can be installed without requiring access to the inside face (or blind face). This method typically requires a pre-drilled hole prior to inserting the rivet. Punch rivets are similar to blind rivets except the back face of the connected materials must be accessible for the installation tool. These rivets generally do not require a pre-drilled hole, and do not have a separate mandrel that deforms the rivet. These rivets are typically solid instead of sleeved as the case for blind rivets.

Fig. 128:
Blind rivets

Pop rivets hold well, but are not removable. They can be used for fastening studs to track, or various other framing applications, but are rarely used for truss joints. Riveted connections are typically used in a factory setting.

Rivets are relatively easy to install and offer an attractive finish. They leave a smooth surface on one side, which is ideal when sheathing panels are to be installed over them. The disadvantage is that pre-drilling is an extra step and can make the connection process uneconomical.

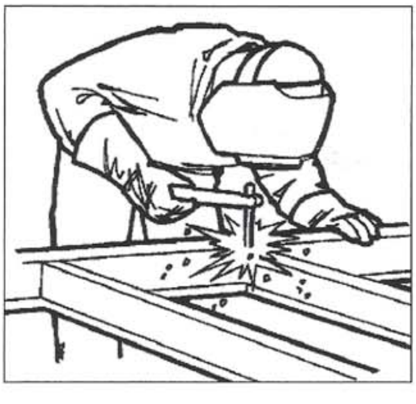
Welds

Welding has been used in limited applications for light gauge steel. Most often, this method of connection is done in a fabrication plant. Galvanized steel can be joined by spot or continuous welding. Welding may be an economical joining method when shop fabricating standard wall or roof assemblies. Although both welding operations volatilize the zinc coating at the weld site, spot welding is a much more localized process and does not damage the surrounding zinc coating. Welding requires experienced workers and specialized equipment. Welding must be done in a well-ventilated area to avoid harmful fumes given off when zinc coatings are burned.

Welding is most often done at a fabricators shop to connect framing components into panel assemblies or trusses. Welding is commonly used to attach shelf angles to steel framing. Types of welds include flare bevel groove, flare V-groove, lap joint fillet, and T-joint fillet welds.

Welds can provide some of the strongest types of connections, and in a factory setting welds can be made relatively quickly. Weld design is simple and usually code recognized making it ideal for engineers and designers. Fabricators must be well trained and experienced in welding light gauge steel. Welding of thin gauge steels (33 mils or thinner, 0.84 mm) is typically nor recommended or done because of the concern of burning through the metal. Although some welding has been done to join thin steel members, it is usually not permitted in site built applications.

Fig. 129:
Field welding



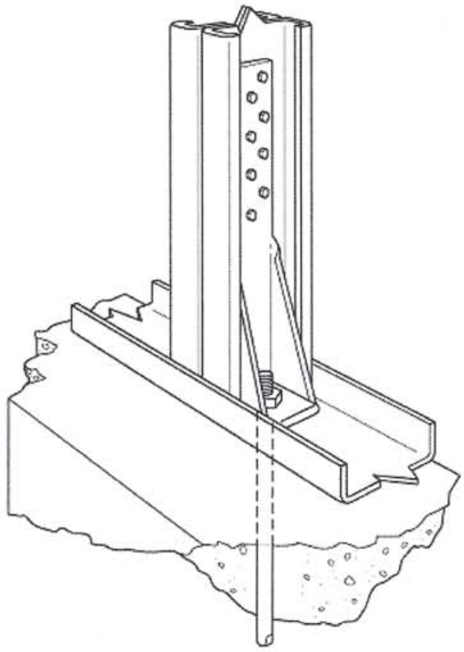


Fig. 130:
Bolted bracket
to foundation

Bolts

Bolts or anchors are typically used to attach structural members to the foundation, or to connect structural members to heavy steel members.

Foundation bolts are usually pre-installed in concrete foundations. Light gauge steel track can be attached to the bolts with washers and nuts. Often, oversized washers are used to enhance the bolted connection. Pneumatic wrenches or hand tools are used for installation. Bolts are primarily used for foundation anchors. The anchor bolts are typically set in place when the concrete foundation is poured. However, expansion bolts can be installed after the concrete foundation is cured. Epoxy can be used with these bolts to strengthen the connection. Bolts are also used to connect thicker gauge steel components.

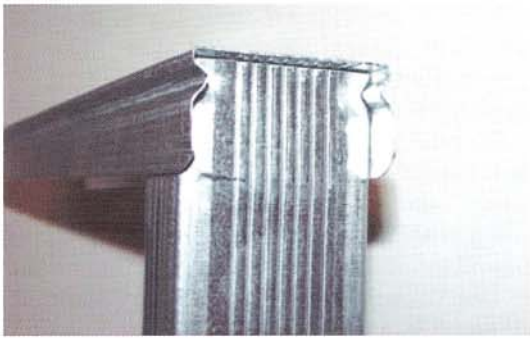
Bolted connections can provide adequate strength and are easily dismantled if needed. No special tools are required and connections can be easily verified. If separate nuts have to be installed, the connection rate is very slow. The connection requires a minimum of three separate pieces of hardware for each connection (bolt, washer, and nut) and holes usually need to be predrilled.

Clip-together systems

They consist of specially formed components that are designed to lock into place without the need for fasteners or special tools. Some require the member to be twisted into position, while others use slots, tabs, or flanges to lock them together. These types of connections are limited to use on non-structural or nonload bearing systems, but also can be used as temporary connections until structural fasteners, such as screws, are installed.

Twist-in studs are installed by hand. The stud is slid between the top and bottom tracks at a slight angle to allow it to be positioned. Once positioned, the stud is locked into place by twisting it into the pre-formed matching profile. Other proprietary methods are available and usually consist of tabs or flaps that have been cold-formed into the structural shapes.

Fig. 131: Twist-in studs



Clip together type connections are usually restricted to non-bearing walls, and other nonstructural components. These connections have been very successful for partition walls.

Clip together components can be fastened together very quickly, and most can be dismantled if needed. Some require no tools to install and others only require a hammer. Most clip together connections are not approved for load bearing conditions unless additional fasteners are installed.

Adhesives

Adhesives are often used and sometimes required when pins or nails are used to attach subfloors and underlayment to steel joists. Adhesives are also used to attach drywall to steel studs in order to reduce some but not all of the mechanical fasteners. Only approved types of adhesives should be employed as specified by the adhesive manufacturer. Consideration for temperature and moisture conditions should be included to assure strength is maintained. Adhesives are applied with manual or auto-feed pneumatic guns.

Adhesives tend to distribute forces over a larger area and therefore force concentrations can be avoided. The continuous connections that adhesives provide can help eliminate squeaks in floors when used in conjunction with nails or pins.

Glues and adhesives can be sensitive to temperature and moisture. Quality control is extremely important and often hard to verify. Nails, screws, and even welds, can be visually inspected, but glued joints are nearly impossible to verify. Therefore, gluing typically is not used as a sole fastening method, but often used in addition to mechanical fasteners.

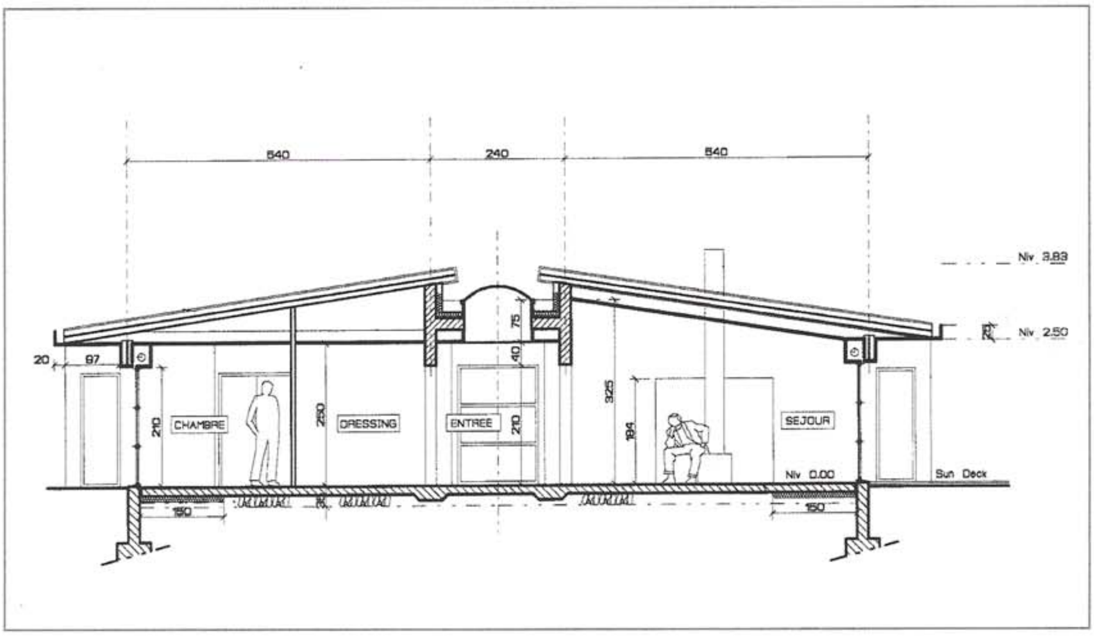
Examples

France

Demonstration steel house built in the parc de La Villette in Paris with a Styltech structure. A large kitchen, the living room and a patio in between are on the first floor; the parents' room is by the living room. The children have their own spaces on the second floor: a large room and a terrace which is part of the roof. G. Hamonic and J.-C. Masson architects.

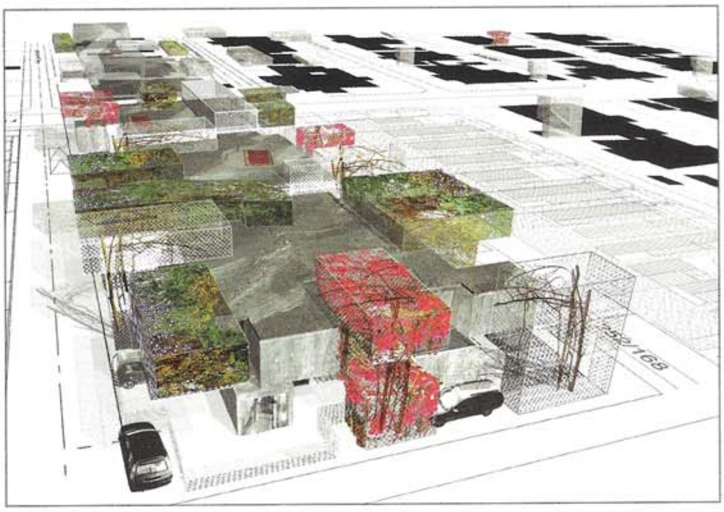
France

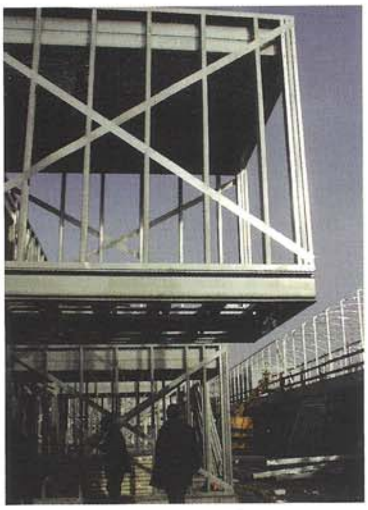
Private house built in Marly with a Styltech structure. The whole house is at street-level: the common spaces and the bedrooms are separated by a space lightened and protected by a glass roof. Gérard Hyppolite architect.



France

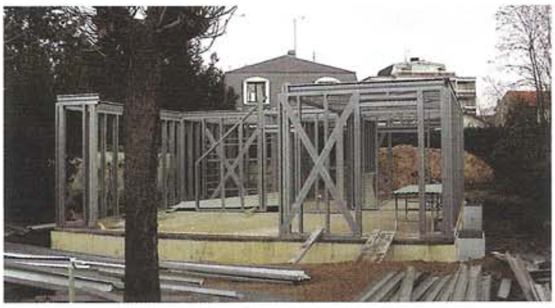
Group of steel houses of the "Cité manifeste" in Mulhouse, with a Styltech structure and regular sections to support the cantilever of the second floor. The façade is formed with steel cladding and glass. Those two-floor houses interlock. Duncan Lewis, Scape architecture & Block architects.





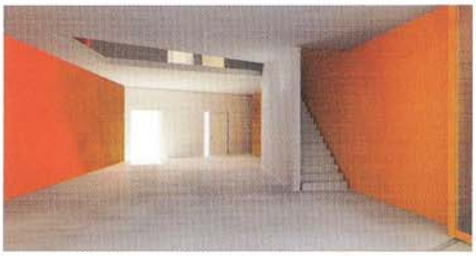
France

This private house near Paris is a good example of a rather traditional architecture built with a Styltech structure. Pascal Bonaud architect.



France

Group of houses of the «Cité manifeste» in Mulhouse built with a Styltech structure. Each house has two levels plus an attic. All the bedrooms are on the second floor while the first floor is for the living room and the kitchen. The houses are wide open on the inside of the cité and are closed by a steel cladding on the street side. Ateliers Jean Nouvel architects.



France

Country house near Biscarrosse built in the Landes forest. The Styltech structure was erected on a concrete base on piles. Wood and glass are also very important in this architecture. Joxe Aranguren architect.

Spain

Isolated single family house built with a galvanized metallic structure on concrete foundations in Sils (Girona). The inside sheeting is made of plasterboard and the exterior is an application of concrete finishing. The insulation material is rock wool in the metallic structure with a vapour barrier. The roof is built with steel trusses supporting clay tiles on water-repellent wood panels.
Daniel Mediavilla architect.

Spain

Detached house of 175 m2 included in an eighteen plots estate in Casar de Talamanca (Guadalajara). The exterior cladding is made of single layer mortar. The house has two floors.
Luis de Pereda architect.

Portugal

House built in Moita.The system is quite a success as it can be designed and built very rapidly, within summer holidays for example. Gestedi building company.

Portugal

House built in Eixo. Gestedi building company.

Portugal

House built in Avanca on Bara. Gestedi building company.

Finland

The Loiste house in Kotka is a modern low-energy house for a family with two children. It was erected for the Finnish housing fair. Kaipainen Oy architects.

Finland

Arabiantanra is a residential building in Helsinki. ARK Oy Kahri & Co architects.

Germany

Semi-detached houses in Ramstein. Profilhaus Consult, Dettingen.

Germany

Two-family house in Waldeck-Höringhausen. Richter system, Griesheim.

Germany

Heightening of a historical half timbered house in Dinslaken. The traditional architecture accomodates very well to a lightweight structure which is completly hidden. Architekturbüro Husmann architects.

Germany

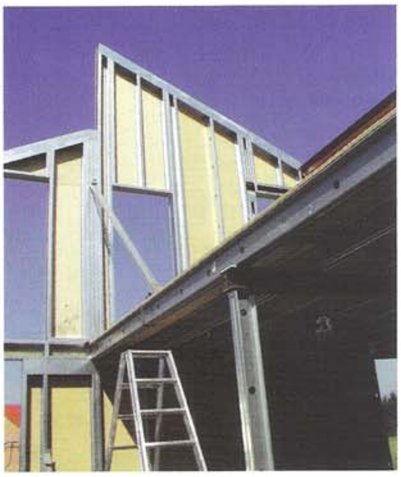
Single-family house in Böbingen/Rems. SwitchHaus, Bopfingen.

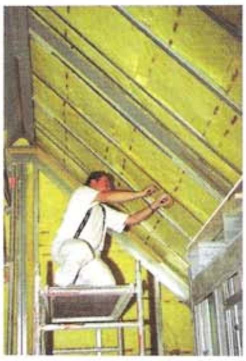
Germany

Studio house in Düsseldorf. Michael Müller and Christian Schlüter architects.

Germany

Prefabricated panels and light steel framing for a traditional family house in Hoyerswerda.





Germany

Residential house in Malsch. Michael Müller and Christian Schlüter architects.

The Netherlands

Smarthouse, built in Rotterdam, is proposed as a vision of what a living place can be in the 21st century. The floors, façades and roofing constructions are built with prefabricated light steel framing components. Mei architects.

The Netherlands

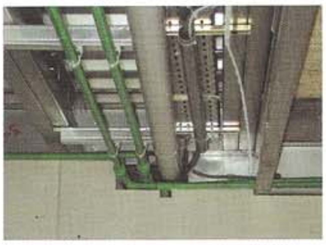
Multiple Choice house, here built in Almere, is a combination of light steel framing, timberwork and hot rolled sections. This house is sold as an enveloppe in which the owner is free to design his own spaces, guided by a CD-rom. Architecten Cie. This concept was awarded by the Dutch governement.

The Netherlands

Steel Study house
in Zoetermeer.
Eric Vreedenburgh -
Archipel
Ontwerpers
Architects.

Belgium

Experimental house built in Liège. Each façade of this lightweight steel structure house is treated differently. It shows that steel can be married with different materials. Véronique Salmon architect.



United Kingdom

Students' house in Oxford Brookes University. Corus Framing, The Steel Construction Institute Oxford Brookes University and Taywood Homes carried out the project in order to demonstrate the benefits of light steel framing and use of innovative construction techniques in modern domestic construction. Berman Guedes Stretton Partnership architects.

United Kingdom

The dwellings are constructed using a system developed by Forge Llewellyn. The system brings together a lightweight steel frame with pre-decked floor cassettes to enable the shell and upper floors of a dwelling to be erected within a day. This operation was conducted in the framework of a regeneration programme to create a new and sustainable centre for Oakridge. HTA architects.

Erection

The erection process of a lightweight steel-framed house follows a simple path from the factory to the construction site.

1. Coils of galvanized steel sheets are delivered from the mills to be profiled into studs and beams.

2. The studs cut to length are packaged in the factory.

3. The delivery on site is made by truck.

4. Packages are displayed on site following their position in the house.

5-6. Special portable tools facilitate handling of the studs or connections.

7. The studs can easily be manipulated by hand.

8. Connections to foundations can be made by bolts.

9. Self drilling tapping screws are easily put in place with a portable electric screw gun.

10 . Bolts are among the different fastening methods available on site.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11. Pre-assembled elements such as roof trusses or panels can be moved by hand without the need for a crane.

12. The post and beam structure is directly assembled on the foundation slab to form the frame of the building.

13. Electric wiring or plumbing can be set in the depth of the structure.

14. Insulation is put in between the vertical studs.

15. Plasterboards are screwed on the steel frame to form the inside finish of the rooms.

16. The exterior cladding can be made of various materials.

17. The steel structure can support various kinds of roof cover, including traditional tiles.

18. Once finished, the steel frame completely disappears in favour of the required architectural design.


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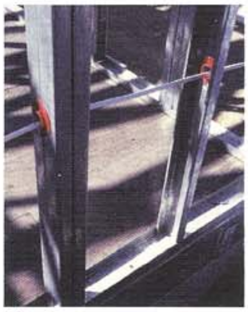
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European Lightweight Steel-framed Construction

The European Light Steel Construction Association (LSK) is an international non-profit association under Belgian law.
Its members are the key players of the cold-formed galvanized steel framed construction market, that is to say: architects, engineering companies, home builders, contractors, technical enforcers and industry (materials, tolls and equipments).
This membership is at there individual as well as company level. These key players federate around the Eurocode 3, part 1-3, the European standard that defines the rules of building construction using cold-formed thin steel sections.

In order to promote in Europe the recourse to these construction systems, which are particularly relevant in terms of:

- speed and quality of construction,
- reduced impact on the environment, this at all the ages of the building,
- flexibility and adaptability of built spaces, and consequently in terms of global cost and use relevance.

LSK takes actions of several natures such as:

- to compile and publish information for the users,
- to contribute to the adoption and the update of the normative specifications relating to manufacture and use of steel profiles and derived products,
- to allow the dissemination of knowledge through the setting of seminars and the publication of documents. These actions are inspired by those achieved in the United States of America by the LGSEA (Light Gauge Steel Engineers Association), that has a thousand members and of which LSK is the European correspondent.

The members of LSK have access to the most recent knowledge and know-how.

In addition, they are informed, as soon as possible, of innovations as regards products, methods of design or construction techniques.

Thus can they always better answer to the aspirations and requirements of their customers and increase their competitiveness continuously.

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