Lindab Construline

Lindab Lightweight Wall Constructions

Application Guide

Lindab

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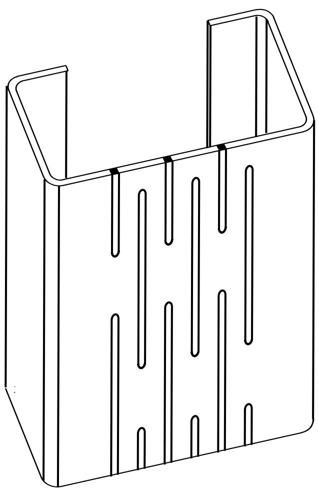

LINDAB Kft. (2051 Biatorbágy, Állomás út 1/a.)
2006

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PRODUCT DESCRIPTION

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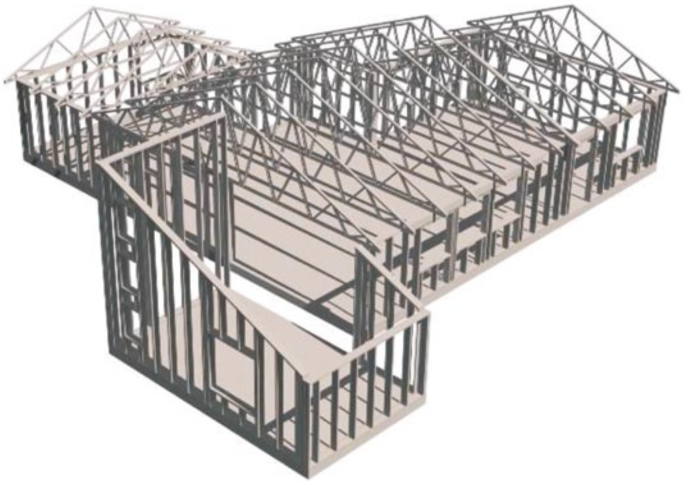
A – Product description

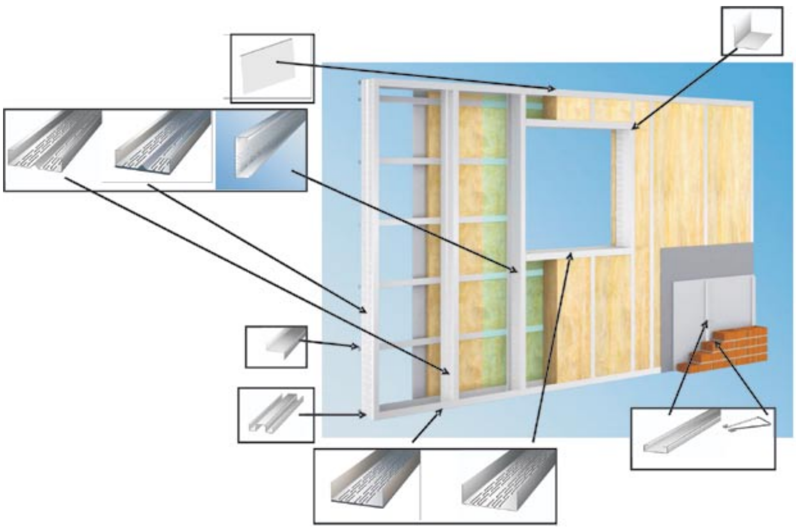
1. Application Field

The Construline light-gauge hot-dip galvanized steel profiles, produced and sold by Lindab, can be used in the following application field:

Main application field of the Construline slotted exterior wall profiles:
- Load-bearing wall structure of complete lightweight frame construction of one- or two-levelled dwelling houses, detached family buildings.
- Non load-bearing exterior wall construction of multi-storey high buildings with own main load-bearing skeleton made of reinforced concrete or hot-rolled steel; such as infill walls, curtain walls of hotels, hostels, office buildings etc.



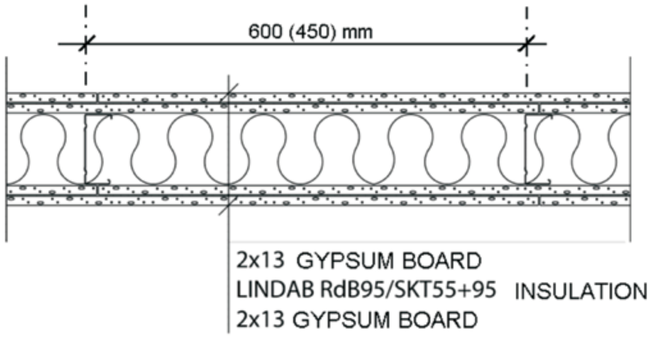
In all the application fields, the most important advantage of the lightweight wall construction, having the frame made of slotted profiles, is utilized, this is the very good thermal characteristic. The reason of the punched oval holes ("slots"), placed in several lines longitudinally shifted to each other, is to the make the path of the heat conduction through the steel stud significantly longer, thus providing very good thermal performance, that means very low value of resultant heat transfer coefficient. This way the final solution of the wall construction is very economic and of high technical level. The frame construction made of light-gauge slotted profile will then be completed with infill insulation (glass wool, rock wool), and board materials (gypsum, wood, OSB, steel trapezoid sheet etc.) on both sides. Alternatively, before placing the board material on the internal side, a horizontal secondary profile system (Z- or hat-section) can be fixed to the inner flange of the slotted studs (maximum spacing of 600mm), ensuring adequate space for installations. It is very important to build the vapour barrier foil on the internal ("warm") side of the wall insulation, making the whole wall surface continuously airtight and all the connections fully sealed.



Lightweight exterior wall construction built from Lindab slotted studs and runners

A – Product description

Main application field of the Construline partition wall profiles:
Inner steel frame structure of non-load-bearing lightweight partition walls, in any kind of building with load-bearing main structure made of any material and system, with any kind of function (family houses, block-of-flats, office buildings, hotels, educational buildings, industrial applications, hall buildings etc.). The most favourable advantage of this partition wall systems is the very good acoustic performance and the very quick and easy erection of dry technology.



FIRE RESISTANCE	R'	R'w + C50-3150
EI 60	50 dB	45 dB

Lightweight partition wall construction made of Lindab profiles

Advantages of Lindab lightweight constructions in general:
- Light weight – simple and easy to erect
- Exact shape and geometry for whole duration
- Durable, resistant raw material of zinc coated steel
- Dry mounting technology, quick erection
- Slotted exterior wall profiles: excellent thermal performance
- Partition wall profiles: outstanding sound isolation parameters
- Great load-bearing capacity coming from the high strength steel
- For the Lindab light-gauge skeleton various types of external façade cladding can be applied

2. Raw Material (Steel Core, Zinc Layer)

The raw material of every Lindab profile is hot-dip galvanized steel sheet:

- External slotted profiles: **S350GD+Z275 (EN 10326)**
- Partition wall profiles, accessories: **DX51D+Z120 (EN 10327)**

According to the standard marking, quantity of the zinc layer on the steel core is 275g/m^2 (equal to thickness of cca. 20 micron on both sides) in case of exterior profiles; while 120g/m2 (cca. 8.5 micron on both sides) in case of partition wall profiles.

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3. Product List with Geometry

3.1 Exterior Wall Profiles and Accessories

Mark	Figure	Profile Height (mm)	Thickness (mm)	Flange sizes (mm)	Length (mm)	Short description
MAIN STRUCTURAL MEMBERS						
HRY-C		100/120/150/200	1.0/1.2/1.5	41/47	1000-13000	C-profile stud with slotted web
C		100/120/150/200	1.0/1.2/1.5	41/47	1000-13000	C-profile with unslotted (solid) web (in case of wall openings)
HSKY-U		100/120/150/200	1.0/1.2/1.5	56/56	1000-13000	U-profile runner with slotted web
ADDITIONAL STRUCTURAL ELEMENTS AND ACCESSORIES						
ÄA		100/120/150/200	0.70	15	X	End stiffener for compression stud
YVX		215/240/290	1.0/1.2/1.5	15/20/25	1000-4000	L-profile lintel beam (works together with the board!)
LPY		100/120/150/200	0.70	50/50	X	L-profile connection elements (e.g. for openings)
L50 / L100		50/100	0.70	12	1000-4000	L-profiled edge element for board
RZ		45/50/70/75	0.70	30/30	1000-4000	Z-profiled secondary beam (for installation and/or extra insulation)
RCY		45/50/70/75	0.50	30/50	1000-4000	C-profiled element around opening (for installation and/or extra insulation)
MSK		27	0.8/1.0		2500	Fixing channel for brick façade cladding (t=0.8 is stainless)
MK		90/120/150	3.0		X	Brick tie for brick façade cladding (capacity: 0.5kN/pcs; min. 40mm length in brick wall)
B08		4,8x16			X	Structural self-drilling screws
PD10		100/120/145/195			70m	10mm polyethene strip under runners

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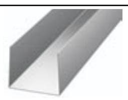
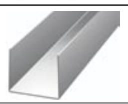
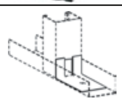
3.2 Partition Wall Profiles and Accessories

Mark	Figure	Profile Height (mm)	Thickness (mm)	Flange sizes (mm)	Length (mm)	Short description
MAIN STRUCTURAL MEMBERS						
RE		45	0.56	34/37	1000-7500	Wall studs without acoustic pattern
RdB		70/95/120	0.56	34/37	1000-7500	Acoustic wall stud
RdBF		70/95/120	0.56	48/48	1000-6000	Acoustic wall stud with wider flanges
SK		45/70/95	0.56	30	1000-4200	Runner profile with 30mm flange size
SK55		45/70/95/120	0.56	55	1000-4200	Runner profile with 55mm flange size
ADDITIONAL STRUCTURAL MEMBERS						
KR; FR		45/70/95/120	1.00/1.50	41/45	1000-8000	Door stud and lintel beam
KSK		45/70/95/120	1.00	50/50	1000-4000	Runner profile for KR studs
FSK60		45/70/95/120	1.50	60/60	1000-4000	Runner profile for FR studs
ACCESSORIES						
HR		60	0.56	60	1000-4000	Corner studs for board connection
PD4		45/70/95			50m	4mm-es polyethene strip under runners (below 40dB)
GT		45/70/95/120			50m 25m	EPDM rubber strip under runners (from 40dB above)
FRK		45/70/95/120	1.50	35	X	L-connection piece for KR- and FR-studs to runner
DK		45/70/95/120	0.70	45	X	Accessory for electric installation

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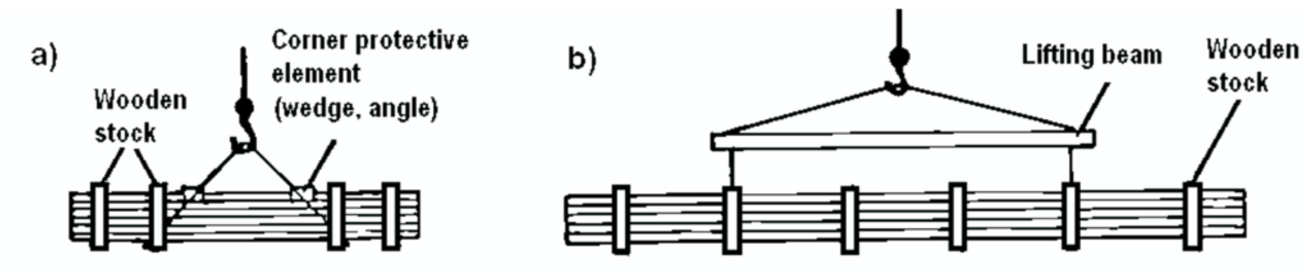
Mark	Figure	Profile Height (mm)	Thickness (mm)	Flange sizes (mm)	Length (mm)	Short description
LP; KLP		50/55	0.6; 1.00	50/50	1000-4000	Corner pieces for boards (LP: t=0.6; KLP: t=1.0)
HS		29	0.50	29/29	2450-3000	Perforated corner piece for boards
VBA		100/200	0.56	X	50-25m	Coil perforated in the middle for corners, in rolls
TSKA		10	0.56	60	1000-3000	T Connection piece between boards (PE coated white)
J; JL		12.5	0.50	13,5/32	2450-3000	Edge trim for board ("J" nature galvanized; "JL" PE coated white)
BA		100-170-300	0.56-0.70	X	15-25-50m	Solid coil in rolls
BAD		100	0.56	X	1000-4000	Steel sheet plates

It should be mentioned that the tolerance of all the profile geometry satisfies the regulations of the EN 10143 standard.

4. Delivery and Storage Regulations

In case of **exterior slotted profiles**, the regulations and rules for delivery and storage are the same as those are for the traditional Z/C/U-profiles generally used as secondary load-bearing elements (roof purlins, wall girts) of industrial buildings, hall constructions, since the raw material is just the same (S350+Z275).
Before delivery, the profiles with different lengths should be packed together, fixed with wooden stocks and/or metal straps. Attention must be paid for the fixing points where the profiles should be protected by wooden wedges or steel angle profiles, to avoid local deformations due to the concentrated forces in case of lifting. For lifting the packages, appropriate lifting ropes, straps or – in case of longer (8-10m<) packages – strong lifting beams are proposed to use. The transportation of the packaged products can be solved by fork-lifting trucks in case of shorter pieces, and mobile cranes in case of longer products.



Packs in case of shorter (<8m) and longer (8-10m<) production lengths

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The hot-dip galvanized steel profiles must be stored in dry, open (ventilated) air on site, in cool places, if possible. Close placing to, or direct contact of, aggressive, corrosive and wet materials, building materials (wet unconsolidated concrete, mortar, lime, soil) and chemicals (acids, salty liquids) should be strongly avoided. Harmful influence can be derived from radiating heat and other metals that can cause contact corrosion with the zinc (e.g. copper, lead). It is strongly recommended that neither water, nor dust can be accumulated on the surface of the profiles during the storage. This latter protection can be realized by means of inclined position of the packages with longitudinal slope of cca. 2-3%, ensuring the water to let flow away. In case of hot-dip galvanized materials, the so-called “white rust” can be formed on the surface during quite short time of wet air or vapour condensation. It does not mean damage, it can be removed by cleaning the surface with dry tool before building in. Outside storage must be limited in time (3-6 months as maximum), the profiles should be build in within 6 months after delivery, at the latest.

Storage of packages from the profiles ensuring slight slope

The profiles should be protected against direct contact of water and wet materials during the erection, as well. Some water, rain can be accumulated in lower runners, quite typically, that must be taken away, by means of drilling some holes, for example. Before placing any further materials (insulation, foils, gypsum boards etc.), it is always should be carefully checked that the light-gauge frame is clean and dry!

In case of delivery of the partition profiles the same attention must be paid for creating the packages, as it was mentioned at exterior profiles. However, because of the lower thickness (t=0.56; 0.60; 0.70) and the consequently lighter weight, the transportation and the unloading of packages, stocks can be solved simply by hand in the most of the cases, alternatively by means of smaller fork-lifting trucks. On the other hand, the thinner profiles require even more careful handling in case of packaging, transportation and erection, to avoid any damage caused by strong and concentrated mechanical affects.

The **partition wall profiles** are finally always applied for internal use, and are covered by boarding materials, this why a lower quantity of zinc layer (120g/m^2) on the steel core is enough for providing appropriate durability. From other aspect, because of the less thickness of zinc coating, the outside storage of partition wall profiles can be allowed for shorter time than for exterior profiles (not more than 2-3 months), and it is proposed to transport the packages into dry, closed place and to store them unpacked to let the air be ventilated along the surfaces of profiles.

Other regulations are the same as in case of exterior profiles: to avoid wet and corrosive building materials, liquids in storage and in erection, as well; or to place the packages inclined before unpacking to let the possible water or vapour go away; or the cleaning of “white rust”. It is also proposed to build the partition wall profiles in their final construction within 6 months.

B
GENERAL DESIGN ASPECTS OF LIGHT-WEIGHT CONSTRUCTIONS

(by Dr. TÓTH, Elek, Budapest University of Technology and Economics)

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B
GENERAL DESIGN ASPECTS OF LIGHT-WEIGHT CONSTRUCTIONS

(by Dr. TÓTH, Elek, Budapest University of Technology and Economics)

Light-gauge steel U- and C-profiles with slotted webs, produced by Lindab Kft. in Hungary, creates the opportunity of using exterior and interior light-weight structural walls in a wide range. In the interest to design these kinds of constructions and to avoid designing and building failures, it is suitable to survey the foreign literature of the subject, and to draw the lessons from them.

1. Protection Against Heat and Moisture

1.1 Thermal insulation in winter

In the external walls of light-weight steel-framed constructions, the primary insulating layer is situated between the load-bearing studs. The space between the load-bearing studs has to be filled in with insulating material to avoid thermal bridges and thermal flows. The insulating material between the studs are often completed with additional exterior or interior insulating layer for avoiding thermal bridges (Figure 1).

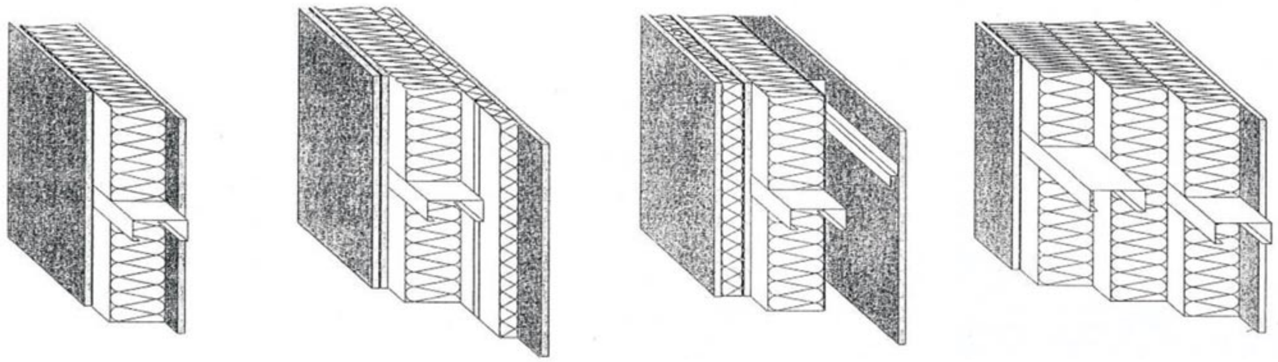

Figure 1:Structural principles of light-weight exterior walls constructions

Requirements for low energy houses are almost always achieved in the cases of lightweight steel-framed constructions. It takes just an additional thermal insulation for them to meet the requirements of passive houses.

Lightweight steel-framed constructions present, thanks to thinner walls, a surface gain of nearly 5-10% in relation to a classic, monolithic system.

1.1.1 Avoiding thermal bridges

To guarantee the insulation ability of the lightweight steel-framed buildings mentioned above, it is indispensable to think over in details the thermal protection of the junctions.

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 (convention thermal bridges) in the external cladding.

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

Steel members that are fully crossing the entire wall thickness must absolutely be avoided.

Next to sections, the temperature of the interior cladding can fall below dew point. Mechanical fasteners such as screws or connection elements, also cause lower surface temperatures.

B – General design aspects of light-weight constructions

The following Figure 2 shows examples how to prevent geometrical and construction thermal bridges.

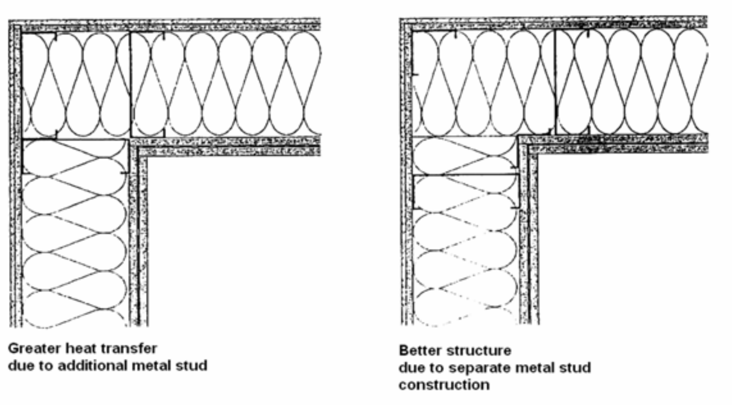

Figure 2: Superposition of a material heat bridge with a geometrical thermal bridge

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. This standard is valid for homogenous walls, and gives a trial load method applicable to heterogeneous layers, with the exception of cases, where insulation layer is penetrated by steel member.
Thermal bridges can be calculated by a 3D finite element method defined in standard EN ISO 10211. In the 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. This is easy to obtain by lining the walls and installing an external insulation.

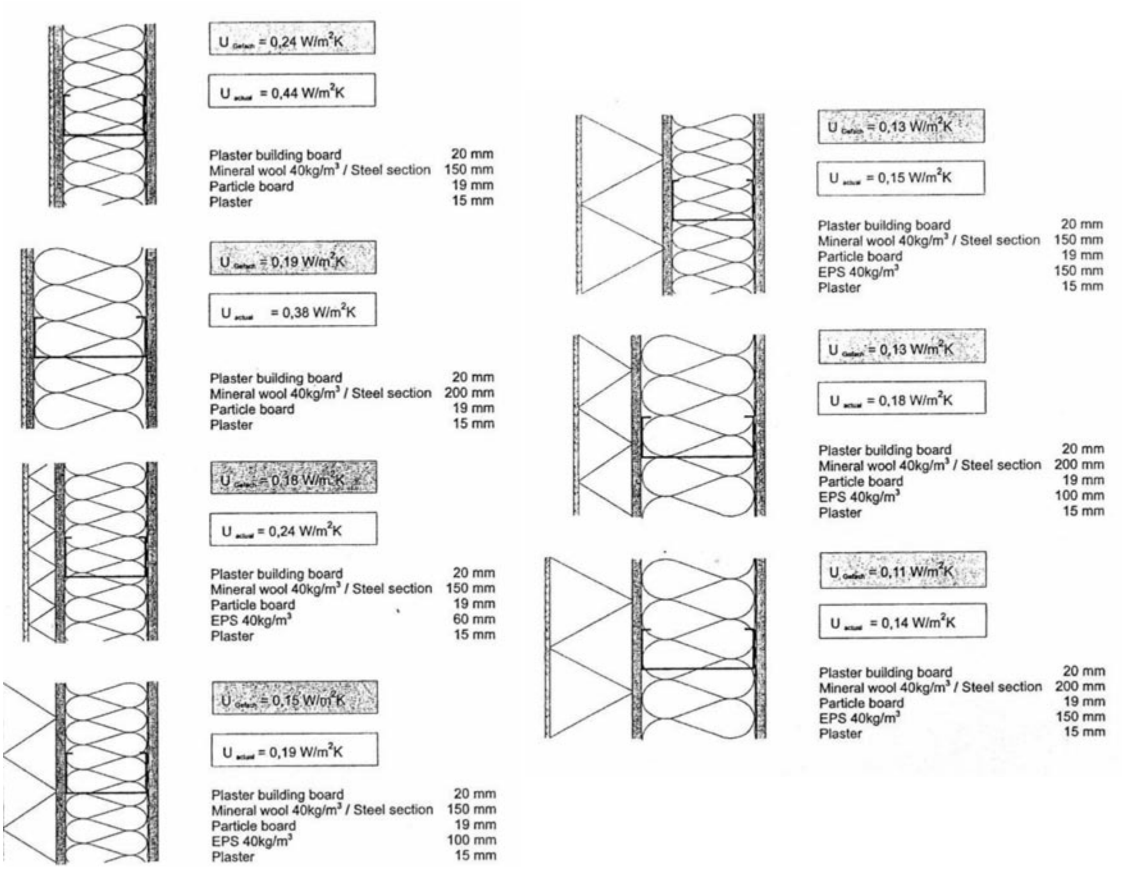

Figure 3: Effect of thermal bridges in the steel wall constructions (samples from Swedish literature)

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Figure 3 shows the effect of thermal bridges in case of different types of constructional solutions and different thicknesses of insulation. By using thermal bridge breakage fasteners with an additional insulation layer, the effect of thermal bridges come from steel studs are quite well limited. With an additional external insulation which is more than 60mm 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 broken with longitudinal holes to reduce conductivity. These slotted profiles favourably reduce the direct conduction. According to the layout of these slots and the width of web plates, the path taken by the heat can be multiplied by three (Figure 4). This significantly reduced propagation of the heat.

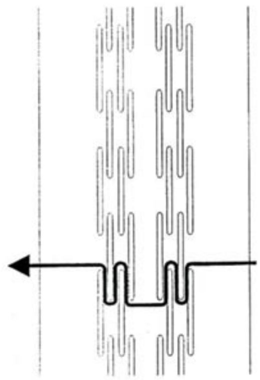

Figure 4: The way of heat flow through the slotted web

1.1.2 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 athmosphere, absence of construction fault, inside air quality and energy balance.

As “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). We can say as general rule, waterproof membranes are installed on the inner side of external coatings.
We can 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 negative effect on the thermal performances of a contruction member.
The outer side of the external cladding insulation is lined with wind-tight insulation membranes (like the bulit-in roofs vapour-conductive cover supports). Of course, value of $s_{d,outer}$ must be smaller than that of $s_{d,inner}$ (see Figure 5).

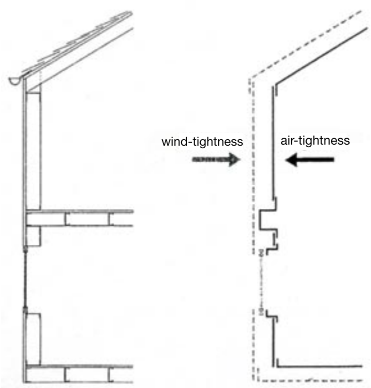

Figure 5: The difference between air-tightness and wind-tightness

B – General design aspects of light-weight constructions

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.

The provide excellent inside air-conditions, it is indispensable using an air-tight layer. It also helps to prevent the intrusion of unpleasant scents from ajacent apartments and, possibly, dank air from the basement, fine dust particles and other disturbing emissions from inside the building.

1.1.3 Energy savings

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. Because of the fault of the external air-tightness, the outside air gets into the wall, from where it can get into the inside air because of the defective air-tightness of the inner plates or defective connection between two parts (Figure 6). The inside hot air can flow out in the same way causing a significant loss energy. To avoid this, the interior side of the construction must be equipped with an air- and vapour-tight membrane. In the lack of this, the condenzation of vapour-filled air ruins the structure. On the other hand, the fibrious insulating materials are always ventillated by the outside air, so their insulating effect is reduced.

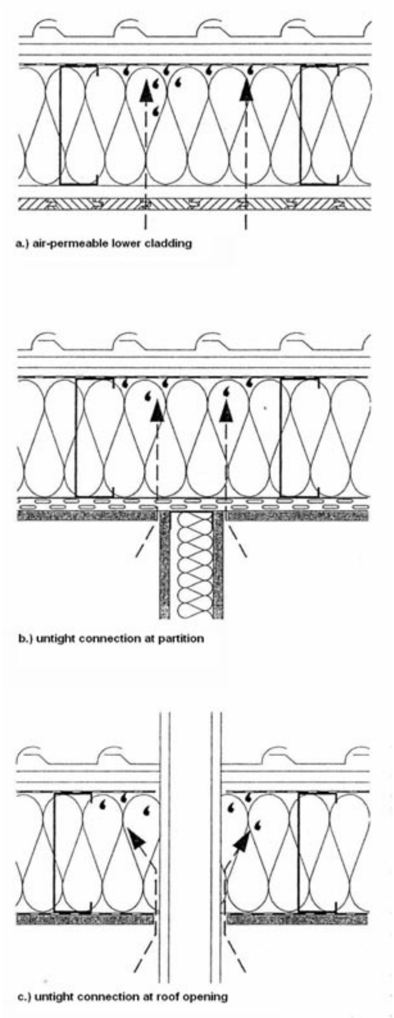

Figure 6: Air-tightness problems at assembled roofs

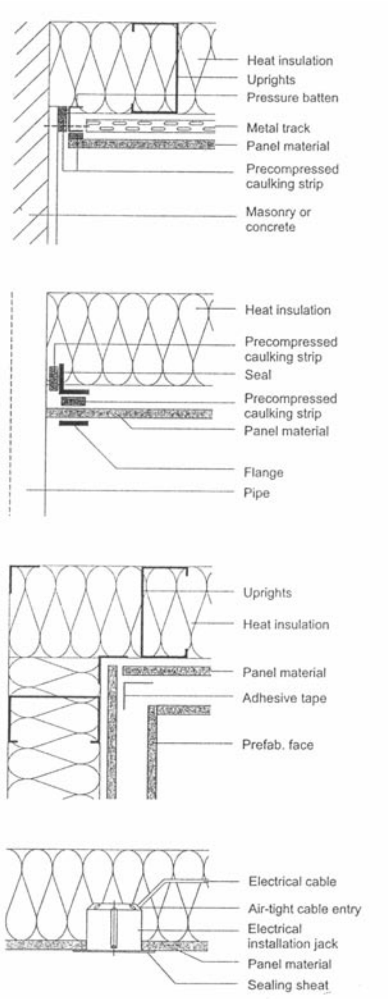

Figure 7: Development of air-tight junctions

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 (Figure 7).

B – General design aspects of light-weight constructions

It is also the basic condition for installing controlled ventilation guaranteeing for hygienic reasons, air renewal in well insulated buildings.

1.2 Damages caused by moisture

If the interior coating is not sufficiently tight, hot air and vapour can penetrate the building's exterior members through convection (Figure 6). 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 avoided, because its effects and damages remain visible for a long time.
The intensity of humiditification by convection is significantly higher than tby diffusion because the steam quantities carried through the air are significantly higher.
A connection to an adjacent construction member can only be durable if it is made with a flexible material (membrane). This can be achieved if it is covered with a coating, a double facing for example.
Installing gypsum plasterboards onstead of wood or artificial wood plasterboards is a better 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. Namely, air-tightness is much more important in the case of lightweight structure buildings, than in the case of the traditional buildings.
If thin foils (vapour-proof or vapour-breaker) are used providing air-tightness, some factors must be taken into account:

- To avoid cross connections, the width of the membrane must exceedthe height of the corresponding member. On the roofing, the membrane must be continuous.
- At least 100 mm overlapping has to be guaranteed at the horizontal connections (Figure 8).

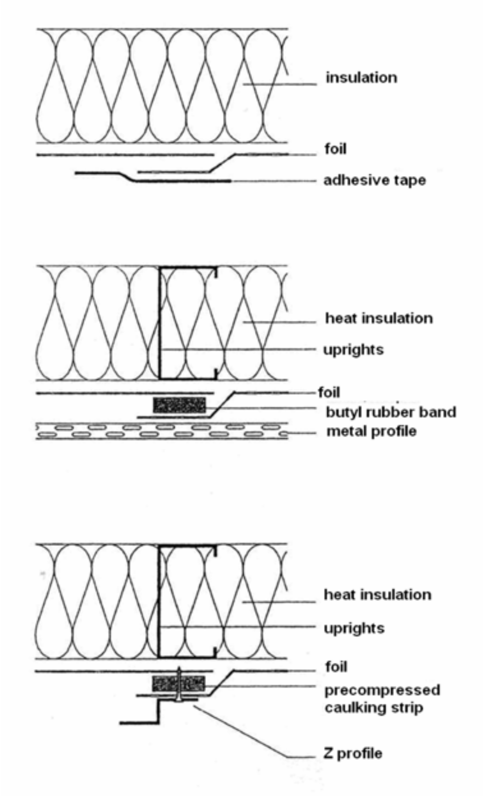

Figure 8: Overlapping of air-tight foils

For connection, a special bond or two or single sided adhesive strips, recommended by the manufacturer, have to be used to the membrane fabric. Overlapping width must be guaranteed in each case. 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.

B – General design aspects of light-weight constructions

At adjacent members, a sufficient covering must be glued or compressed by the sections on the entire lengths (Figure 9).

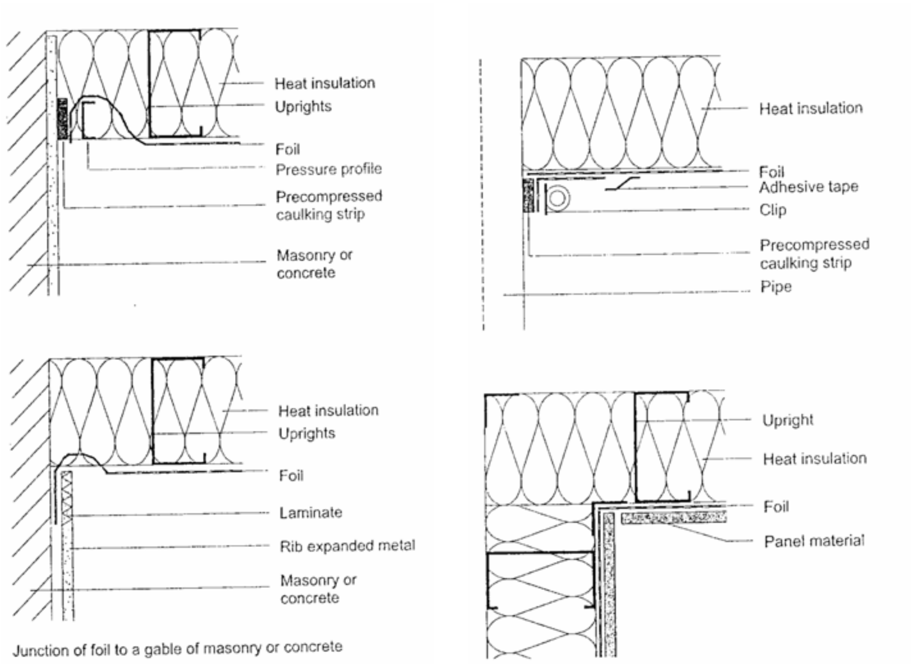

Figure 9: Connections of airtight foils to neighbouring structures

In addition to the attention paid to these intersections, special care must be taken in the installing power outlets and switches, pipe fittings, heating devices and door frames. In sandwich board constructions, the electrical or sanitary equipment, independently of the job quality, penetrates the sealed surface and establishes a link with the internal cavity. It must be therefore be surrounded by a hermetic seal (Figure 10).

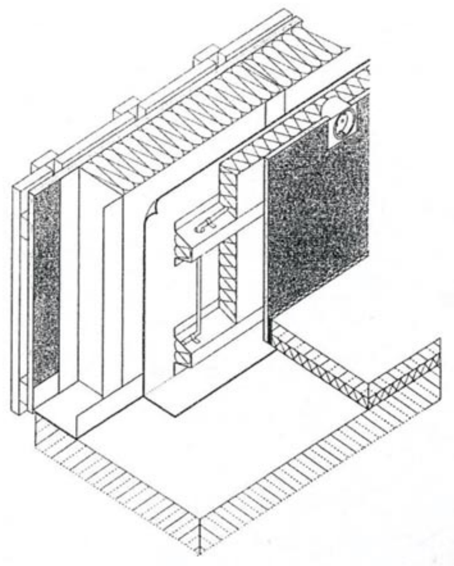

Figure 10: Structural detail of an inside installation plane with undisturbed airtight planel

B – General design aspects of light-weight constructions

The measures below result tightness in dry in lightweight steel structures:

- adapting the construction to the principle of air and wind tightnesses, by avoiding for example air penetration into the external skin, by separating certain parts (balconies, for example);
- installing an impermeable coating, by gluing the plates or widths of a membrane and overlapping them by at least 100 mm;
- installing broad membrane widths to minimise the number of connections;
- meticulous execution of holes (for instance at pipes);
- use of members especially designed for sandwich board constructions (such as roof windows wih connections for the waterproof membrane or for the electrical installations);
- use of an inside installation plane; a simple, trustworthy way of preventing damage to the waterproof membrane.

If the volume to be sealed contains too many holes from penetration by corbeleld joists (such as balconies and arcades), projecting tie beams or rafters, then it becomes difficult to carry out durable, state-of-art waterproofing job.
That is why this type of traditional construction is not ideal with lightweight steel structure: in such cases it is better to replace this process by a more advantageous variant from a thermal viewpoint!
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 and must be faultlessly installed.

1.2.1 The ventillation of buildings

In lightweight steel-framed buildings contrary to traditional buildings, particular attention must be paid to air circulation through the exterior members. Each layer's vapour barrier must be installed from the interior towards the exterior inorder to prevent condensation.

1.2.2 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% (75% according to Hungarain Standard MSZ 04-140-2:1991). 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.

1.2.3 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.
If these certificates contain condensation risk, the construction must be modified as follows:

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

Generally, in the exterior panels 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.

1.3 Thermal insulation in summer

When designing a building, one must take the summer heat into account, in order to avoid an unpleasant temperature due to strong solar radiation and outside temperature.
A building obtains heat through solar energy. This is true for solid constructions as well as for lightweight constructions. Sunrays go through transparent members such as windows and are transformed into heat energy. They are therefore the primary source of air temperature rise in the 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 temperatures rises in a building are caused by the following reasons:

- the high permeability index of the glass;
- size and orientation of the window;
- absence of the interior and exterior protection of the bay against the sun;
- impossibility of airing the room, especially night-time ventilation;

B – General design aspects of light-weight constructions

- low thermal inertia of members;
- unfavourable heat loss index of the materials of the outside members;
- inhibiting behaviour of the external members.

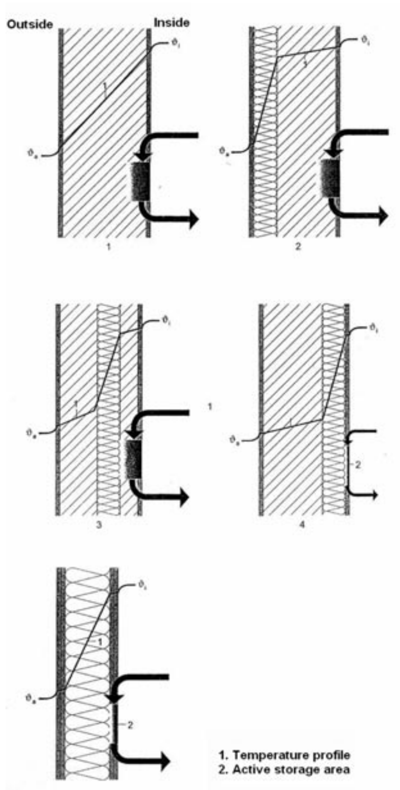

Figure 11: Different heat storing ability of the building materials

In properly insulated houses, the difference between night and day is minimal. Therefore, storage possibilities are limited and often overestimated when we include the houses' fittings (furniture, stairs and wall coverings etc.) into the calculations.
Thermal inertia, less in light-weight steel structure construction than in 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 massiv 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.
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.
Annex G in Standard EN 832 proposes data for solar contributions, through a method for calculating the quantity of energy to provide.

The afore-mentioned Hungarain Ministry decree 7/2006(IV.24.)TNM counts the summer radiation heat loads with the following equations:

$Q_{sd,summer}=\Sigma A_{glass}*I*G_{summer}$
$A_{glass} = 0,75\ A_w$
"I" is the solar intensity due to the orientation
$G_{summer} = g*N$ (where N is the solar coefficient)

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Construction recommendations

During designing the following factors have to be monitored (by order of priority):

- reduce the intensity of solar radiation through glass surfaces (design, orientation, room geometry, installation of screens, properties of the glass), see Figure 12;
- suitable thermal insulation,
- optimise the size of the 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 nocturnalventilation);
- optimise the permeability index and thermal inertia linked to the temperature of radiation through each member.

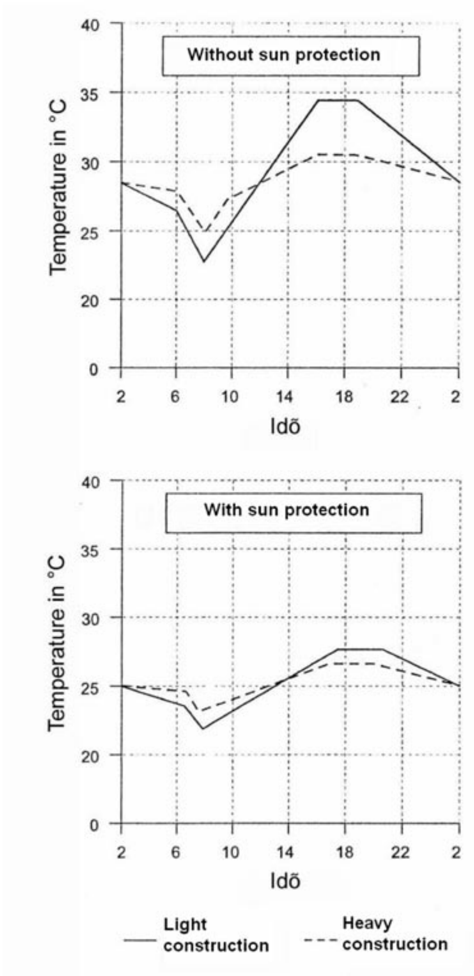

Figure 12: Influence of shading of window areas on the heating up behavior of buildings

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 in enhanced by a device which allows cross aeration. An efficient naturalnight-time ventilation is highly important. by complying with these rules, lightweight steel-framed constructions also offer excellent conditions.

On average, light-weight structures' temperature will be 0.5-1.0 K above that of solid construction buildings, but the installation of screens reduces the temperature effectively.

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2. Acoustic Behaviour

2.1 Basic characteristics in acoustics

Regarding to acoustic performance of building structures, especially in design and erection phase, the following basic notions are important to take into account:

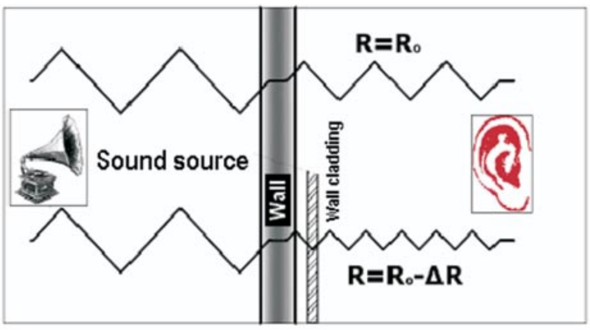
- **Sound absorption coefficient (α)** gives the absorption rate of sound waves that impact the surface of the building construction (wall cladding, floor covering or ceiling) when the sound source is in the same room.
- **Retardant number of air-borne sound (R)** describes the retardation (withstanding) capability of a building structure (e.g. wall, floor, ceiling with or without openings, windows), that is placed between two rooms, against air-borne sound.
- **Pressure level of step-borne sound (L_n)** characterized the retardation (withstanding) capability of a floor structure (alone or together with floor covering and lower ceiling), that is placed between two rooms above each other, against step-borne sound provided by an impact sound source from the room above.

In case of different type of building constructions, the relevant acoustic parameters are summarized in the following table.

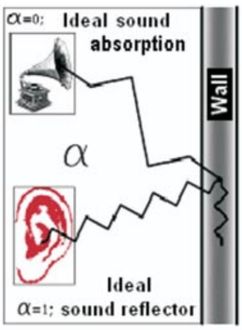
	ACOUSTIC PARAMETERS				
BUILDING CONSTRUCTION	R	ΔR	L_n	ΔL_n	α
Walls (load-bearing walls, partition walls, façade walls, interior walls, masonry or light-weight multi-layer walls)					
Wall claddings					
Floor structures (inside the building)					
Suspended ceiling					
Floor coverings (soft, hard, flexible, floating)					
Windows, doors (internal, external, of balcony, entrance)					

Where (see also the Figures below):

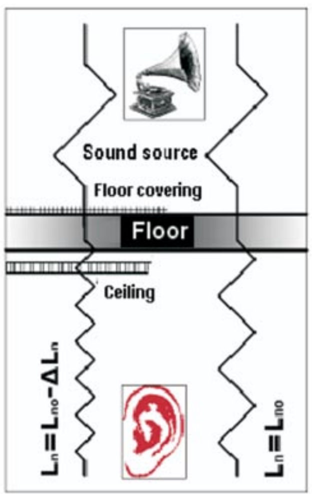
R is the retardant number of air-borne sound
ΔR is the change in the retardant number of air-borne sound (improvement or degradation)
L_n is the pressure level of step-borne sound
ΔL_n is the change in pressure level of step-borne sound (reduction)
α is the sound absorption coefficient



Air-borne sound retardation (R)



Sound absorption coefficient (α)



Pressure level of step-borne sound (L_n)

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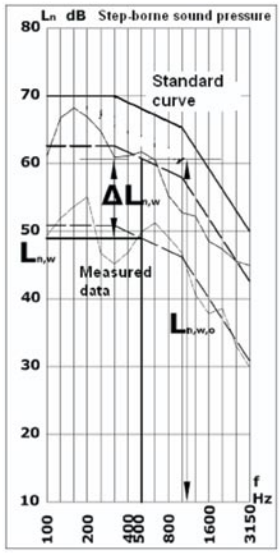
The weighted values of pressure level of step-borne sound and retardant number of air-borne sound

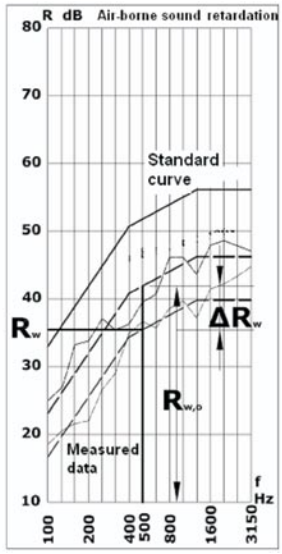
In the practice, the rate of the pressure level of step-borne sound, and that of the retardation of air-borne sound, is expressed by only one physical number. For both parameters, a standard curve is vertically moved so as to fit to the measured or calculated acoustic curves (in the function of frequency of the sound source) as close as possible. In the position, when the standard curve is fitted the best way, the ordinate belonging to frequency of 500 Hz will be the **weighted acoustic values** of the given parameter. The lower index "w" in the notation of an acoustic parameter shows that it is weighted values, instead of other frequency period.

In this way, the $\Delta L_{n,w}$ and ΔR_w notations give the weighted acoustic values of step-borne sound reduction and that of change in air-borne sound retardation, respectively, for the building construction, such as wall, floor coverings or ceiling.

In the design practice, there are limit numbers for the weighted acoustic values given in local Standards or Regulations that must be fulfilled by the real value (measured or calculated) of the structure. In general, the requirements are regarded to multi-storey flat houses, block-of-flats, hotels, office buildings and educational buildings (schools). It is important to mention that there is very difficult to find appropriate calculation methods to determine the acoustic values for multi-layer light-weight construction. Therefore laboratory tests are necessary to be prepared in the most of the cases when high acoustic requirement is given.



Weighted step-borne sound reduction



Weighted air-born sound retardation

Some example for Hungarian acoustic requirements in case of building construction separating two rooms:	In one room near the other room	In one room above the other room	
	R'$_w$, dB	**R'$_w$, dB**	**L'$_{nw}$, dB**
Between two rooms of with same noise level in educational building	**47**	**55**	**55**
Between two rooms of with different noise level in educational building	**55**	**55**	**46**
Between two flats in hospitals and youth hostels	**42**	**52**	**55**
Between two apartments in maximum 2-star hotel	**45**	**52**	**55**
Between two apartments in minimum 3-star hotel	**48**	**52**	**55**
Between private flats in block-of-flats	**52**	**52**	**55**

Maximum allowed noise level in different rooms according to Hungarian regulation	L_{AM} dB
Rooms, compartments in hospitals, sanatoriums, medical buildings; private rooms – at night	**30**
Rooms, compartments in hospitals, sanatoriums, medical buildings – in daytime	**35**
Class-rooms, auditoriums in educational buildings, schools; meeting rooms, private rooms in daytime	**40**
Office rooms of high standard (intensive mental work)	**50**
Restaurants, bars, espresso, office rooms with high sound source of machines	**55**
Shops, service buildings, drawing rooms, office rooms of medium standard	**60**
Office rooms of low standard, laboratories, noise protective chamber	**65**
Physical work place of high standard, service rooms with high client traffic, laboratories with machines	**70**
Computer room, kitchen room	**75**
In any working place to avoid ear injury	**85**

In case of lack of special acoustic requirement, for design purposes, the necessary limit values of the sound absorption coefficient and the weighted air- or step-borne sound retardation parameters should be determined by taking into account the allowable noise level of the room with a certain function, the sound level of the adjacent rooms and the external environment.

2.2 Multi-layered walls
For insulation from airborne and impact sound and footsteps, the acoustic principles of dry, light constructions prevail. Soundproofing is not due to the mass of material (since these walls have only a small mass), but the basics of the acoustic performance is the result of a mass-spring-mass construction.
If we consider weight, thickness and price, the soundproofing of steel frame panels (covered, for example, with plasterboards or fibre-plaster) provides very good results. 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.
All these members form a complex system that constitutes a “mass-spring-mass” member from an acoustic viewpoint. The following factors effect the soundproofing the most:

- the stiffness of the junction between the two gypsum boards, the way the metal supports are mounted and arranged, as well as the way the plates are fixed on the supports, among other things, affect this factor;
- the spacing between the plates;
- the elasticity of the plates. 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 wavelenghts, for example) and filling level of the insulating material.

2.3 Attenuation of airborne noise in a building with a light-weight steel structure
The following criteria have positive effect on the soundproofing of a multi-layer sandwich panel structure.

2.3.1 Preparation of flexible cladding made of material with high mass-to-surface ratio
To obtain good soundproofing, the cladding board must be flexible from acoustic point of view. This type of board is about 20 mm thick that may be in plaster, fibre or even in wood. The mass per unit surface of the cladding board also has a positive influence on the soundproofing of a panel. The higher the mass, the better the soundproofing of the panel, but because of the previous, the two-layered 12.5 mm gypsum board coating is more effective as the 1x25 mm.

2.3.2 Separating the fastenings of the two boards
The link between two boards, for example by the studs, creates an acoustic bridge.
To obtain better soundproofing, the two sides must be as separated as possible (for example by adding flexible materials between the board and the studs, see Figure 13) or ideally, completely independent (each side is fastened on separate studs), so double-wall has to be made.

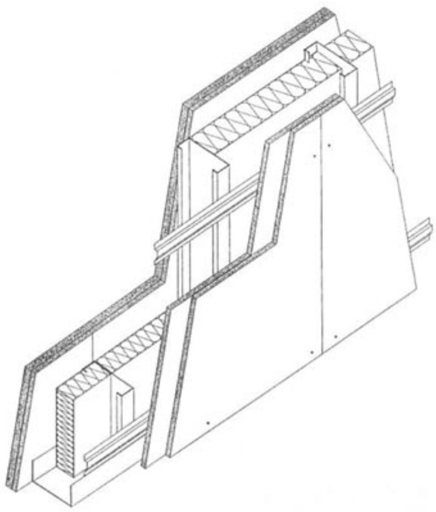


Figure 13: Wall structure made of steel studs with flexible secondary channel

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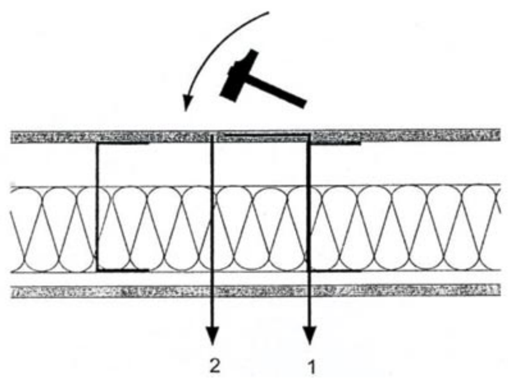
Constructor techniques:
- larger spacings (according to the statics requirements);
- larger spaces between the boards (wider wall structures);
- fastenings of boards on insulating strips, resilient sections or springs;
- sections that limit acoustical bridges (for example, pinched or grooved sections, MW sections),
- separation of the two sides of the panel (double supports).

2.3.3 Insulation of the internal cavity
To improve acoustic performance, the spaces 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.
Constructor techniques:
- Filling up to 80% of the space between the plates with a fibrous matter (to avoid creating acoustical bridge through this material).

2.4 Light-weight steel floor structures
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 (see Figure 14). 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.

Figure 14: Impact sound transmission in light-weight steel floors



(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.
Constructor techniques:
- Elasticity and high mass of the slab in relation to the surface.;
- Flexibility of the thick sound-insulating material (up to 50 mm thick);
- Aoiding acoustical bridges near the walls and the load carrying structures;
- Careful execution of junctions with walls;
- Hhigh mass of coating, (for example slabs);
- Elastic floor covering (for example carpet).

Nowadays using lightweight floors is a general method, where the seatings under coatings working as rigid plates are taken into account when calculating soundproofing. The effect of a floating floor is less for low frequencies than for high frequences.
The underside of the floor is covered with a ceiling plate, which can be fastened directly under the joints. We improve the acoustic performance of this covering by paying attention to the following **constructor techniques:**
- designing elastic and relatively high mass covering;
- flexible assembly, in terms of sound, of this covering under the joists using insulating strips, resilient sections, two cap sections or flexible fastenings.

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To comply with minimum soundproofing standards for light floors in residental buildings built using dry constructions, the following **constructor techniques** sould be used:

- >20 mm thick dry slab;
- good quality insulating material > 20 mm;
- load carrying framework > 19 mm thickness; filling of internal cavity < 80% ;
- resilient sections, spring links, independent fastenings;
- two layers of floor covering $\approx$2x15 mm.

It is generally not possible to comply with standards without 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 thickness between 10 and 12.5 mm or gypsum board with thickness between 12.5 and 15 mm). 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, rising the dead weight.
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.
Comparing to the traditional “floating floor”, 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.

2.5 Propagation of sound in a roundabout way
Roundabout propagation via adjacent members is one of the possible routes. 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 in the partitioning wall.
In light-weight steel-framed construction, the partitioning members and the adjacent parts are not connected directly to each other. They can, therefore, oscillate independently without mutual interaction. But this does not mean that the lateral transmission of sound is weaker. 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 constuction, whether they are walls, ceilings or floors. First, the coating surface and second, the internal cavity.
Solutions for minimising sound wave propagation in the internal cavity include filling it with fibrous material 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; sound is propagated less through two layers of coating than through a single one. The most efficient solution is to ensure the absence of a continuous plating between two adjacent rooms. This divisioning perpendicular to the propagation of sound brakes the propagation of longitudinal soundwaves.

2.6 Appropriate modes of connections between members
The appropriate solution of connections between flexible double partitions and adjacent parts (ceilings, floors and walls) is very important. In light-weight constructions, the connection of two structural members generally leaves some gap between (Figure 15), this should be improved by hermetic acoustic seals that have to be put in these gaps (Figure 16).

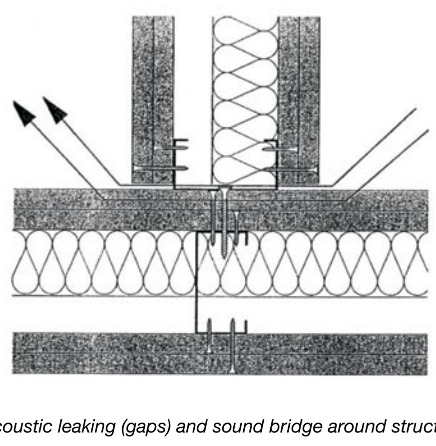

Figure 15: Acoustic leaking (gaps) and sound bridge around structural connections

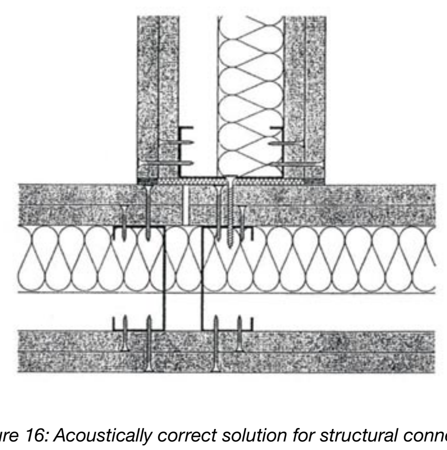

Figure 16: Acoustically correct solution for structural connections by separation of the sound conductive elements

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Defective or damaged sealing would result in sound bridges enabling airborne noises to move from room to room.
Constructor techniques:

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

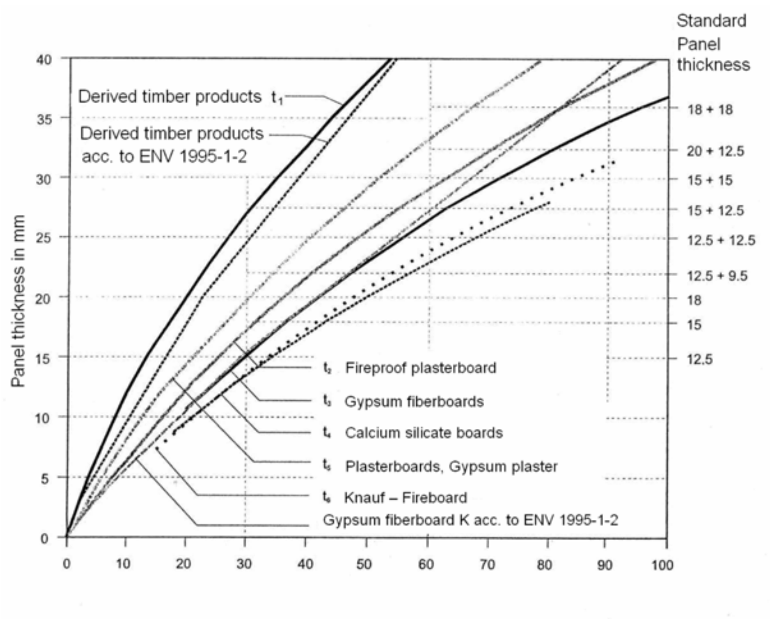
3. Fire Protection

The load-bearing capacity of steel (strength and ductility) falls linearly when the temperature rises above 500 °C. Steel members are incombustible, but altough, 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.

3.1 Fire performances of different materials used in light-weight steel-framed constructions
The thin sections must be covered with a sheating to prevent them from being ravaged by the fire. The following materials can be used successfully for fire protection:;

- 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 Figure 17 the heating time of various materials by different manufacturers is shown.



Fiugre 17: Characteristic burn-through times of different panel materials

The results can serve as useful indication and information on the fire resistance of the steel member coverings. Tests have proved that plaster-fibre boards presented the same level of fire preformance as GKF gypsum boards (reinforced fire insulation plasterboard).
When placing an insulant in the internal cavities of the panel, it is important to know if it is load-bearingor not.
In a non-loadbearing member, the insulant can impove the fire resistance of the construction. We resort to mineral fibrous insulating material which have a elting 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.

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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 insultant 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, than without insultant (Figure 18)!

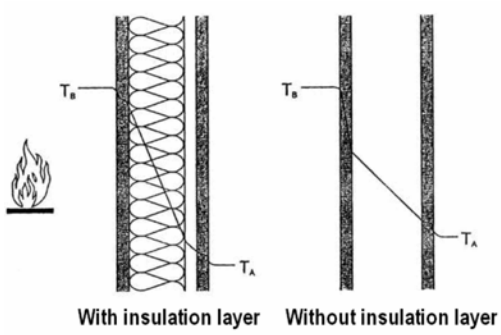

Figure 18: Changing the temperature in case of fire on one side

If, from the fire protection viewpoint, insulation is not necessary or can even be harmful, it can neverthelessturn out to be essential from the thermal and sound viewpoint. One must therefore weigh the advantages and disadvantages for each individual case. If an insultant is installed for acoustic or thermal reasons, it must be therefore belong ro class B2 and be ypproved, because its presence can have negative effects on the fire performances of a member.
In lightweight steel-framed construtcions, the installation of a vapour barrier or wind and air tight membranes are not detrimental to fire protection.

3.2 Defining the values of fire resistance
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.

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

Each component of a lightweight steel structure construction and its location determines the category of the whole structure.

3.3 Performance of walls against fire

3.3.1 Load-bearing walls and partitions
In terms of fire protection, it doesn't matter if a wall is load-bearing or not. What determines the value 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 partition wall must prevent the propagation of fire to the next room during a certain time (length of fire resistance).
A load-bearing wall must additionally, maintain its load-bearing capacity. This means that all load-bearing members must be protected by means of appropriate insulation from the effects of the fire. This concerns steel studs and floor beams, as well as bracing members such as rods, steel cables or plates.

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3.3.2 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 minutes), 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 (Figure 19).

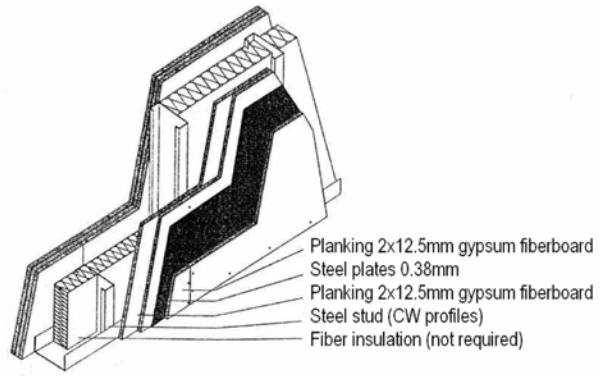

Figure 19: Firewall in lightweight steel construction

Firewalls can be divided into three categories: load resistant, load-bearing and non-load-bearing. In the case of fire, load resistant walls must not receive more than the allowable maximum load (kN/m). The dimensions of load-bearing firewalls are calculated according to the loads applied to them. Static and commissioning check is needed.
When installing fire partitions (non-load-bearing), the appropriate measures must be taken to prevent that in case of fire theydo not receive any unexcepted load, due to a sagging floor for example. If a floor is expected to deflect more than 10 mm, then a slipping joint must be installed at the partition/ceiling connection (Figure 20).

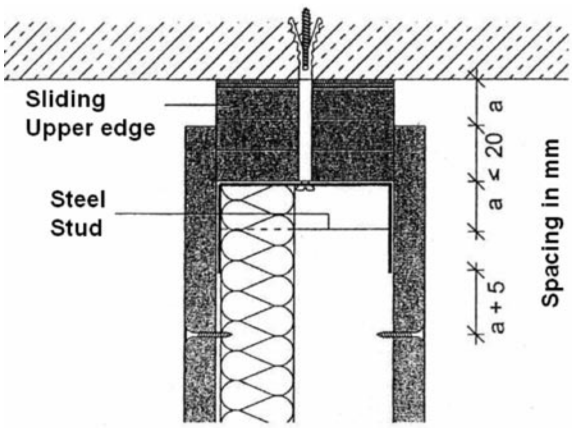

Figure 20: Sliding ceiling connection of a nonstructural wall with fire protection requirements

In addition, care must be taken to ensure that all the structural members that brace the 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 joists.
During designing, attention has to be paid to the followings:

- 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.

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3.3.3 Electrical installations in walls and floors

Enclosures for hollow walls can be installed anywhere in a wall regardless of whether it is load-bearing or not. However, one must simply comply with some installation restrictions, shown in Figure 21. Besides these, equipment can be routed freely anywhere.
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 to each other in the dividing walls, but they must be located in the different compartments.
- Electrical enclosures facing each other in a double upright wall, where spacing of plates is less than 600 mm, must be separated by a fireproof plasterboard 600 mm x 600 mm reinforced insulation board as thick as the covering.
- The fire insulation material around an electrical enclosure in a double partition must be at least 30 mm thick.
- In walls not fitted with fire insulant (without any insulant or with a no fireproof insulant) enclosures must be surrounded by at least 20 mm thick plaster.

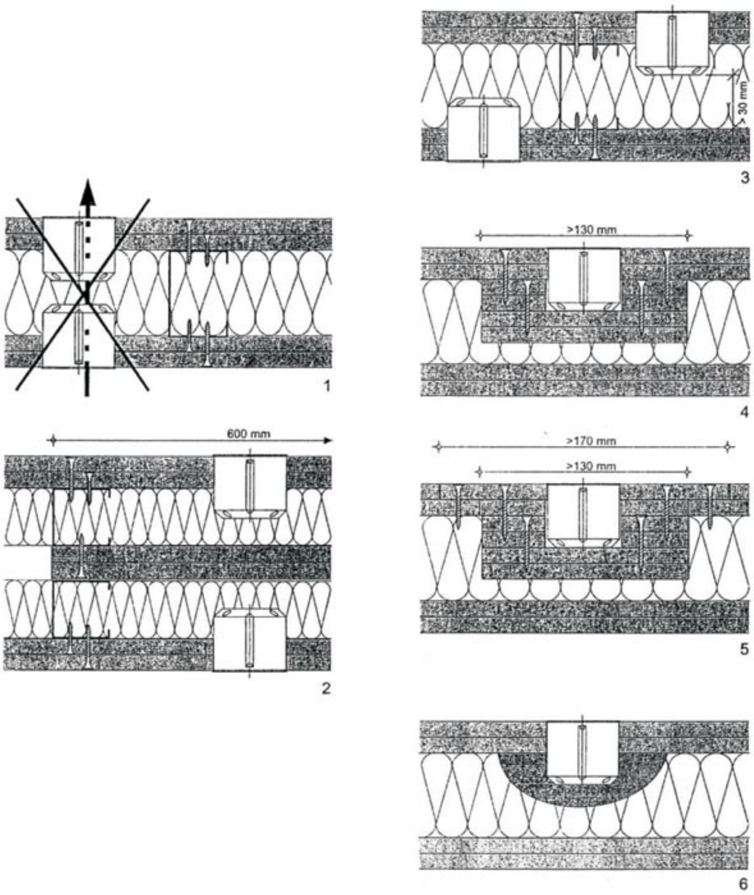

Figure 21: Installation rules for electrical installation outlets in a wall with fire protection requirements

3.4 Fire protecion of steel floor beams

The classification of fire performances of lightweight steel structure floors follow the same principle as the walls. However, a floor must be considered as 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 minutes, is based on the 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. This is true for the ceilings (directly under joists) and for false ceilings (or suspended ceilings).

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3.4.1 Fire protection 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 the 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.
Some ceilings can be directly fastened to the floor without any independent structure. Inthis case, the spacing between the joists must not be higher than 40 cm.

3.4.2 Fire protection from the topside
For lightweight steel structure 30 minutes fireproofing is needed. The floating slabs protect 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, plasterfibre or pressed wood can be accepted up to 60 minutes fire resistance category.
For category 90 minutes floors, we can also use plasterboard or fibre-plaster after inspection or appraisal by an expert.

3.4.3 Fire performance of multi-layer panels
Lightweight steel-framed constructions are made of “multi-layer” or mounted “composite panels”. Fire can therefore spread in the internal cavity and harmful gases flow into parts of thebuilding affected by the fire.
To prevent the propagation of fire and ensure smoke proof connections between the different members, some points have to be monitored.

3.4.4 Connection of members and equipment routing
Particular attention must be paid to the tightness of horizontal and vertical connections between the different members. They must be lined with incombustible mineral wood strips, mastic or expanded foam, and completed by a careful final covering (Figure 22 and 23).
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.
When any equipment bores a hole into a construction member, in addition to ensuring that fireproof properties of the member are intact, we must also ensure that the fire cannot spread through the power outlet, for example! Openings >50 mm (for pipes) must be covered unless it is an incombustible pipe corresponding to the same standards as well.

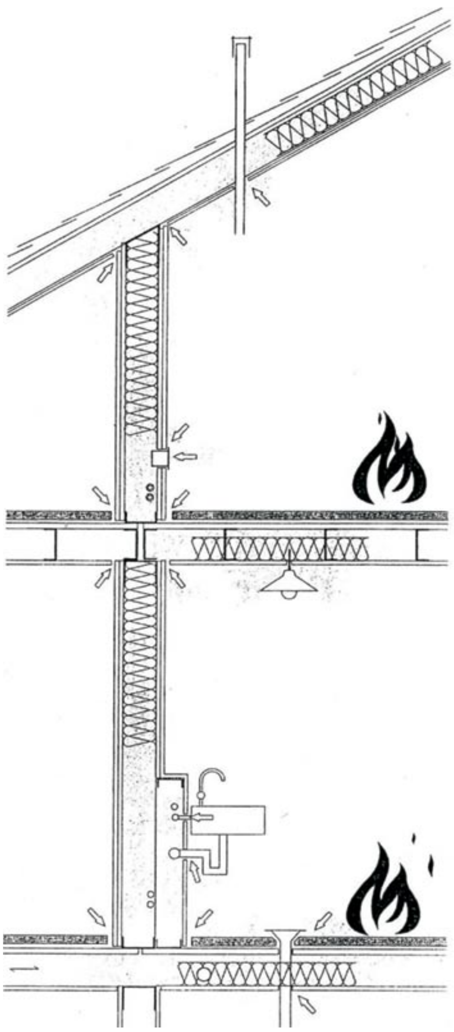

Figure 22: Details to be considered during planning to prevent smoke and the fire from spreading in multi-layer hollow structures

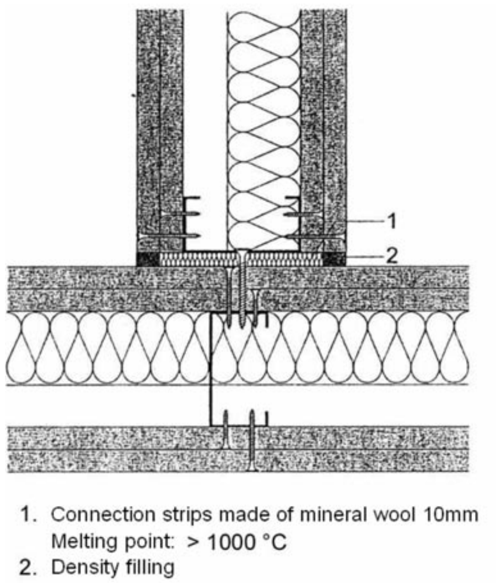

Figure 23: Effective way to prevent fire spreading at “T” wall connections

4. Corrosion Protection

The cold rolled profiles are manifactured from hot-dip galvanized steel strips, they are covered with a zinc layer of cca. 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. Furthermore, 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, but it is wellworth to think over using galvane-spray.

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, insolube 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 dry, cool place. If right after manufacture the sections interact wuth moisture, a white rust forms on the surface due to the insufficient oxygen and carbon dioxide. This white and flaky hydroxide is very volumonous. 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.
If high corrosion is predicted in buildings exposed to marine environments for example, and sections are left without protective sheating, it is possible to treat them organically in addition to the galvanisation. Then we talk ok "duplex system". The paint coating prevents the slow erosion of the passivated coating. The zinc coating in tun prevents the steel corrosion, its transformation into rust.

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 forcold sections can be treated continuously, in other words receive right after galvanization anorganic bath (paint or polimer) or a protective film. We use sectionstreated 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 of 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.

References

[1] **European Lightweight Steel-framed Construction**. Published book by Light Steel Construction Association (LSK) and ARCELOR, 2005, Luxemburg (ISBN: 2-9523318-2-0)

[2] T. Höglund és H. Burstrand: **Slotted Steel Studs to Reduce Thermal Bridges in Insulated Walls**. Paper to "Journal of Thin-Walled Structures", Royal Institute of Technology, Department of Structural Engineering, 2000, Stockholm (Sweden)

C
THERMAL DESIGN OF PROFILES WITH SLOTTED WEB

(by Dr. TÓTH, Elek, Budapest University of Technology and Economics)

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C –Thermal design of profiles with slotted web

C
THERMAL DESIGN OF PROFILES WITH SLOTTED WEB

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1. Background: Swedish Experiences

The inner frame of an insulated wall made with dry technology contains usually thin steel girders. The calculation of heat transfer is quite difficult due to the big difference in the heat conduction capacity of the insulation and the steel structure. The process of these kind of special problems can be solved by three-dimensional numerical analyses. In the following some results will be presented according to Swedish literature [1] based on high experience of Scandinavian lightweight building technology.

1.1 Computer programs for building physics

Nowadays, for thermal calculations there are several numerical computer programs available for the designers. These software are generally solve the differential equations of the heat transfer numerically, by finite element method. One of these programs is the **HEAT2 software**, that is applicable to handle two-dimensional heat transferring problems, therefore to determine the U_r resultant heat transmission coefficient. (It is important to mention that the U_r resultant heat transmission coefficient of a given layer, as defined in the relevant Hungarian Ministry regulation 7/2006(IV.24.)TNM, is different from the so-called "k" heat transmission coefficient defined in the previous Hungarian Code MSZ 04-140-2:1991 for thermal design, because the U_r resultant heat transmission coefficient includes the effect of the cold bridges, as well.). Using HEAT2 software it is possible to take into account the effect of floor temperature and the heat loss through the ground, to analyze the effect and behaviour of thermal bridges and also the optimalization of insulation. The heat equation is solved by using the method of finite differences, with the help of over-relaxation method that is applied for the steady state calculations .

A more developed version of the software is the HEAT3 program, that is applicable already for three-dimensional calculations of steady-state or transient heat flows. For solving the heat equation this program also uses the finite differences method. The program can be used for instance for analyses of three-dimensional thermal bridges, heat transfer through corners of a window, heat losses from the house to the ground. The program makes it possible to incorporate further modifications, such as radiation in cavities and heat sources.

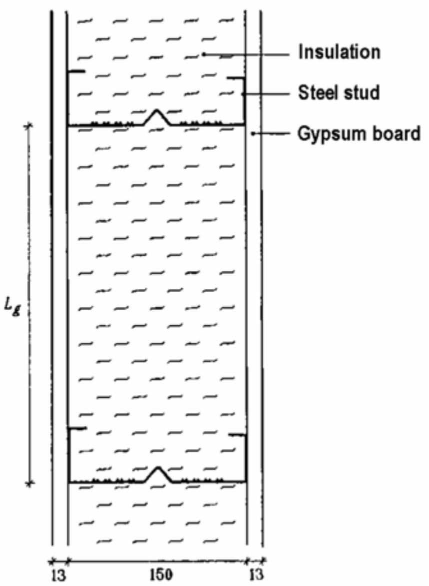

Figure 1: Principle sketch of wall with C-profiled steel studs

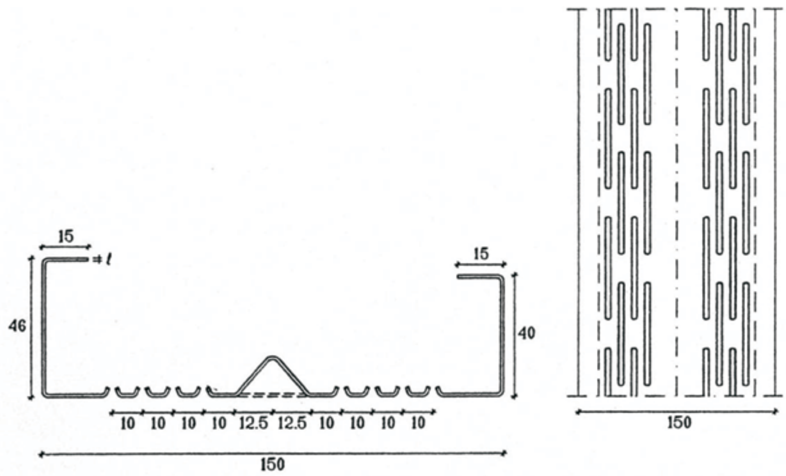

Figure 2: C-profile with slotted web (cross-section and side view)

Figure 1 shows a sketch of wall containing insulation between two 13 mm thick gypsum boards. Lg shows the distance between two metal C-studs. In this case there is an extra heat loss caused by the wall studs. This heat loss can be reduced by slotting the web of the C-girders perpendicular to the heat flow direction, as shown in Figure 2. The thickness of the girder is denoted by t. The calculations were made by HEAT3.

C – Thermal design of profiles with slotted web

1.2 Data for numerical calculations
The problem is not perfectly symmetric due to the different flange lenghts (40 and 46 mm, see Figure 2). However, this is neglected in the calculations, so the left flange length (46 mm) is used for both sides. The Swedish Standards for calculation of the U-value prescribes that the sum of the inner and outer surface resistances ($1/\alpha=1/h$) have to be 0.17 m^2K/W. The inner and outer surface resistances are put to half of this value (0.085 m^2K/W) in the calculations that follow. The elevated part in the middle of the web is neglected, the web being modelled as being straight, as shown in Figure 2. by the dashed lines. This will give a slightly overestimated (by less than 1%) value for heat flow through the wall.
The slotting process causes small elevated rims, as shown in Figure 2. These rims are also neglected in the calculations, and the effect of this is discussed later.
The calculations have been made for the shaded volume shown in Figure 3. The height perpendicular to the plane of Figure 1 is denoted by s. The temperature of the air is 0°C on one side of the wall and 0.5°C in the mid-section (because of the supposed 1°C temperature difference between the two sides of the wall). The thermal conductivity is λ=0.036 W/mK for the insulation between the gypsum boards and λ=0.22 W/mK for the gypsum boards.

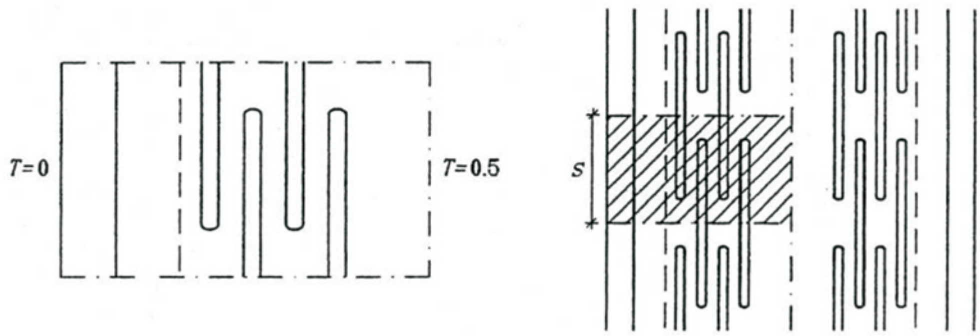

Figure 3: The part of the stud used in the simulations

The number of cells, required to obtain satisfactory numerical accuracy, depends on various parameters. The following criterion has been recommended as a European standard (CEN,1992). The sum of the absolute values for all the heat flows entering the object is calculated twice, once for n cells and once for 2n cells. The relative difference between the flows needs to be smaller than 2%. If not, further division of the mesh is required.
Having about 30,000 cells placed in an expansive mesh satisfied this criterion for the case considered, because the relative difference became ten times smaller, 0.2%.
Figure 4 shows the projection of the numerical mesh on the x-y and x-z plains in the case involving 30,000 cells. The position of the steel girder is shown by thicker lines. The over-relaxation coefficient was put to ω =1.95.

C – Thermal design of profiles with slotted web

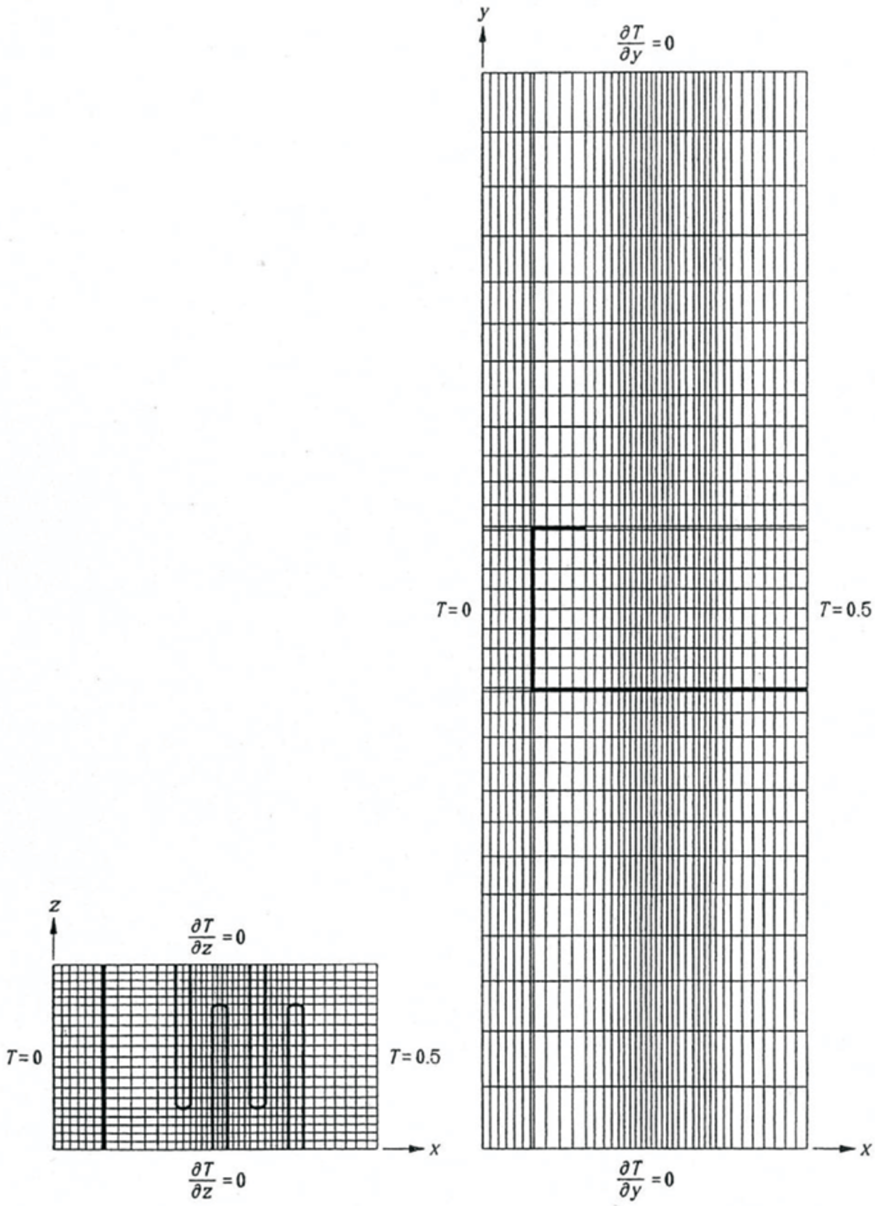

Figure 4: Projection of numerical mesh on the x,y-plane and the x,z-plane in the case involving 30,000 computational cells

1.3 Sample calculation

An initial numerical simulation is presented for a reference case involving the following data:

- the thermal conductivity of the steel is λ_s = 60 W/mK.
- the distance between the girders is L_g = 0.6 m and
- the thickness of the steel is t= 0.7 mm (see Figure 1 and 2).

The results:

- The calculated heat flow through the wall becomes $\mathbf{Q_{calc}}$ **= 0.00786 W/K**
- The extra heat loss Q_{extra} due to the steel is as follows:
  $\mathbf{Q_{extra}}$ = Q_{calc}–U_{1d}*L_g*s = 0.00786–0.225*0.6*0.05 = **0.00111 W/K** ;
  where U_{1d} is the U-value of the wall without studs.
- The total thermal resistance is **R =** 0.17+2*0.013/0.22+0.150/0.036 = **4.44 m²K/W**,
  and U_{1d} becomes $\mathbf{U_{1d}}$ =1/4.44= **0.225 W/m²K**.

C – Thermal design of profiles with slotted web

1.4 Varying the distance between the girders

The U-value of the wall varies with the distance between the girders L_g. As L_g increases, the U-value will approach the U-value of the wall without studs U_{1d}. It is reasonable to assume that the extra heat loss for each girder is the same as in the reference case, Q_{extra}. This allows the following approximation of the U-value as a function of L_g:

$$U = \frac{Q_{extra}}{L_g * s} + U_{1d} = \frac{0.00111}{L_g * 0.05} + 0.225 = 0.0222 / L_g + 0.225 \quad [W/m^2K] \qquad (01)$$

Equation (01) is valid for center distances large enough that the heat flows due to any two girders that are adjacent to each other have negligible influence on each other. Numerical tests show that a center distance of 0.1 m gives an error of 2% as compared with Eq. (01). The error increases with decreasing distance. However, the center distances are in reality much larger than 0.1 m.

1.5 Varying the thermal conductivity of the steel

The thermal conductivity of the steel is much greater than the thermal conductivity of the insulation. Therefore, the heat flow between the steel and the insulation should be relatively small compared to the flow along the steel. Separating the problem into two cases and adding the two flows turns out to provide a rather good approximation.
In the first case, the steel is not taken into account. The one-dimensional flow with a temperature difference of 1 unit is

$U_{1d}*L_g*s = 0.225*0.6*0.05 = 0.00675$ W/K.

In the second case, the effect of the insulation is neglected, and only the flow between the steel and the gypsum is being calculated. The boundary conditions between the steel and the insulation, and between the gypsum and the insulation is adiabatic. Numerical simulation gives for $\lambda_s=60$ a heat flow of 0.00105 W/K. The flow is essentially proportional to the thermal conductivity of the steel. Thus, heat flow as a function of λ_s becomes $0.00105*(\lambda_s/60) = 17.5*10\text{-}6*\lambda_s$.
Adding the two contributions gives the following approximate formula:

$$Q_{calc} = 0.00675 + 17.5 * 10^{-6} * \lambda_s \quad [W/K] \qquad (02)$$

This equation is shown in Figure 5 as Fitted curve number 1.
The black triangles show Q_{calc} from direct numerical calculations for different λ_s. Based on the results of the numerical calculations, for the straight line between values $\lambda_s=10$ and $\lambda_s=60$ gives:

$$Q_{calc} = 0.00696 + 15 * 10^{-6} * \lambda_s \quad [W/K] \qquad (03)$$

This equation is shown in Figure 5 as Fitted curve number 2.

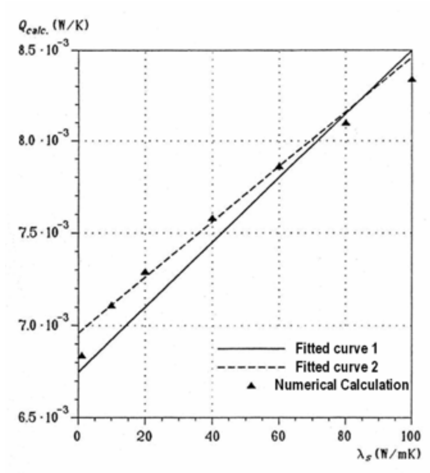

Figure 5: Heat flows as a function of λ_s based on the calculations in 3D

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Based on the previous, an approximate expression for the U-value as a function of λ_s and L_g can be provided. On the basis on Eq. 01 and 02 the fitted curve number 2 according to Eq. 01 gives with s=0.05m:

$$U = \frac{Q_{extra}}{L_g * s} + U_{1d}$$

$$U = \frac{0.00696 + 15 * 10^{-6} * \lambda_s - 0.225 * L_g * s}{L_g * s} + 0.225 =$$

$$= \frac{0.0042 + 0.0003 * \lambda_s}{L_g} + 0.225 \ \ [W/m^2K] \qquad (04)$$

Figure 6 shows U-values based on Eq. (04). The U-values obtained through direct numerical calculations given in brackets. The error is less than 2%.

λ_s	L_g=0.3 m	L_g=0.6 m	L_g=1.0 m	L_g=0.1 m
60	0.299 (0.300)	0.262 (0.262)	0.247 (0.246)	0.447 (0.456)
40	0.279 (0.282)	0.252 (0.253)	0.241 (0.241)	
20	0.259 (0.263)	0.242 (0.243)	0.235 (0.235)	
10	0.249 (0.252)	0.237 (0.237)	0.232 (0.232)	

Figure 6: U-values based on Eq. (04) and on numerical calculations (in brackets)

1.6 Varying the thickness of the steel

Since the heat flow in the steel is approximately proportional to λ_s, one can assume that it is also proportional to the thickness of the steel t. Equation (04) is then modified to

$$U = \frac{0.0042 + 0.0003 * \lambda_s * \frac{t}{0.0007}}{L_g} + 0.225 = \frac{0.0042 + 0.43 * \lambda_s * t}{L_g} + 0.225 \ \ [W/m^2K] \qquad (05)$$

where
$L_g > 0.1$ m, $\lambda_s \geq 10$ W/mK, $t \geq 0.0001$ m

Figure 7 shows U-values for various values for t, λ_s and L_g based on Eq. (05). The results obtained from the numerical calculations are in brackets. The maximum error is 2%.

It may be noted that it is possible to establish an equation that also takes into account the wall thickness H(m) and the thermal conductivity of the insulation λ_{insul}(W/mK).

Thus, the U-value could easily be calculated as a function of U = f (λ_s, L_g, t, λ_{insul}, H).

t	λ_s	L_g	U
1	60	0.6	0.275 (0.272)
1.5	60	0.6	0.296 (0.289)
1	10	1.0	0.233 (0.233)
1.5	10	0.3	0.260 (0.265)

Figure 7: U-values based on Eq. (05) and on numerical calculations (in brackets)

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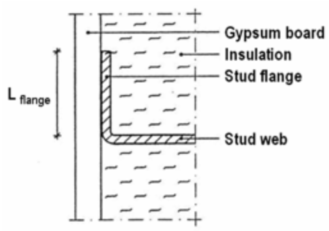
1.7 Studs without slots
Numerical calculations have also been made for a wall with girders without slots (λ_s=60, t=0.7mm and L_g=0.6m). The U-value becomes U=0.413 W/m²K, which is 83% larger than the U-value for the wall alone (0.413/0.225=1.83).
A wall with slotted studs, according to the table shown in Figure 6, has only 16% greater flow than a wall without any studs (0.262/0.225=1.16).

1.8 Effect of flange sizes
The flanges act as collectors of heat. If the flange size Lflange in Figure 8 is decreased, the U-value will also decrease. Figure 9 shows U-values for λ_s=60, t=0.7 and L_g=0.6m obtained from two-dimensional calculations for a wall with studs without slots.



L_{flange}	U (W/m²K)	lowered U-value
0.046	0.413	-
0.020	0.389	6%
0.005	0.347	19%

Figure 8: The heat flow along the web decreases as Lflange decreases

Figure 9: U-values for different flange lengths

1.9 Heat transfer within the slots
The cavities due to the slotted steel probably will be filled with air instead of insulation. In the numerical computations this space is assumed to be filled with insulation material. The following discussion concerns an estimate of the amount of heat transferred by radiation and convection inside these air gaps.
The size of a gap is D=2mm according to Figure 10. We see that the heat transferred by radiation and convection inside the gaps is about the same as that transferred by pure conduction in the insulation. Thus, the heat flow between the gaps is negligible compared to the flow along the steel.

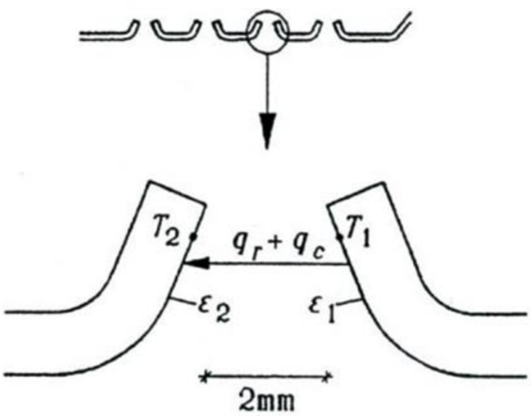


Figure 10: Heat transferred by radiation and convection in air gaps of slots

1.10 Steel studs compared to wooden studs
It is interesting to compare the U-value for a wall having steel C-studs to that of a wall having wooden studs placed in the same position as the steel girders.
Calculations show that, for λ_s=60, t=0.7 and L_g=0.6 m, the reference wall containing slotted steel studs has the same U-value as a wall containing 0.04 m thick wooden studs with thermal conductivity of 0.14 W/mK.

1.11 Conclusions

On the base of the previous analyses, it is proved that slotting of the stud web is very efficient way to decrease the heat flow. A numerical example showed that the thermal conductivity is decreased by a factor of 6 to make up for the slotting. The heat flow through a stud even more decreases as the number of narrow slots increases.

Equation (05) gives a U-value that depends on the thermal conductivity of the steel (λ_s), the center distance between the studs (L_g) and the thickness of the steel studs (t). The error is less than 2% compared to direct three-dimensional numerical calculations.

2. Thermal Behaviour of Light-Gauge Slotted Lindab Studs

In this chapter – on the base of the Scandinavian experiences presented before – the thermal behaviour of slotted studs produced in the factory of Hungarian subsidiary Lindab Kft. is investigated. The exact geometry of HRY-C and HSKY-U light-gauge profiles with the slotting pattern can be seen in Figure 11.

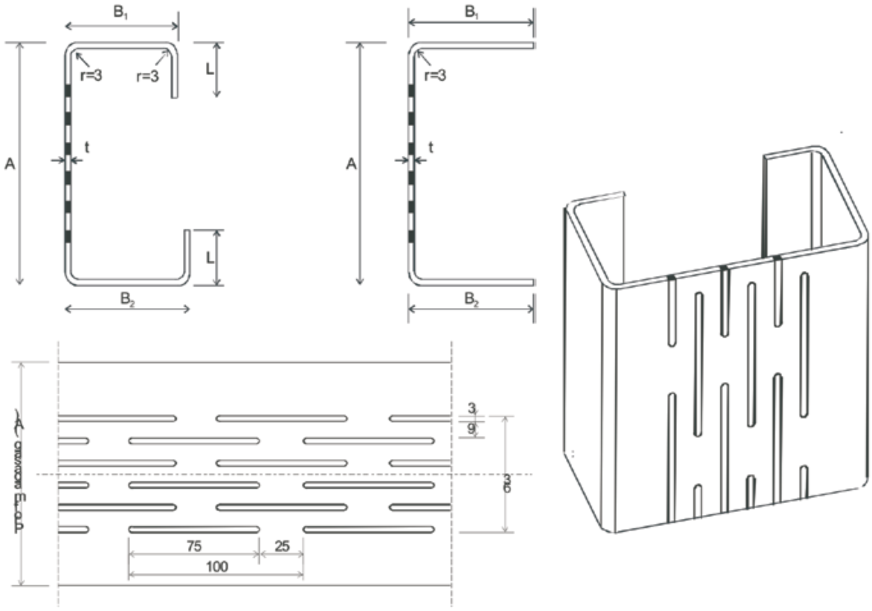


Figure 11: Geometrical parameters of slotted Lindab profiles: HRY-C stud and HSKY runner

The Swedish and Hungarian principals of desgin are different in several respects. The main differences are based mostly on the climate, and it can be perceived also in the Standards. In Hungary – and in all other countries in the region – the local values have to be used in the energetical calculations, such as the value of the heat transfer coefficient for the two sides of the wall. Therefore it is showed with the help of HEAT3 program and the experiences from the previously checked model, how the slotted girder works according to the Hungarian standards.

2.1 Analysis of the slotted Lindab studs

Thicknesses of the slotted profiles produced in Hungary are: t = 1.0 mm; 1.2 mm és 1.5 mm
Height of the slotted profiles: h = 100 – 120 – 150 – 200 mm
The heat conductivity of the steel used in the calculations: λ_{steel} = 60 W/mK
The heat conductivity of the gypsum board used in the calculations: λ_{gypsum} = 0.22 W/mK
The alternative heat conductivity of the insulations between the girders used in the calculations:

$\lambda_{insul-1}$ = 0.036 W/mK
$\lambda_{insul-2}$ = 0.045 W/mK

The surface heat transfer coefficient for exterior walls: h_e=24 and h_i=8, thus the surface heat transfer resistance used in the calculations is **R**=1/2*(1/24+1/8)**=0.085 m²K/W.**

C – Thermal design of profiles with slotted web

2.2 Thermal performance of slotted studs compared to non-slotted ones

A wall containing studs (h=150mm web height, t=1.0mm thickness, L_g=60 cm), 12.5 mm (13 mm) gypsum board on each side, and 15cm fibreglass insulation ($\lambda_{insul-1}$=0.036 W/mK) between the studs has been examined. The calculation has been made on the half cross-section with 0.5 °C temperature difference and R=0.085 m²K/W outer surface heat transfer resistance according to the original method.

The results became as follows:

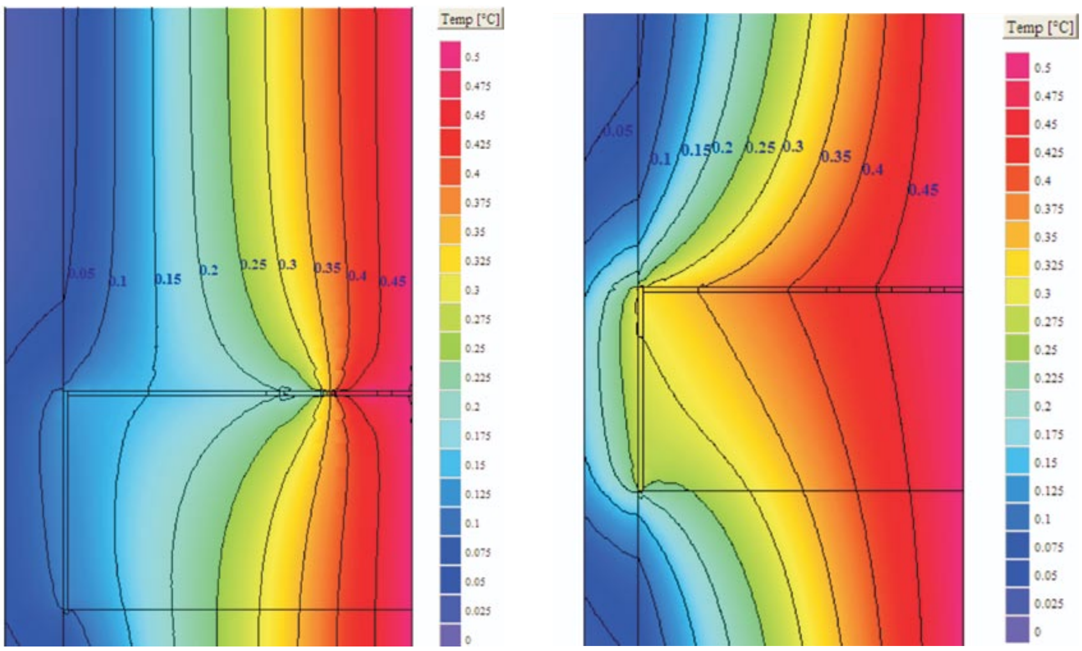
	Non-slotted studs (h=150mm, t= 1.0mm, L_g=60cm)	Slotted studs (h=150mm, t=1.0mm, L_g=60cm)
Q_{calc} (W)	0.0135	0.0089
Q_{extra} (W)	0.00675	0.00215
$U_{r,slotted}$ (W/m²K)	--------	0.297
$U_{r,nonslotted}$ (W/m²K)	0.451	------------

Figure 12: U_r-values of slotted and non-slotted studs

The resultant heat transmission coefficient ($U_{r,slotted}$=0.297 W/m²K) for the wall containing 150mm high slotted studs is around the 66% of the coefficient of the wall containing studs without slots ($U_{r,nonslotted}$=0.451 W/m²K)!

If the slotted steel stud is changed to a wooden stud, the resultant heat transmission is going to be:

- Wooden stud in size 7.5/15 cm: $U_{r,wooden,75x150}$ =0.286 W/m²K,
- Wooden stud in size 10/15 cm: $U_{r,wooden,100x150}$ =0.306 W/m²K



(a) The change of temperature shown with isotherms on the calculated part of the wall with slotted steel stud

(b) The change of temperature shown with isotherms on the calculated part of the wall with steel stud without slots

Figure 13: The isotherms in the surroundings of the slotted and non-slotted studs

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2.3 Varying the thickness of the slotted stud
The effect on the resultant heat transmission coefficient of changing the thickness of the slotted studs (t=1.0 mm; 1.2 mm and 1.5 mm) at a wall with studs of 150 mm web height with L_g=60 cm, gypsum boards on the two sides containing glasswool insulation has been calculated.
The results are as follows: (λ_{steel}=60 W/mK; $\lambda_{cladding}$=0.22 W/mK; $\lambda_{insul-1}$=0.036 W/mK)

	t=1.0 mm	t=1.2 mm	t=1.5 mm
$U_{r,slotted}$ (W/m²K)	0.297	0.307	0.321
Percentage:	100%	103.4%	108.1%

Figure 14: The effect of changing the thickness on the U_r-value of the wall with slotted studs

As excepted, as the thickness grows, the resultant heat transmission coefficient of the wall becomes worse, but this makes only 10% difference also in the most unfavourable cases (by increasing the thickness of the web by 50%).

2.4 Varying the web height of the slotted studs
Obviously the most different results will be resulted in this case, since the height change of the slotted girder will also cause change in the thickness of the filling insulation.
The initial parameters of the calculation: t=1.0mm; Lg=0.6m; λ_{steel}=60W/mK; $\lambda_{cladding}$=0.22W/mK; $\lambda_{insul-1}$=0.036W/mK.
The results are as follows:

Web height:	h=100 mm	h=120 mm	h=150 mm	h=200 mm
$U_{r,slotted}$ (W/m²K)	0.397	0.346	0.297	0.246
Percentage:	100%	87.2%	74.8%	62%

Figure 15: The effect of changing the web height of the slotted stud on the U_r-value of the wall

The results of the calculations are extremely favourable, if the following are taken into account:
- the wall containing slotted steel studs with h=100mm web height even satisfies the U_r=0.45 W/m²K value given for exterior walls by the new and quite strong Hungarian Ministry decree 7/2006(V.24.),
- the wall containing slotted steel studs with h=120mm web height already satisfies the U_r=0.35W/m²K heat transmission value proposed for light-weight exterior walls in the referred Hungarian decree.

2.5 Varying the type and quality of the material built into the wall

2.5.1 Insulations
By all means thready insulation had to be used between the slotted girders for heat and sound insulation. In the calculations the thermal conductivity $\lambda_{insul-1}$=0.036 W/mK also used in the original Swedish system has been given, this can generally be achieved by glass wool insulation.
It is suitable to have a look at the changes when mineral wool insulation with the slightly worse $\lambda_{insul-2}$=0.045 W/mK thermal conductivity value is used.

For the wall (containing stud with 150 mm web height, t=1.0 mm thickness and Lg=60 cm distance between the studs and with one layer of gypsum boards on each side) used in the calculations, the results are summarized in the table that follows:

The thermal conductivity of the insulation	$\lambda_{insul-1}$=0.036 W/mK	$\lambda_{insul-2}$=0.045 W/mK	25% loss
$U_{r,slotted}$ (W/m²K)	0.297	0.349	17.5% loss

Figure 16: The effect of changing the quality of the insulation material on the U_r-value of the wall

So the 25% decrease in the insulation capacity drives to the 17.5% loss in the value of the resultant heat transmission coefficient, but the structure can satisfy the U_r=0.45 W/m²K value given for exterior walls in the Hungarian Ministry decree 7/2006(V.24.) with large safety.

C – Thermal design of profiles with slotted web

2.5.2 Cladding boards

Corresponding to the original Swedish example, 13 mm thick gypsum board with λ_{gypsum}=0.22 W/mK heat conduction coefficient value were used in the previous calculations.

The resultant heat transfer coefficient value of the layer structures does not change essentially when different claddings are used, because the difference between the heat transfer value of the cladding materials are insignificant.

The materials used in practice in Hungary and surrounding countries:

- gypsum board with thickness of 9-12.5-2x12.5 mm (λ_{gypsum}=0.22 W/mK)
- OSB-3 board with thickness of 8-10-12-15-18-22-25 mm ($\lambda_{OSB,board}$≈0.20 W/mK)
- Betonyp (CK) board with thickness of 8-10-12-14-16-18-20-24 mm ($\lambda_{betonyp}$=0.26 W/mK)

So the different cladding boards can be calculated nearly with the same heat transmission coefficient, and their effect considering to the insulation capacity of the whole layer is usually small. More favourable values can be achieved rather with using thicker or multi-layered claddings.

The comparison between the heat transmission coefficient of walls containing stud (h=150 mm web height, t=1.0 mm thickness) and Lg=60 cm distance between the studs and with insulation
$\lambda_{insul-2}$=0.045 W/mK for 2x1 layers and 2x2 layers of gypsum boards with 12.5 mm thickness:

	$U_{r,slotted}$ (W/m²K)	Ratio
2x1 layers gypsum boards	0.349	100%
2x2 layers gypsum boards	0.334	95.7%

Figure 17: The effect of changing the cladding on the U_r-value of the wall

The heat transmission coefficient of the wall became 4.3% better according to using doubled gypsum boards.

2.6 Varying the distance between the slotted studs

By decreasing the distance between the studs, the unfavourable effect on the resultant heat transmission coefficient is getting higher. This increase is shown in the data that follows (t=1.0 mm; h=150 mm; λ_{steel}=60 W/mK; $\lambda_{cladding}$=0.22 W/mK; $\lambda_{insul-1}$=0.045 W/mK):

Spacing of the studs:	L_g=0.6m	L_g=0.4m	L_g=0.3m
$U_{r,slotted}$ (W/m²K)	0.349	0.392	0.434
Change in percentage:	100%	112%	124%

Figure 18: The effect of changing distance between studs on the U_r-value of the wall

C –Thermal design of profiles with slotted web

3. Summary of the Calculated Results

Here all the results are graphically shown in the next Figures (Figure 19 and 20).

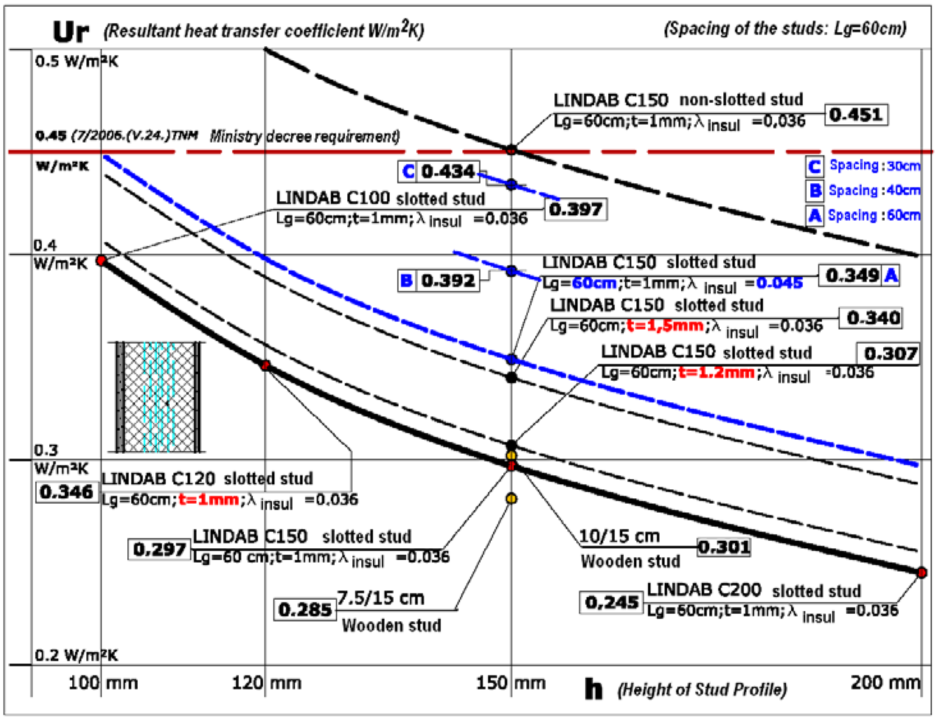

Figure 19: Graphic representation of U_r heat transmission coefficient values of the wall (I)

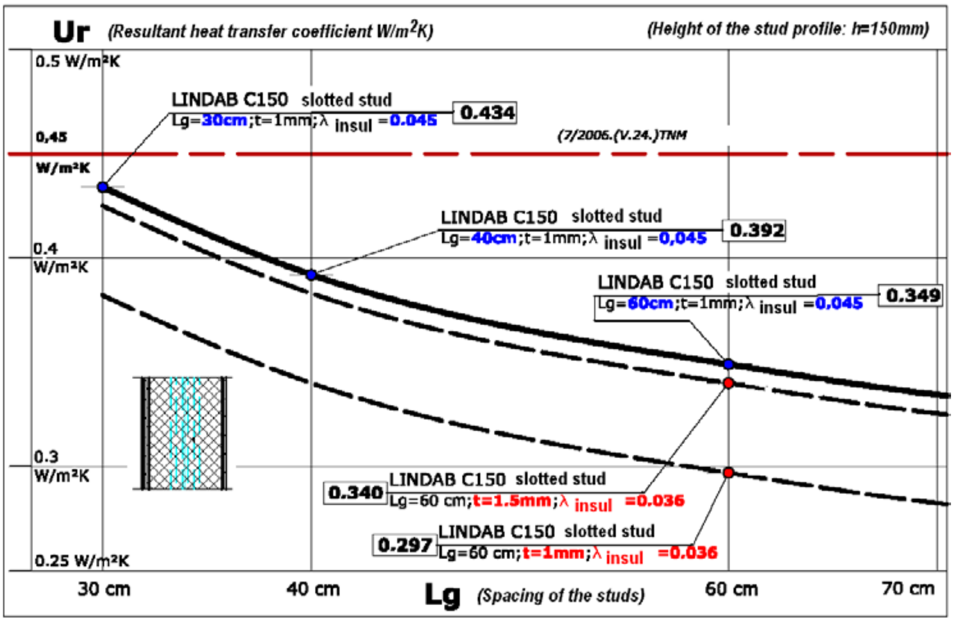

Figure 20: Graphic representation of U_r heat transmission coefficient values of the wall (II)

C – Thermal design of profiles with slotted web

In the following, for the sake of quick thermal design and check, the calculation results are summarized in Design Tables. The tabulated data provide the resultant heat transmission coefficient U_r value [W/m²K] in case of insulated light-weight Lindab construction made of slotted HRY studs and covered by 12.5 mm thick gypsum board on both sides. The changing parameters are:

- h = web height of the slotted stud that is equal to thickness of the insulation [mm]
- t = thickness of the slotted steel stud [mm]
- L_g = spacing of the slotted studs [cm]
- L_{insul} = heat conductivity coefficient of the infill insulation [W/mK]

	LINDAB HRY-C200 slotted stud, h=200 mm			
L_{insul}= 0.045 W/mK	L_g (spacing)	t=1.0 mm	t=1.2 mm	t=1.5 mm
	30 cm	**0.382**	**0.392**	**0.425**
	40 cm	**0.345**	**0,355**	**0.388**
	60 cm	**0.297**	**0.307**	**0.340**

	LINDAB HRY-C200 slotted stud, h=200 mm			
L_{insul}= 0.036 W/mK	L_g (spacing)	t=1.0 mm	t=1.2 mm	t=1.5 mm
	30 cm	**0.330**	**0.340**	**0.373**
	40 cm	**0.293**	**0.303**	**0.336**
	60 cm	**0.245**	**0.255**	**0.288**

	LINDAB HRY-C150 slotted stud, h=150 mm			
L_{insul}= 0.045 W/mK	L_g (spacing)	t=1.0 mm	t=1.2 mm	t=1.5 mm
	30 cm	**0.434**	**0.444**	0.477
	40 cm	**0.397**	**0.407**	**0.440**
	60 cm	**0.349**	**0.359**	**0.392**

	LINDAB HRY-C150 slotted stud, h=150 mm			
L_{insul}= 0.036 W/mK	L_g (spacing)	t=1.0 mm	t=1.2 mm	t=1.5 mm
	30 cm	**0.382**	**0.392**	**0.425**
	40 cm	**0.345**	**0.355**	**0.388**
	60 cm	**0.297**	**0.307**	**0.340**

	LINDAB HRY-C120 slotted stud, h=120 mm			
L_{insul}= 0.045 W/mK	L_g (spacing)	t=1.0 mm	t=1.2 mm	t=1.5 mm
	30 cm	0.483	0.493	0.526
	40 cm	**0.446**	0.456	0.489
	60 cm	**0.398**	**0.408**	**0.441**

	LINDAB HRY-C120 slotted stud, h=120 mm			
L_{insul}= 0.036 W/mK	L_g (spacing)	t=1.0 mm	t=1.2 mm	t=1.5 mm
	30 cm	**0.431**	**0.441**	0.474
	40 cm	**0.394**	**0.404**	**0.437**
	60 cm	**0.346**	**0.356**	**0.389**

	LINDAB HRY-C100 slotted stud, h=100 mm			
L_{insul}= 0.045 W/mK	L_g (spacing)	t=1.0 mm	t=1.2 mm	t=1.5 mm
	30 cm	0.534	0.544	0.577
	40 cm	0.497	0.507	0.540
	60 cm	**0.449**	0.459	0.492*

	LINDAB HRY-C100 slotted stud, h=100 mm			
L_{insul}= 0.036 W/mK	L_g (spacing)	t=1.0 mm	t=1.2 mm	t=1.5 mm
	30 cm	0.482	0.492	0.525
	40 cm	**0.445**	0.455	0.488
	60 cm	**0.397**	**0.407**	**0.440**

Design Table: U_r-values of wall constructions made of Lindab slotted profiles (W/m²K)

(λ_{steel}=60.0 W/mK; $\lambda_{cladding}$=0.22 W/mK; R=0.085 m²K/W)

According to the regulations of the previous Hungarian Standard, all the results are satisfactory (U_r < 0.70). The values typed with bold numbers fulfil also the stronger requirements of the newer Hungarian Ministry decree that is closer to the European Norms ($U_r \leq$ 0.45)! In other countries the local regulations and standards should be checked and the appropriate configuration of the wall construction made of HRY-C slotted studs can be selected by means of the above Design Table.

C – Thermal design of profiles with slotted web

References

[1] Thomas R. Blomberg: **Heat Conduction in Two and Three Dimensions**, Computer Modelling of Building Physics Applications. Report TVBH-1006, Department of Building Physics, Lund University, 1994, Sweden (ISBN: 91-628-1311-0)

[2] **European Lightweight Steel-framed Construction.** Published book by Light Steel Construction Association (LSK) and ARCELOR, 2005, Luxemburg (ISBN: 2-9523318-2-0)

D
STATIC DESIGN OF PROFILES WITH SLOTTED WEB

(by Dr. ÁDÁNY, Sándor and Dr. DUNAI László,
Budapest University of Technology and Economics)

TARTALOMJEGYZÉK

D
STATIC DESIGN OF PROFILES WITH SLOTTED WEB

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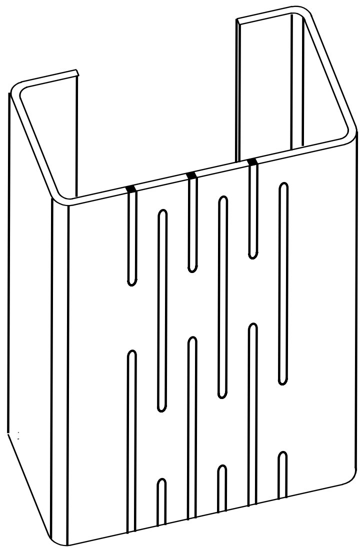
1. Introduction

1.1. Aim

This Design Guide discusses the static calculation of Lindab profiles with slotted webs. These profiles, similarly to the usual Z/C profiles, are produced from thin steel plates by cold-rolling, but their webs are slotted as illustrated in Figure 1.1. The slots are applied primarily to improve building physics characteristics, since web slots significantly increase heat resistance capacity of the section. That is why these sections are used mainly as members of outer walls in light-gauge buildings: C-shaped sections as columns, U-shaped sections as beams. The range of their application provides constraints for the static models to be investigated.



1.1. ábra: Gerinc perforációja

1.2. Standard basis of the applied design method

Similarly to many other Lindab design guides, this Design Guide is based on the following two standards: loads should be calculated according to the relevant Hungarian Standard, while load bearing capacities are calculated in accordance with the relevant Swedish Codes and practice.

The applied web slots influences not only heat resistance, but also the static behaviour: the web rigidity – especially shear rigidity – is reduced, which is reflected not only in the reduction of shear strength, but also in the modification of the behaviour. The so-called Bernoulli-Navier hypothesis (i.e. principle of plain cross-sections), which is universally applied in the analysis of beams and columns, cannot be accepted, therefore, the well-known formulae and procedures used in case of regular (non-slotted) sections for the calculation of bending and normal resistance, cannot be kept.

Though the application of slotted-web profiles is a novelty in Hungary and the surrounding Central and Eastern European countries, they have been applied in abroad (Scandinavia, North America, Australia) for years. This Design Guide, primarily, is based on the Scandinavian practice, due to the obvious close connection between the Lindab Hungary Ltd and the Swedish Lindab company. The applied principles and proposed application rules of the current Design Guide closely follow those worked out and successfully applied at the Swedish Lindab for several years. Thus, the presented principles, methods, formulae can be regarded as the – essentially identical – Hungarian adaptation of those of Swedish Lindab.

2. Geometry and Material Properties of Slotted Profiles

2.1 Geometry
This Design Guide discusses two products:
- a product with C-shaped cross-section, called HRY, and
- a product with U-shaped cross-section, called HSKY.

Both products are available with various cross-section dimensions and thicknesses, as detailed in the following figures and tables:

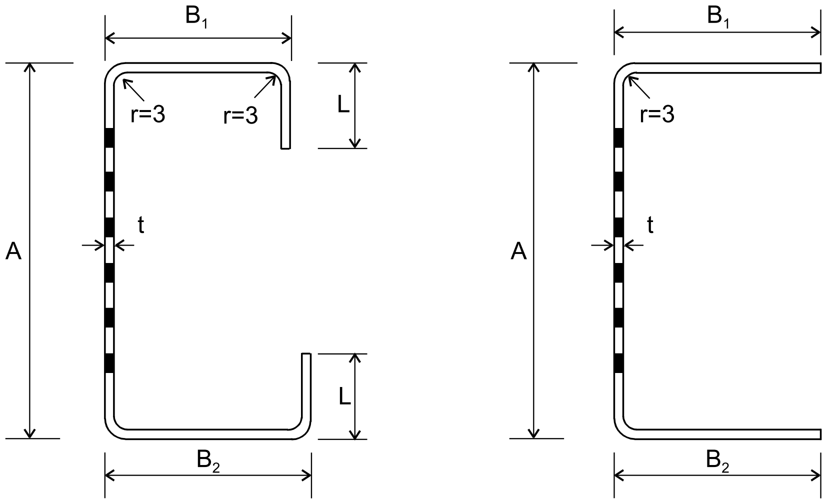


Figure 2.1: Lindab HRY and HSKY profiles

A [mm]	t_n [mm]	B_1 [mm]	B_2 [mm]	L [mm]
100	1.0	47	41	16.2
	1.2	47	41	16.8
	1.5	47	41	17.7
120	1.0	47	41	16.2
	1.2	47	41	16.8
	1.5	47	41	17.7
150	1.0	47	41	16.2
	1.2	47	41	16.8
	1.5	47	41	17.7
200	1.0	47	41	16.2
	1.2	47	41	16.8
	1.5	47	41	17.7

Table 2.1: Geometrical data of Lindab HRY profiles

D – Static design of profiles with slotted web

A [mm]	t_n [mm]	B_1 [mm]	B_2 [mm]
100	1.0	56	56
	1.2	56	56
	1.5	56	56
120	1.0	56	56
	1.2	56	56
	1.5	56	56
150	1.0	56	56
	1.2	56	56
	1.5	56	56
200	1.0	56	56
	1.2	56	56
	1.5	56	56

Table 2.2: Geometrical data of Lindab HSKY profiles

The same geometry of web slots is used for both profiles, as illustrated in Figure 2.2.

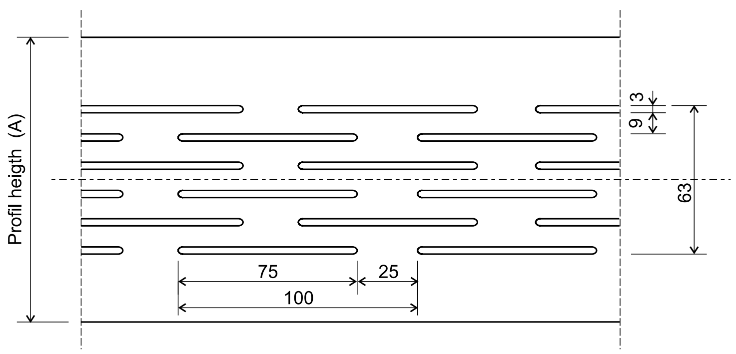


Figure 2.2: Geometry of web slots of Lindab HRY and HSKY profiles

2.2. Material properties

Material grade for the Lindab HRY and HSKY profiles: **S350GD+Z275** (MSZ EN 10326).
The most important material characteristics are as follows:

Characteristic value of yield strength:	f_{yk} = 350 N/mm^2
Modulus of elasticity:	E = 210000 MPa
Shear modulus:	G = 81000 MPa
Poisson's ratio:	ν= 0,3
Characteristic value of the web shear strength*:	τ_{uk} = 15 N/mm^2
Reduction factor for web shear rigidity*:	τ_G = 0.04

*The web shear strength and the reduction factor for web shear rigidity have been determined by tests in Sweden.

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2.3. Geometrical and material properties used in the calculations

2.3.1. Simplified cross-section
As it can be seen from the above tables, HRY profiles are not fully symmetrical, since the two flange widths are not equal. However, in the presented calculations symmetry is enforced, i.e. two identical flanges are assumed with an average width. This introduces certain small inaccuracy, but has two important advantages: symmetrical cross-sections are theoretically simpler to handle, and it is not necessary to distinguish between the two possible placements (i.e. wider flange at the bottom, wider flange at the top) which reduces to half the number of necessary capacity tables. Note that the same assumption is applied in the Design Guide for (non-slotted) Lindab C-profiles.

2.3.2. Design thickness
The design thickness of the cross-section elements is determined in accordance with [4], by using the following formula:

$$t = \frac{t_{\min}}{0.95}$$

where:
t_{min} is the smallest value of plate thickness allowed in the statistical sample.

It is to be noted that the resulted design thicknesses are smaller than those of other codes, such as Eurocode 3. The reason is that the reduction in the thickness in the Swedish Code takes into consideration not only the uncertainty in the plate thickness, but the uncertainty of the yield strength, too (see also below).

2.3.3. Design value of yield strength
According to [4] the design value of the yield strength can be calculated by the following formula:

$$f_y = \frac{f_{yk}}{\gamma_m \gamma_n}$$

where:
γ_m the safety factor to consider the uncertainty in the material;
γ_n the safety factor to consider safety class (which may depend on e.g. the importance of the building, etc.) and may vary between 1.0 and 1.2.
As mentioned in the preceding Section, the uncertainty of the yield strength is covered by the reduction in the plate thickness, consequently:

$\gamma_m = 1.0.$

The application of the γn safety factor on the resistance side, that considers the structural function, is unusual in the Hungarian practice (as well as it is not common in the Eurocodes). In Hungary, for example, the function (and importance) of the given structural member is taken into consideration partially by the safety factors for the loads (e.g. snow), partially by the rigidity requirements (which are much stricter than the Scandinavian ones). For this reason this Design Guide accepts the γn value as given for safety class #1, as follows:

$\gamma_n = 1.0$

3. Summary of Design Method

3.1. Introduction
The most important static effect of the existence of web slots is that the web shear rigidity is deteriorated, thus, the Bernoulli-Navier hypothesis for plane cross-sections, which is generally used in beams and columns, is not valid any more. Consequently, the usual procedures and formulae that are normally used for the analysis of regular (non-slotted) members, cannot be applied.
This Design Guide follows the procedure described in [7] (and summarized in [6], too), which utilizes some parts of the [4 and 5] Swedish Codes for thin-walled cold-formed members. On the basis of the design procedure capacity tables have been worked out which cover the most frequent practical cases (static model, loading, supports, etc.).

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Though it is believed that the cases discussed by this Design Guide cover the most important practical cases, there certainly exist situations that cannot be handled with appropriate accuracy by the static models assumed and discussed here. In these cases it is proposed to apply the DimStud software that has been developed by Lindab, and which, though uses the same principles presented here, is more general.

3.2. Assumptions concerning structural details

This Design Guide applies the following simplifying assumptions.

- Both flanges are restrained laterally by some structural or non-structural elements (such as gypsum board or similar), thus, lateral displacement of the flanges is effectively prevented (at least at the locations of fasteners).
- The gypsum boards (or similar) are fastened to the slotted-web profiles by screws. Screws are equally spaced, and the screw spacing is identical for both flanges.
- Asymmetry of the slotted-web profiles is neglected (i.e. an average flange dimension is used for both flanges). Consequently, transverse loads which are acting parallel with the web cause simple bending (and not skew bending).
- It is assumed that structural detail of girder ends effectively excludes the occurrence of web crippling due to concentric transverse forces.

3.3. Static model

In this Design Guide the static model as presented in Figure 3.1 is assumed. Namely:

- The girder is a single-span simply supported girder.
- The girder is subjected to an N normal force and a q uniformly distributed load (distributed over the whole length).
- The UDL is parallel with the web.
- The UDL maybe pressure or suction. Due to the speciality of the assumed static model and the forced symmetry of the cross-section, the loading direction does not make difference, thus, the presented load bearing values can be applied for both pressure and suction loads.
- The normal force may be concentric or eccentric.
- Concentric normal force does not induce bending, i.e. it is assumed to have a uniform stress distribution over the cross-section.
- If the normal force is eccentric, it is assumed that it is acting at the mass centre of one of the flange zones. (For the interpretation of flange zones, see Sections 3.5.)
- Though the presented design method can theoretically be applied to either tensile of compressive forces, this Design Guide considers compression only, since significant tensile force is unlikely to occur in most of practical situations.

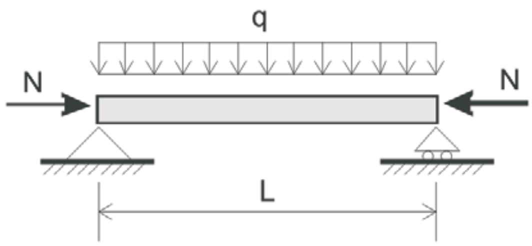

Figure 3.1: Static model

3.4. Calculation of loads

Jelen útmutató nem foglalkozik a terhek felvételének kérdésével. Az alábbiakban csak néhány szempontot foglalunk össze.

This Design Guide does not intend to give detailed description for how to calculate loads. Some important aspects are mentioned as follows.

- In Hungary the loads are proposed to calculate according to the relevant [1-3] Hungarian Standards. In other countries, it should be investigated what is the appropriate code to determine the loads and the safety factors of the load combinations, which can be used when the checking methods come from Swedish Code.
- Loads must be calculated on the above-described static model.
- It is assumed that slotted-web members are loaded parallel with their webs. Perpendicular loads are assumed to be resisted by other structural elements.
- The capacity values presented here include the safety factors needed on the resistance side, but do not include safety factors needed on the loading side. Thus, the presented values should be compared with factored loads (i.e. combinations calculated with the appropriate safety and combination factors).
- The presented load bearing capacity values do not include the self-weight, thus, self-weight should be taken into consideration during load combination calculation.

3.5. Brief summary of the calculations

3.5.1.Basic idea

The basic idea of the design procedure is that the member is divided into three characteristic zones: two flange zones and the zone of slotted web part (see Figure 3.2). The two flange zones can resist normal force and bending moment, while the web zone the shear only. Static equilibrium as well as geometric compatibility must be satisfied for the three zones, which finally leads to zone forces/moments. It is to be noted that the calculation of zone forces/moments is significantly dependent on the analyzed static model. Knowing the zone forces/moments, necessary verifications can be performed. These verifications are partially dependent on the problem (structural details, etc.).

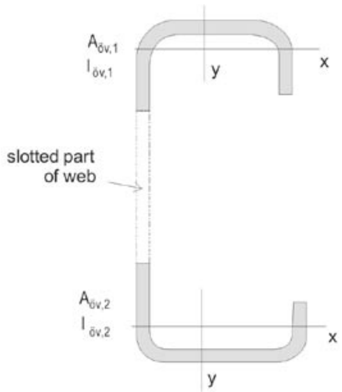

Figure 3.2: Cross-section zones

3.5.2. Zone forces/moments

Determination of zone forces/moments requires complicated considerations and resulted in complicated formulae. These formulae are not detailed here, only some remarks are mentioned as follows.

- The zone forces/moments are dependent on the loading (i.e. distinct formulae can be derived for UDL and for normal force).
- The zone forces/moments are obviously dependent on the support conditions. In this Design Guide simple supported girders are considered.
- Generally we may say that the slotted web is resulted in a partial interaction between the two flanges, which is reflected in zone forces/moments as well as distribution of strains and stresses over the cross-section. It practically means that the real behaviour of the girder is somewhere in between the case of full interaction (i.e. non-slotted web) and the case of no interaction (i.e. web shear rigidity is zero -> flange zones behave independently of each other). This is demonstrated in Figure 3.3 where typical stress (strain) distributions are presented for UDL and eccentric normal force.

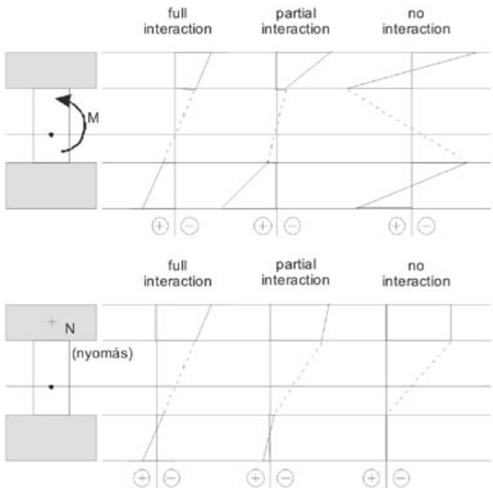

Figure 3.3: Typical stress diagrams

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3.5.3. Checks
In this Design Guide the following verifications are considered:
- flange buckling in the plane of the web,
- lateral buckling of flanges (perpendicularly to the web),
- buckling of the whole member in the plane of the web,
- normal force – bending moment interaction for the whole member,
- web shear,
- deflections.

These verifications are essentially identical to those generally used for thin-walled members. Some important features are summarized as follows.
- When flange buckling in the plane of the web is analyzed, the compressed flange zone is checked against buckling between screws. In principle, this is a verification of a column. The buckling length is taken as 0.7 times the distance between screws, since buckling of flanges is partially restrained by the slotted web and other connecting elements (such as gypsum board, etc.).
- In case of lateral buckling of flanges it is assumed that flanges are elastically restrained by some connecting elements (such as gypsum boards), thus, they are analyzed as columns on elastic foundations. The equivalent (distributed) spring stiffness can be calculated from the shear stiffness of the screws and screw spacing. Shear stiffness of the screws are determined from (Swedish) tests. Assumed conservative value is a constant 80 N/mm.
- In the case of buckling of the whole member in the plane of the web, it is assumed that the connecting elements (such as gypsum boards) are not effective against this failure mode. The resistance is defined as the maximum of the following two: either the buckling resistance of the whole member by considering shear deformations, or the sum of (independent) buckling resistances of the flanges only. The corresponding critical forces determine which one is the above two may be governing.
- When buckling is checked, the buckling reduction factor is calculated by the formula as defined in [5].
- If the member is subjected to a (concentric or eccentric) compressive force, the interaction of compression and bending must be checked, by considering also second-order effects. The interaction formula as defined in [4] is applied.
- The web shear check is formally identical to a shear stress check. The applied shear strength (see Section 2.2), however, considers not only material yielding, but the complex behaviour of the slotted web, determined by experiments.
- In the calculation of deflections the effect of partial interaction between the flanges must be considered, since this effect lead to larger deflections (than deflections with full interaction between flanges).

It is to be noted that all of the above checks include the consideration of local plate buckling through the application of effective widths and/or thicknesses, with the assumptions as follows.
- Radii at corners are small enough so that their effect can be neglected.
- The asymmetry of the C-shaped HRY profiles is neglected, by applying an average flange width (and lip length) for both flanges. Thus, the presented capacity tables can be used independently of the placement of the section (wider flange at the top or bottom).

4. Performing the Design by Capacity Tables

4.1. Capacity tables and the used notations
In the Appendix of this Design Guide capacity tables are presented. These tables include the maximal permissible (limit) values of loads for various cases. The capacity tables use the following parameters:

- Type of the profile: HRY or HSKY.
- Size of the cross-section, which is given by the h web depth. Possible values: 100, 120, 150 or 200 mm (nominal values).
- Nominal value of plate thickness (t_n). Possible values: 1.0, 1.2 or 1.5 mm.
- Screw spacing d_{cs} (assumed to be the same for both flanges). Assumed values: 100, 300 or 600 mm.
- Span L of the girder, which varies between 3.0 and 6.6 m.

The following loading cases are considered:

- ULS,q – UDL, capacity values are calculated for ULS
- ULS,N,concentric – concentric normal force, capacity values are calculated for ULS
- ULS,N,eccentric – eccentric normal force, capacity values are calculated for ULS (the force is assumed to act at the mass centre of a flange zone)

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- SLS,q – UDL, capacity values are calculated for SLS
- SLS,N,eccentric – eccentric normal force, capacity values are calculated for SLS (the force is assumed to act at the mass centre of a flange zone)

Remarks:
- Since symmetry is enforced for the cross-section, the 'N,eccentric' case is valid for both possible eccentricities (i.e. force may act at upper or lower flange).
- UDL may be either positive (downward, pressure) or negative (upward, suction). The presented values are valid for both.
- Normal force is assumed to be compressive. (In case of tension, the presented values can be used only as rough approximations. This application is not encouraged.)
- There is no deflection from concentric normal force.

4.2. Design by the application of capacity tables
If the structure to be analyzed satisfies the basic assumptions of the capacity tables, the static design can directly be performed.

ULS calculation:

1. Calculation of governing load combination(s) for ULS (q_{ULS} and N_{ULS}).
2. Determination of maximal permissible loading from the capacity tables (from the relevant 'ULS' rows) ($q_{lim,ULS}$ and/or $N_{lim,ULS}$).
3. Verifications:
   $q_{ULS} \leq q_{lim,ULS}$ and/or $N_{ULS} \leq N_{lim,ULS}$
4. If UDL and normal force are acting simultaneously, their interaction may be checked approximately as follows:
   $$\frac{q_{ULS}}{q_{\lim,ULS}} + \frac{N_{ULS}}{N_{\lim,ULS}} \leq 1$$
5. Evaluation of the results and making changes if necessary.

Remarks:
- If UDL and normal force are acting simultaneously, the normal (compressive) force is usually unfavourable.
- In case of concentric normal (compression) force the effect of UDL and the effect of normal force are simply summed in absolute value.
- In case of eccentric normal (compression) force the effect of UDL and the effect of normal force are still simply summed (in absolute value) if the normal force is acting in that flange which is in compression from the UDL.
- If the normal force is acting in that flange which is in tension from the UDL, the maximal stresses from UDL and those of normal force develop in different locations of the cross-section. In these situations the interaction between the two actions is usually small, but usually unfavourable. As an approximation on the safe side, the simply sum (in absolute value) of the two actions may still be applied. More accurate results may be achieved by a more detailed calculation.
- For screw spacing which is not included in the capacity tables linear interpolation can be used.

SLS calculation:

1. Calculation of governing load combination(s) for SLS (q_{SLS} and/or N_{SLS}).
2. Determination of maximal permissible loading from the capacity tables (from the relevant 'SLS' rows) ($q_{lim,SLS}$ and/or $N_{lim,SLS}$).
3. Verifications:
   $q_{SLS} \leq q_{lim,SLS}$ and/or $N_{SLS} \leq N_{lim,SLS}$
4. If UDL and normal force are acting simultaneously, their interaction may be checked approximately as follows:
   $$\frac{q_{SLS}}{q_{\lim,SLS}} \pm \frac{N_{SLS}}{N_{\lim,SLS}} \leq 1$$
5. Evaluation of the results and making changes if necessary.

D – Static design of profiles with slotted web

Remarks:

- The capacity values have been calculated for L/300 limit. If the actual limit is different, the capacity values should be modified accordingly, by taking advantage of the linear relationship between loads and deflections. For example, in case of a limit L/200, the SLS values given in the capacity tables should be multiplied by 1.5, in case of L/150 by 2.0, etc.
- If UDL and normal force are acting simultaneously, superposition may certainly be used (neglecting second-order effects). Nevertheless, signs must be carefully handled. The normal force may be favourable or unfavourable, depending on the sign of UDL and normal force. This question, however, can easily be judged by simple engineering considerations. For example, in case of positive (downward) UDL the deflection is positive (downward), and a compression force in the upper (compressed) flange obviously increases the deflection, while a compression force in the lower (tensioned from UDL) flange obviously decreases the deflection.

It is proposed that the cases which are not covered by this Design Guide should be analyzed by the Lindab DimStud software.

4.3. Capacity tables

The capacity tables, as described in Section 4.1, are presented in the subsequent pages. The tabulated (q and N) values are the capacity (q_{lim} and N_{lim}) values (for UDL and concentric/eccentric normal force) to be used in the above verification formulae, separately for ULS and SLS verifications.

D – Static design of profiles with slotted web

HRY 100						Span [m]												
t_n [mm]	Load type				d_{cs} [mm]	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8
1,0	ULS	q	---	[kN/m]	100	2.366	1.862	1.535	1.306	1.136	1.006	0.902	0.817	0.748	0.689	0.638	0.595	0.557
		N	Concentric	[kN]	100	37.709	37.050	36.242	35.261	34.076	32.657	30.994	29.109	27.070	24.971	22.905	20.945	19.131
		N	Eccentric	[kN]	100	17.014	16.654	16.241	15.775	15.248	14.652	13.981	13.237	12.432	11.649	10.976	10.304	9.651
		q	---	[kN/m]	300	2.366	1.862	1.535	1.306	1.136	1.006	0.902	0.817	0.748	0.689	0.638	0.595	0.554
		N	Concentric	[kN]	300	36.458	36.458	36.242	35.261	34.076	32.657	30.994	29.109	27.070	24.971	22.905	20.945	19.131
		N	Eccentric	[kN]	300	17.014	16.654	16.241	15.775	15.248	14.652	13.981	13.237	12.432	11.649	10.976	10.304	9.651
		q	---	[kN/m]	600	2.366	1.862	1.535	1.306	1.136	1.006	0.902	0.817	0.719	0.613	0.529	0.461	0.406
		N	Concentric	[kN]	600	26.715	26.715	26.715	26.715	26.715	26.715	26.715	26.715	26.715	24.971	22.905	20.945	19.131
		N	Eccentric	[kN]	600	12.936	12.936	12.936	12.936	12.936	12.936	12.936	12.936	12.432	11.649	10.976	10.304	9.651
	SLS	q	---	[kN/m]	---	4.630	2.918	1.933	1.334	0.953	0.701	0.529	0.408	0.321	0.257	0.208	0.171	0.142
		N	Eccentric	[kN]	---	31.869	25.388	21.108	18.068	15.795	14.032	12.623	11.472	10.513	9.703	9.008	8.407	7.881
1,2	ULS	q	---	[kN/m]	100	2.877	2.263	1.865	1.586	1.380	1.221	1.095	0.992	0.908	0.836	0.775	0.722	0.676
		N	Concentric	[kN]	100	53.179	52.079	50.706	49.012	46.942	44.469	41.624	38.517	35.311	32.171	29.213	26.503	24.060
		N	Eccentric	[kN]	100	23.880	23.305	22.639	21.873	20.995	19.992	18.866	17.638	16.461	15.429	14.403	13.413	12.476
		q	---	[kN/m]	300	2.877	2.263	1.865	1.586	1.380	1.221	1.095	0.992	0.908	0.836	0.775	0.722	0.676
		N	Concentric	[kN]	300	50.438	50.438	50.438	49.012	46.942	44.469	41.624	38.517	35.311	32.171	29.213	26.503	24.060
		N	Eccentric	[kN]	300	23.880	23.305	22.639	21.873	20.995	19.992	18.866	17.638	16.461	15.429	14.403	13.413	12.476
		q	---	[kN/m]	600	2.877	2.263	1.865	1.586	1.380	1.221	1.095	0.992	0.908	0.826	0.712	0.621	0.546
		N	Concentric	[kN]	600	36.507	36.507	36.507	36.507	36.507	36.507	36.507	36.507	35.311	32.171	29.213	26.503	24.060
		N	Eccentric	[kN]	600	17.652	17.652	17.652	17.652	17.652	17.652	17.652	17.638	16.461	15.429	14.403	13.413	12.476
	SLS	q	---	[kN/m]	---	5.629	3.550	2.352	1.624	1.161	0.854	0.645	0.498	0.392	0.313	0.254	0.209	0.174
		N	Eccentric	[kN]	---	38.986	31.050	25.813	22.093	19.314	17.157	15.434	14.026	12.854	11.863	11.014	10.278	9.635
1,5	ULS	q	---	[kN/m]	100	3.618	2.844	2.343	1.992	1.733	1.533	1.374	1.246	1.139	1.049	0.972	0.906	0.848
		N	Concentric	[kN]	100	71.907	70.559	68.499	65.937	62.802	59.082	54.872	50.386	45.880	41.570	37.589	33.992	30.785
		N	Eccentric	[kN]	100	32.358	31.525	30.549	29.419	28.114	26.622	24.958	23.171	21.688	20.224	18.796	17.438	16.168
		q	---	[kN/m]	300	3.618	2.844	2.343	1.992	1.733	1.533	1.374	1.246	1.139	1.049	0.972	0.906	0.848
		N	Concentric	[kN]	300	66.910	66.829	66.829	65.937	62.802	59.082	54.872	50.386	45.880	41.570	37.589	33.992	30.785
		N	Eccentric	[kN]	300	32.356	31.525	30.549	29.419	28.114	26.622	24.958	23.171	21.688	20.224	18.796	17.438	16.168
		q	---	[kN/m]	600	3.618	2.844	2.343	1.992	1.733	1.533	1.374	1.246	1.139	1.049	0.947	0.825	0.726
		N	Concentric	[kN]	600	48.533	48.533	48.533	48.533	48.533	48.533	48.533	48.533	45.880	41.570	37.589	33.992	30.785
		N	Eccentric	[kN]	600	23.469	23.469	23.469	23.469	23.469	23.469	23.469	23.171	21.688	20.224	18.796	17.438	16.168
	SLS	q	---	[kN/m]	---	7.079	4.468	2.963	2.047	1.464	1.078	0.814	0.628	0.494	0.395	0.321	0.264	0.219
		N	Eccentric	[kN]	---	49.488	39.400	32.748	28.026	24.497	21.760	19.575	17.788	16.302	15.044	13.967	13.034	12.218

D – Static design of profiles with slotted web

HRY 120						Span [m]												
t_n [mm]		Load type			d_{cs} [mm]	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8
1,0	ULS	q	---	[kN/m]	100	2.872	2.246	1.844	1.564	1.358	1.200	1.075	0.973	0.889	0.819	0.758	0.706	0.661
		N	Concentric	[kN]	100	38.253	38.074	37.550	36.940	36.232	35.410	34.458	33.356	32.095	30.676	29.119	27.462	25.756
		N	Eccentric	[kN]	100	17.403	17.140	16.843	16.517	16.160	15.771	15.346	14.878	14.363	13.800	13.190	12.542	11.869
		q	---	[kN/m]	300	2.872	2.246	1.844	1.564	1.358	1.200	1.075	0.973	0.889	0.819	0.758	0.706	0.661
		N	Concentric	[kN]	300	36.763	36.763	36.763	36.763	36.232	35.410	34.458	33.356	32.095	30.676	29.119	27.462	25.756
		N	Eccentric	[kN]	300	17.403	17.140	16.843	16.517	16.160	15.771	15.346	14.878	14.363	13.800	13.190	12.542	11.869
		q	---	[kN/m]	600	2.872	2.246	1.844	1.564	1.358	1.200	1.075	0.973	0.889	0.819	0.724	0.631	0.555
		N	Concentric	[kN]	600	29.108	29.108	29.108	29.108	29.108	29.108	29.108	29.108	29.108	29.108	29.108	27.462	25.756
		N	Eccentric	[kN]	600	14.016	14.016	14.016	14.016	14.016	14.016	14.016	14.016	14.016	13.800	13.190	12.542	11.869
	SLS	q	---	[kN/m]	---	6.781	4.321	2.889	2.009	1.444	1.067	0.809	0.626	0.493	0.395	0.321	0.264	0.220
		N	Eccentric	[kN]	---	42.843	34.010	28.223	24.130	21.080	18.717	16.831	15.292	14.012	12.929	12.002	11.200	10.498
1,2	ULS	q	---	[kN/m]	100	3.489	2.728	2.239	1.899	1.649	1.457	1.305	1.182	1.080	0.994	0.921	0.858	0.802
		N	Concentric	[kN]	100	53.752	53.752	52.924	51.902	50.698	49.281	47.621	45.698	43.513	41.106	38.547	35.930	33.343
		N	Eccentric	[kN]	100	24.518	24.104	23.635	23.113	22.537	21.899	21.191	20.405	19.538	18.595	17.591	16.605	15.773
		q	---	[kN/m]	300	3.489	2.728	2.239	1.899	1.649	1.457	1.305	1.182	1.080	0.994	0.921	0.858	0.802
		N	Concentric	[kN]	300	51.038	51.020	51.020	51.020	50.698	49.281	47.621	45.698	43.513	41.106	38.547	35.930	33.343
		N	Eccentric	[kN]	300	24.518	24.104	23.635	23.113	22.537	21.899	21.191	20.405	19.538	18.595	17.591	16.605	15.773
		q	---	[kN/m]	600	3.489	2.728	2.239	1.899	1.649	1.457	1.305	1.182	1.080	0.994	0.921	0.858	0.761
		N	Concentric	[kN]	600	40.311	40.311	40.311	40.311	40.311	40.311	40.311	40.311	40.311	40.311	38.547	35.930	33.343
		N	Eccentric	[kN]	600	19.388	19.388	19.388	19.388	19.388	19.388	19.388	19.388	19.388	18.595	17.591	16.605	15.773
	SLS	q	---	[kN/m]	---	8.247	5.258	3.517	2.447	1.759	1.301	0.986	0.763	0.601	0.482	0.392	0.322	0.268
		N	Eccentric	[kN]	---	52.372	41.569	34.493	29.490	25.761	22.873	20.569	18.688	17.123	15.800	14.667	13.686	12.829
1,5	ULS	q	---	[kN/m]	100	4.383	3.426	2.812	2.384	2.070	1.829	1.638	1.483	1.355	1.247	1.155	1.076	1.007
		N	Concentric	[kN]	100	75.925	75.925	75.251	73.556	71.532	69.128	66.302	63.048	59.419	55.533	51.544	47.608	43.843
		N	Eccentric	[kN]	100	34.886	34.239	33.500	32.670	31.741	30.701	29.536	28.238	26.813	25.286	23.791	22.519	21.244
		q	---	[kN/m]	300	4.383	3.426	2.812	2.384	2.070	1.829	1.638	1.483	1.355	1.247	1.155	1.076	1.007
		N	Concentric	[kN]	300	71.027	70.781	70.781	70.781	70.781	69.128	66.302	63.048	59.419	55.533	51.544	47.608	43.843
		N	Eccentric	[kN]	300	34.140	34.021	33.500	32.670	31.741	30.701	29.536	28.238	26.813	25.286	23.791	22.519	21.244
		q	---	[kN/m]	600	4.383	3.426	2.812	2.384	2.070	1.829	1.638	1.483	1.355	1.247	1.155	1.076	1.007
		N	Concentric	[kN]	600	56.871	56.871	56.871	56.871	56.871	56.871	56.871	56.871	56.871	55.533	51.544	47.608	43.843
		N	Eccentric	[kN]	600	27.336	27.335	27.335	27.335	27.335	27.335	27.335	27.335	26.813	25.286	23.791	22.519	21.244
	SLS	q	---	[kN/m]	---	10.375	6.621	4.433	3.085	2.219	1.642	1.244	0.963	0.760	0.609	0.495	0.407	0.339
		N	Eccentric	[kN]	---	66.406	52.696	43.722	37.377	32.650	28.988	26.068	23.683	21.699	20.023	18.587	17.344	16.257

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HRY 150						Span [m]												
t_n [mm]	Load type				d_{cs} [mm]	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7	6.0
1,0	ULS	q	---	[kN/m]	100	1.698	1.496	1.336	1.208	1.102	1.013	0.937	0.872	0.816	0.766	0.722	0.666	0.602
		N	Concentric	[kN]	100	37.786	37.317	36.796	36.216	35.568	34.844	34.036	33.135	32.139	31.048	29.871	28.624	27.327
		N	Eccentric	[kN]	100	16.879	16.623	16.353	16.066	15.761	15.436	15.087	14.714	14.312	13.882	13.424	12.941	12.437
		q	---	[kN/m]	300	1.698	1.496	1.336	1.208	1.102	1.013	0.937	0.872	0.816	0.766	0.715	0.642	0.580
		N	Concentric	[kN]	300	37.032	37.032	36.796	36.216	35.568	34.844	34.036	33.135	32.139	31.048	29.871	28.624	27.327
		N	Eccentric	[kN]	300	16.879	16.623	16.353	16.066	15.761	15.436	15.087	14.714	14.312	13.882	13.424	12.941	12.437
		q	---	[kN/m]	600	1.698	1.496	1.336	1.208	1.102	1.013	0.937	0.849	0.747	0.662	0.591	0.531	0.479
		N	Concentric	[kN]	600	30.586	30.586	30.586	30.586	30.586	30.586	30.586	30.586	30.586	30.586	29.871	28.624	27.327
		N	Eccentric	[kN]	600	14.633	14.633	14.633	14.633	14.633	14.633	14.633	14.633	14.312	13.882	13.424	12.941	12.437
	SLS	q	---	[kN/m]	---	2.379	1.769	1.347	1.046	0.827	0.664	0.541	0.446	0.372	0.313	0.266	0.228	0.196
		N	Eccentric	[kN]	---	30.287	26.856	24.129	21.907	20.062	18.505	17.173	16.020	15.013	14.125	13.337	12.632	11.998
1,2	ULS	q	---	[kN/m]	100	2.062	1.816	1.623	1.467	1.338	1.230	1.138	1.059	0.990	0.930	0.876	0.829	0.786
		N	Concentric	[kN]	100	53.320	52.542	51.666	50.678	49.563	48.305	46.892	45.321	43.597	41.740	39.782	37.765	35.733
		N	Eccentric	[kN]	100	23.719	23.312	22.878	22.413	21.913	21.374	20.792	20.162	19.485	18.763	18.003	17.214	16.481
		q	---	[kN/m]	300	2.062	1.816	1.623	1.467	1.338	1.230	1.138	1.059	0.990	0.930	0.876	0.829	0.786
		N	Concentric	[kN]	300	51.528	51.528	51.528	50.678	49.563	48.305	46.892	45.321	43.597	41.740	39.782	37.765	35.733
		N	Eccentric	[kN]	300	23.719	23.312	22.878	22.413	21.913	21.374	20.792	20.162	19.485	18.763	18.003	17.214	16.481
		q	---	[kN/m]	600	2.062	1.816	1.623	1.467	1.338	1.230	1.138	1.059	0.990	0.921	0.822	0.738	0.667
		N	Concentric	[kN]	600	42.712	42.712	42.712	42.712	42.712	42.712	42.712	42.712	42.712	41.740	39.782	37.765	35.733
		N	Eccentric	[kN]	600	20.415	20.415	20.415	20.415	20.415	20.415	20.415	20.162	19.485	18.763	18.003	17.214	16.481
	SLS	q	---	[kN/m]	---	2.899	2.157	1.642	1.276	1.009	0.810	0.660	0.544	0.454	0.382	0.324	0.278	0.240
		N	Eccentric	[kN]	---	36.991	32.801	29.470	26.757	24.503	22.601	20.974	19.566	18.336	17.252	16.289	15.428	14.654
1,5	ULS	q	---	[kN/m]	100	2.588	2.280	2.037	1.841	1.680	1.544	1.429	1.330	1.243	1.167	1.100	1.040	0.987
		N	Concentric	[kN]	100	75.916	74.636	73.178	71.517	69.626	67.486	65.088	62.441	59.583	56.571	53.478	50.380	47.343
		N	Eccentric	[kN]	100	33.678	33.035	32.340	31.590	30.775	29.890	28.927	27.887	26.774	25.600	24.385	23.342	22.359
		q	---	[kN/m]	300	2.588	2.280	2.037	1.841	1.680	1.544	1.429	1.330	1.243	1.167	1.100	1.040	0.987
		N	Concentric	[kN]	300	71.769	71.769	71.769	71.517	69.626	67.486	65.088	62.441	59.583	56.571	53.478	50.380	47.343
		N	Eccentric	[kN]	300	33.678	33.035	32.340	31.590	30.775	29.890	28.927	27.887	26.774	25.600	24.385	23.342	22.359
		q	---	[kN/m]	600	2.588	2.280	2.037	1.841	1.680	1.544	1.429	1.330	1.243	1.167	1.100	1.040	0.944
		N	Concentric	[kN]	600	60.822	60.822	60.822	60.822	60.822	60.822	60.822	60.822	59.583	56.571	53.478	50.380	47.343
		N	Eccentric	[kN]	600	29.069	29.069	29.069	29.069	29.069	29.069	28.927	27.887	26.774	25.600	24.385	23.342	22.359
	SLS	q	---	[kN/m]	---	3.659	2.723	2.074	1.611	1.275	1.024	0.834	0.688	0.573	0.483	0.410	0.351	0.303
		N	Eccentric	[kN]	---	46.843	41.536	37.318	33.881	31.028	28.619	26.559	24.776	23.218	21.845	20.626	19.536	18.555

D – Static design of profiles with slotted web

HRY 200						Span [m]												
t_n [mm]		Load type			d_{cs} [mm]	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7	6.0	6.3	6.6
1,0	ULS	q	---	[kN/m]	100	1.777	1.601	1.457	1.336	1.234	1.147	1.071	1.004	0.945	0.893	0.808	0.734	0.669
		N	Concentric	[kN]	100	38.441	38.139	37.817	37.472	37.102	36.704	36.276	35.814	35.315	34.776	34.194	33.565	32.888
		N	Eccentric	[kN]	100	17.181	17.005	16.823	16.635	16.440	16.238	16.029	15.811	15.583	15.345	15.096	14.834	14.558
		q	---	[kN/m]	300	1.777	1.601	1.457	1.336	1.234	1.147	1.071	1.004	0.945	0.865	0.781	0.709	0.646
		N	Concentric	[kN]	300	37.274	37.274	37.274	37.274	37.102	36.704	36.276	35.814	35.315	34.776	34.194	33.565	32.888
		N	Eccentric	[kN]	300	17.181	17.005	16.823	16.635	16.440	16.238	16.029	15.811	15.583	15.345	15.096	14.834	14.558
		q	---	[kN/m]	600	1.777	1.601	1.457	1.336	1.234	1.147	1.030	0.913	0.815	0.733	0.662	0.601	0.547
		N	Concentric	[kN]	600	31.569	31.569	31.569	31.569	31.569	31.569	31.569	31.569	31.569	31.569	31.569	31.569	31.569
		N	Eccentric	[kN]	600	15.029	15.029	15.029	15.029	15.029	15.029	15.029	15.029	15.029	15.029	15.029	14.834	14.558
	SLS	q	---	[kN/m]	---	2.587	2.021	1.605	1.294	1.057	0.874	0.730	0.616	0.524	0.449	0.388	0.337	0.295
		N	Eccentric	[kN]	---	39.007	35.357	32.339	29.801	27.634	25.764	24.132	22.696	21.421	20.283	19.261	18.336	17.497
1,2	ULS	q	---	[kN/m]	100	2.159	1.945	1.770	1.623	1.499	1.393	1.301	1.220	1.148	1.085	1.028	0.977	0.931
		N	Concentric	[kN]	100	54.306	53.904	53.375	52.804	52.185	51.514	50.785	49.992	49.129	48.190	47.173	46.075	44.897
		N	Eccentric	[kN]	100	24.213	23.937	23.649	23.350	23.039	22.714	22.374	22.017	21.642	21.247	20.829	20.389	19.925
		q	---	[kN/m]	300	2.159	1.945	1.770	1.623	1.499	1.393	1.301	1.220	1.148	1.085	1.028	0.977	0.903
		N	Concentric	[kN]	300	51.982	51.982	51.982	51.982	51.982	51.514	50.785	49.992	49.129	48.190	47.173	46.075	44.897
		N	Eccentric	[kN]	300	24.213	23.937	23.649	23.350	23.039	22.714	22.374	22.017	21.642	21.247	20.829	20.389	19.925
		q	---	[kN/m]	600	2.159	1.945	1.770	1.623	1.499	1.393	1.301	1.220	1.147	1.031	0.931	0.845	0.770
		N	Concentric	[kN]	600	44.323	44.323	44.323	44.323	44.323	44.323	44.323	44.323	44.323	44.323	44.323	44.323	44.323
		N	Eccentric	[kN]	600	21.084	21.084	21.084	21.084	21.084	21.084	21.084	21.084	21.084	21.084	20.829	20.389	19.925
	SLS	q	---	[kN/m]	---	3.154	2.464	1.957	1.578	1.289	1.066	0.891	0.751	0.639	0.548	0.473	0.411	0.360
		N	Eccentric	[kN]	---	47.610	43.156	39.472	36.373	33.729	31.446	29.455	27.701	26.146	24.757	23.509	22.381	21.356
1,5	ULS	q	---	[kN/m]	100	2.712	2.443	2.223	2.039	1.883	1.750	1.634	1.532	1.443	1.363	1.292	1.227	1.169
		N	Concentric	[kN]	100	76.930	76.877	76.016	75.078	74.054	72.934	71.708	70.366	68.901	67.305	65.577	63.721	61.748
		N	Eccentric	[kN]	100	34.471	34.038	33.585	33.112	32.616	32.096	31.547	30.967	30.353	29.703	29.014	28.285	27.519
		q	---	[kN/m]	300	2.712	2.443	2.223	2.039	1.883	1.750	1.634	1.532	1.443	1.363	1.292	1.227	1.169
		N	Concentric	[kN]	300	72.643	72.643	72.643	72.643	72.643	72.643	71.708	70.366	68.901	67.305	65.577	63.721	61.748
		N	Eccentric	[kN]	300	34.471	34.038	33.585	33.112	32.616	32.096	31.547	30.967	30.353	29.703	29.014	28.285	27.519
		q	---	[kN/m]	600	2.712	2.443	2.223	2.039	1.883	1.750	1.634	1.532	1.443	1.363	1.292	1.218	1.111
		N	Concentric	[kN]	600	63.486	63.486	63.486	63.486	63.486	63.486	63.486	63.486	63.486	63.486	63.486	63.486	61.748
		N	Eccentric	[kN]	600	30.191	30.191	30.191	30.191	30.191	30.191	30.191	30.191	30.191	29.703	29.014	28.285	27.519
	SLS	q	---	[kN/m]	---	3.984	3.113	2.474	1.995	1.630	1.348	1.126	0.950	0.808	0.693	0.598	0.520	0.455
		N	Eccentric	[kN]	---	60.230	54.595	49.935	46.015	42.670	39.782	37.262	35.044	33.077	31.319	29.740	28.313	27.017

D – Static design of profiles with slotted web

HSKY 100						Span [m]												
t_n [mm]		Load type			d_{cs} [mm]	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8
1,0	ULS	q	---	[kN/m]	100	2.394	1.891	1.563	1.332	1.044	0.827	0.670	0.555	0.466	0.398	0.343	0.299	0.263
		N	Concentric	[kN]	100	17.671	17.514	17.336	17.135	16.911	16.661	16.381	16.066	15.711	15.311	14.861	14.359	13.807
		N	Eccentric	[kN]	100	8.172	8.069	7.957	7.837	7.709	7.573	7.430	7.277	7.113	6.937	6.747	6.542	6.322
		q	---	[kN/m]	300	2.394	1.891	1.563	1.319	1.012	0.801	0.650	0.538	0.452	0.386	0.333	0.290	0.255
		N	Concentric	[kN]	300	17.218	17.218	17.218	17.135	16.911	16.661	16.381	16.066	15.711	15.311	14.861	14.359	13.807
		N	Eccentric	[kN]	300	8.172	8.069	7.957	7.837	7.709	7.573	7.430	7.277	7.113	6.937	6.747	6.542	6.322
		q	---	[kN/m]	600	2.394	1.891	1.486	1.096	0.842	0.666	0.540	0.447	0.376	0.321	0.277	0.241	0.212
		N	Concentric	[kN]	600	14.314	14.314	14.314	14.314	14.314	14.314	14.314	14.314	14.314	14.314	14.314	14.314	13.807
		N	Eccentric	[kN]	600	6.992	6.992	6.992	6.992	6.992	6.992	6.992	6.992	6.992	6.937	6.747	6.542	6.322
	SLS	q	---	[kN/m]	---	4.774	2.996	1.977	1.360	0.970	0.712	0.537	0.414	0.325	0.260	0.211	0.173	0.144
		N	Eccentric	[kN]	---	30.894	24.651	20.514	17.568	15.364	13.652	12.283	11.164	10.232	9.444	8.769	8.184	7.672
1,2	ULS	q	---	[kN/m]	100	2.909	2.298	1.899	1.618	1.410	1.191	0.966	0.799	0.672	0.573	0.494	0.431	0.379
		N	Concentric	[kN]	100	25.901	25.636	25.330	24.981	24.585	24.135	23.622	23.036	22.366	21.606	20.755	19.819	18.816
		N	Eccentric	[kN]	100	11.924	11.754	11.567	11.365	11.149	10.916	10.667	10.398	10.105	9.787	9.441	9.067	8.670
		q	---	[kN/m]	300	2.909	2.298	1.899	1.618	1.410	1.153	0.935	0.774	0.651	0.555	0.479	0.417	0.367
		N	Concentric	[kN]	300	25.129	25.129	25.129	24.981	24.585	24.135	23.622	23.036	22.366	21.606	20.755	19.819	18.816
		N	Eccentric	[kN]	300	11.924	11.754	11.567	11.365	11.149	10.916	10.667	10.398	10.105	9.787	9.441	9.067	8.670
		q	---	[kN/m]	600	2.909	2.298	1.899	1.491	1.145	0.906	0.735	0.608	0.511	0.436	0.376	0.328	0.288
		N	Concentric	[kN]	600	19.747	19.747	19.747	19.747	19.747	19.747	19.747	19.747	19.747	19.747	19.747	19.747	18.816
		N	Eccentric	[kN]	600	9.645	9.645	9.645	9.645	9.645	9.645	9.645	9.645	9.645	9.645	9.441	9.067	8.670
	SLS	q	---	[kN/m]	---	5.801	3.640	2.402	1.653	1.178	0.866	0.653	0.503	0.395	0.316	0.256	0.210	0.175
		N	Eccentric	[kN]	---	37.538	29.953	24.926	21.347	18.668	16.588	14.925	13.565	12.433	11.475	10.655	9.944	9.322
1,5	ULS	q	---	[kN/m]	100	3.656	2.888	2.387	2.034	1.772	1.569	1.409	1.216	1.023	0.872	0.752	0.656	0.576
		N	Concentric	[kN]	100	36.589	36.281	35.798	35.242	34.603	33.868	33.021	32.043	30.922	29.654	28.248	26.734	25.154
		N	Eccentric	[kN]	100	16.874	16.613	16.323	16.008	15.668	15.301	14.902	14.466	13.990	13.469	12.903	12.299	11.665
		q	---	[kN/m]	300	3.656	2.888	2.387	2.034	1.772	1.569	1.409	1.178	0.990	0.844	0.728	0.635	0.558
		N	Concentric	[kN]	300	35.452	35.429	35.429	35.242	34.603	33.868	33.021	32.043	30.922	29.654	28.248	26.734	25.154
		N	Eccentric	[kN]	300	16.874	16.613	16.323	16.008	15.668	15.301	14.902	14.466	13.990	13.469	12.903	12.299	11.665
		q	---	[kN/m]	600	3.656	2.888	2.387	2.034	1.668	1.320	1.071	0.886	0.745	0.635	0.548	0.477	0.420
		N	Concentric	[kN]	600	26.652	26.652	26.652	26.652	26.652	26.652	26.652	26.652	26.652	26.652	26.652	26.652	25.154
		N	Eccentric	[kN]	600	13.045	13.045	13.045	13.045	13.045	13.045	13.045	13.045	13.045	13.045	12.903	12.299	11.665
	SLS	q	---	[kN/m]	---	7.290	4.574	3.019	2.077	1.481	1.088	0.820	0.632	0.497	0.397	0.322	0.264	0.220
		N	Eccentric	[kN]	---	47.174	37.641	31.323	26.826	23.460	20.845	18.756	17.047	15.624	14.421	13.389	12.496	11.714

D – Static design of profiles with slotted web

HSKY 120						Span [m]												
t_n [mm]		Load type			d_{cs} [mm]	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8
1,0	ULS	q	---	[kN/m]	100	2.924	2.289	1.881	1.596	1.386	1.102	0.895	0.741	0.624	0.532	0.459	0.400	0.352
		N	Concentric	[kN]	100	17.799	17.749	17.618	17.475	17.318	17.148	16.964	16.763	16.544	16.304	16.040	15.750	15.430
		N	Eccentric	[kN]	100	8.206	8.129	8.044	7.954	7.858	7.758	7.654	7.546	7.433	7.315	7.190	7.059	6.920
		q	---	[kN/m]	300	2.924	2.289	1.881	1.596	1.362	1.080	0.877	0.727	0.612	0.522	0.450	0.393	0.345
		N	Concentric	[kN]	300	17.448	17.448	17.448	17.448	17.318	17.148	16.964	16.763	16.544	16.304	16.040	15.750	15.430
		N	Eccentric	[kN]	300	8.206	8.129	8.044	7.954	7.858	7.758	7.654	7.546	7.433	7.315	7.190	7.059	6.920
		q	---	[kN/m]	600	2.924	2.289	1.881	1.596	1.337	1.061	0.862	0.713	0.600	0.512	0.442	0.385	0.339
		N	Concentric	[kN]	600	17.132	17.132	17.132	17.132	17.132	17.132	16.964	16.763	16.544	16.304	16.040	15.750	15.430
		N	Eccentric	[kN]	600	8.206	8.129	8.044	7.954	7.858	7.758	7.654	7.546	7.433	7.315	7.190	7.059	6.920
	SLS	q	---	[kN/m]	---	6.931	4.396	2.928	2.030	1.455	1.074	0.812	0.628	0.494	0.396	0.321	0.264	0.220
		N	Eccentric	[kN]	---	41.648	33.082	27.463	23.485	20.519	18.220	16.386	14.888	13.642	12.589	11.686	10.905	10.222
1,2	ULS	q	---	[kN/m]	100	3.553	2.782	2.285	1.939	1.684	1.489	1.291	1.069	0.900	0.768	0.663	0.578	0.508
		N	Concentric	[kN]	100	26.025	26.025	25.812	25.568	25.299	25.004	24.679	24.319	23.921	23.479	22.987	22.439	21.833
		N	Eccentric	[kN]	100	11.999	11.872	11.732	11.582	11.423	11.255	11.079	10.894	10.699	10.493	10.273	10.039	9.788
		q	---	[kN/m]	300	3.553	2.782	2.285	1.939	1.684	1.489	1.259	1.043	0.878	0.749	0.646	0.563	0.496
		N	Concentric	[kN]	300	25.396	25.389	25.389	25.389	25.299	25.004	24.679	24.319	23.921	23.479	22.987	22.439	21.833
		N	Eccentric	[kN]	300	11.999	11.872	11.732	11.582	11.423	11.255	11.079	10.894	10.699	10.493	10.273	10.039	9.788
		q	---	[kN/m]	600	3.553	2.782	2.285	1.939	1.684	1.489	1.231	1.020	0.858	0.732	0.632	0.551	0.484
		N	Concentric	[kN]	600	24.976	24.817	24.817	24.817	24.817	24.817	24.679	24.319	23.921	23.479	22.987	22.439	21.833
		N	Eccentric	[kN]	600	11.999	11.872	11.732	11.582	11.423	11.255	11.079	10.894	10.699	10.493	10.273	10.039	9.788
	SLS	q	---	[kN/m]	---	8.422	5.341	3.557	2.466	1.768	1.305	0.987	0.763	0.601	0.481	0.391	0.321	0.267
		N	Eccentric	[kN]	---	50.606	40.197	33.369	28.536	24.931	22.139	19.910	18.090	16.576	15.296	14.200	13.250	12.420
1,5	ULS	q	---	[kN/m]	100	4.465	3.496	2.872	2.437	2.117	1.871	1.676	1.518	1.367	1.166	1.007	0.877	0.772
		N	Concentric	[kN]	100	40.519	40.519	40.331	39.872	39.357	38.780	38.133	37.404	36.583	35.656	34.616	33.456	32.181
		N	Eccentric	[kN]	100	18.717	18.489	18.236	17.963	17.672	17.362	17.033	16.683	16.307	15.903	15.467	14.996	14.489
		q	---	[kN/m]	300	4.465	3.496	2.872	2.437	2.117	1.871	1.676	1.518	1.323	1.128	0.974	0.849	0.747
		N	Concentric	[kN]	300	39.267	39.202	39.202	39.202	39.202	38.780	38.133	37.404	36.583	35.656	34.616	33.456	32.181
		N	Eccentric	[kN]	300	18.717	18.489	18.236	17.963	17.672	17.362	17.033	16.683	16.307	15.903	15.467	14.996	14.489
		q	---	[kN/m]	600	4.465	3.496	2.872	2.437	2.117	1.871	1.676	1.518	1.280	1.092	0.943	0.822	0.723
		N	Concentric	[kN]	600	38.533	37.969	37.943	37.943	37.943	37.943	37.943	37.404	36.583	35.656	34.616	33.456	32.181
		N	Eccentric	[kN]	600	18.583	18.311	18.236	17.963	17.672	17.362	17.033	16.683	16.307	15.903	15.467	14.996	14.489
	SLS	q	---	[kN/m]	---	10.583	6.712	4.470	3.099	2.222	1.640	1.240	0.959	0.755	0.604	0.491	0.404	0.336
		N	Eccentric	[kN]	---	63.594	50.514	41.933	35.860	31.330	27.821	25.020	22.733	20.830	19.222	17.844	16.651	15.608

D – Static design of profiles with slotted web

HSKY 150						Span [m]												
t_n [mm]		Load type			d_{cs} [mm]	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7	6.0
1,0	ULS	q	---	[kN/m]	100	1.726	1.479	1.204	0.999	0.842	0.719	0.621	0.542	0.477	0.423	0.377	0.339	0.306
		N	Concentric	[kN]	100	17.666	17.551	17.431	17.302	17.167	17.023	16.870	16.707	16.533	16.346	16.146	15.930	15.698
		N	Eccentric	[kN]	100	7.986	7.914	7.841	7.765	7.687	7.607	7.524	7.440	7.352	7.262	7.168	7.071	6.969
		q	---	[kN/m]	300	1.726	1.451	1.182	0.980	0.826	0.705	0.609	0.531	0.468	0.415	0.370	0.332	0.300
		N	Concentric	[kN]	300	17.502	17.502	17.431	17.302	17.167	17.023	16.870	16.707	16.533	16.346	16.146	15.930	15.698
		N	Eccentric	[kN]	300	7.986	7.914	7.841	7.765	7.687	7.607	7.524	7.440	7.352	7.262	7.168	7.071	6.969
		q	---	[kN/m]	600	1.726	1.428	1.162	0.964	0.812	0.694	0.599	0.523	0.460	0.408	0.364	0.327	0.295
		N	Concentric	[kN]	600	17.215	17.215	17.215	17.215	17.167	17.023	16.870	16.707	16.533	16.346	16.146	15.930	15.698
		N	Eccentric	[kN]	600	7.986	7.914	7.841	7.765	7.687	7.607	7.524	7.440	7.352	7.262	7.168	7.071	6.969
	SLS	q	---	[kN/m]	---	2.377	1.765	1.341	1.041	0.822	0.660	0.537	0.442	0.369	0.310	0.263	0.225	0.194
		N	Eccentric	[kN]	---	29.515	26.171	23.513	21.348	19.550	18.032	16.734	15.611	14.629	13.764	12.996	12.309	11.691
1,2	ULS	q	---	[kN/m]	100	2.097	1.847	1.651	1.444	1.217	1.039	0.898	0.783	0.689	0.611	0.545	0.490	0.442
		N	Concentric	[kN]	100	25.891	25.699	25.493	25.272	25.037	24.784	24.512	24.218	23.901	23.557	23.185	22.780	22.342
		N	Eccentric	[kN]	100	11.654	11.536	11.413	11.287	11.156	11.020	10.880	10.735	10.584	10.426	10.261	10.087	9.905
		q	---	[kN/m]	300	2.097	1.847	1.651	1.411	1.189	1.015	0.877	0.765	0.673	0.597	0.533	0.478	0.432
		N	Concentric	[kN]	300	25.489	25.489	25.489	25.272	25.037	24.784	24.512	24.218	23.901	23.557	23.185	22.780	22.342
		N	Eccentric	[kN]	300	11.654	11.536	11.413	11.287	11.156	11.020	10.880	10.735	10.584	10.426	10.261	10.087	9.905
		q	---	[kN/m]	600	2.097	1.847	1.651	1.381	1.164	0.994	0.858	0.749	0.659	0.584	0.521	0.468	0.423
		N	Concentric	[kN]	600	24.953	24.953	24.953	24.953	24.953	24.784	24.512	24.218	23.901	23.557	23.185	22.780	22.342
		N	Eccentric	[kN]	600	11.654	11.536	11.413	11.287	11.156	11.020	10.880	10.735	10.584	10.426	10.261	10.087	9.905
	SLS	q	---	[kN/m]	---	2.889	2.144	1.630	1.265	0.999	0.802	0.652	0.538	0.448	0.377	0.320	0.274	0.236
		N	Eccentric	[kN]	---	35.863	31.800	28.570	25.939	23.754	21.910	20.333	18.968	17.775	16.724	15.791	14.956	14.205
1,5	ULS	q	---	[kN/m]	100	2.636	2.322	2.074	1.875	1.710	1.572	1.370	1.195	1.052	0.933	0.832	0.748	0.675
		N	Concentric	[kN]	100	40.480	40.119	39.728	39.304	38.844	38.343	37.796	37.197	36.541	35.821	35.035	34.177	33.249
		N	Eccentric	[kN]	100	18.129	17.915	17.692	17.460	17.218	16.965	16.701	16.424	16.132	15.823	15.496	15.149	14.782
		q	---	[kN/m]	300	2.636	2.322	2.074	1.875	1.710	1.538	1.329	1.159	1.020	0.904	0.807	0.725	0.655
		N	Concentric	[kN]	300	39.415	39.415	39.415	39.304	38.844	38.343	37.796	37.197	36.541	35.821	35.035	34.177	33.249
		N	Eccentric	[kN]	300	18.129	17.915	17.692	17.460	17.218	16.965	16.701	16.424	16.132	15.823	15.496	15.149	14.782
		q	---	[kN/m]	600	2.636	2.322	2.074	1.875	1.710	1.493	1.289	1.125	0.990	0.877	0.783	0.703	0.635
		N	Concentric	[kN]	600	38.248	38.248	38.248	38.248	38.248	38.248	37.796	37.197	36.541	35.821	35.035	34.177	33.249
		N	Eccentric	[kN]	600	18.129	17.915	17.692	17.460	17.218	16.965	16.701	16.424	16.132	15.823	15.496	15.149	14.782
	SLS	q	---	[kN/m]	---	3.630	2.695	2.048	1.589	1.255	1.007	0.820	0.676	0.563	0.474	0.402	0.344	0.297
		N	Eccentric	[kN]	---	45.067	39.961	35.902	32.596	29.850	27.533	25.551	23.836	22.337	21.016	19.843	18.794	17.851

D – Static design of profiles with slotted web

HSKY 200						Span [m]												
t_n [mm]		Load type			d_{cs} [mm]	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7	6.0	6.3	6.6
1,0	ULS	q	---	[kN/m]	100	1.671	1.390	1.173	1.003	0.868	0.758	0.667	0.592	0.529	0.475	0.429	0.390	0.355
		N	Concentric	[kN]	100	17.826	17.747	17.665	17.580	17.492	17.401	17.306	17.208	17.105	16.999	16.888	16.771	16.650
		N	Eccentric	[kN]	100	8.018	7.968	7.916	7.864	7.810	7.756	7.701	7.645	7.589	7.531	7.472	7.412	7.351
		q	---	[kN/m]	300	1.641	1.365	1.152	0.985	0.852	0.744	0.655	0.581	0.519	0.467	0.421	0.383	0.349
		N	Concentric	[kN]	300	17.552	17.552	17.552	17.552	17.492	17.401	17.306	17.208	17.105	16.999	16.888	16.771	16.650
		N	Eccentric	[kN]	300	8.018	7.968	7.916	7.864	7.810	7.756	7.701	7.645	7.589	7.531	7.472	7.412	7.351
		q	---	[kN/m]	600	1.616	1.344	1.134	0.970	0.839	0.732	0.645	0.572	0.511	0.459	0.415	0.377	0.343
		N	Concentric	[kN]	600	17.280	17.280	17.280	17.280	17.280	17.280	17.280	17.208	17.105	16.999	16.888	16.771	16.650
		N	Eccentric	[kN]	600	8.018	7.968	7.916	7.864	7.810	7.756	7.701	7.645	7.589	7.531	7.472	7.412	7.351
	SLS	q	---	[kN/m]	---	2.558	1.996	1.584	1.276	1.042	0.861	0.719	0.606	0.515	0.442	0.381	0.331	0.290
		N	Eccentric	[kN]	---	38.074	34.510	31.562	29.084	26.969	25.143	23.550	22.148	20.904	19.793	18.795	17.893	17.074
1,2	ULS	q	---	[kN/m]	100	2.181	1.965	1.701	1.455	1.258	1.099	0.967	0.858	0.767	0.689	0.622	0.565	0.515
		N	Concentric	[kN]	100	26.155	26.029	25.891	25.747	25.598	25.442	25.278	25.108	24.929	24.741	24.543	24.335	24.115
		N	Eccentric	[kN]	100	11.722	11.639	11.554	11.467	11.378	11.288	11.196	11.102	11.006	10.909	10.809	10.706	10.601
		q	---	[kN/m]	300	2.181	1.965	1.664	1.423	1.231	1.075	0.946	0.840	0.750	0.674	0.609	0.553	0.504
		N	Concentric	[kN]	300	25.581	25.581	25.581	25.581	25.581	25.442	25.278	25.108	24.929	24.741	24.543	24.335	24.115
		N	Eccentric	[kN]	300	11.722	11.639	11.554	11.467	11.378	11.288	11.196	11.102	11.006	10.909	10.809	10.706	10.601
		q	---	[kN/m]	600	2.181	1.932	1.631	1.395	1.206	1.053	0.928	0.823	0.735	0.660	0.597	0.542	0.494
		N	Concentric	[kN]	600	25.076	25.076	25.076	25.076	25.076	25.076	25.076	25.076	24.929	24.741	24.543	24.335	24.115
		N	Eccentric	[kN]	600	11.722	11.639	11.554	11.467	11.378	11.288	11.196	11.102	11.006	10.909	10.809	10.706	10.601
	SLS	q	---	[kN/m]	---	3.108	2.425	1.924	1.550	1.266	1.046	0.873	0.736	0.626	0.537	0.463	0.403	0.352
		N	Eccentric	[kN]	---	46.262	41.931	38.350	35.338	32.769	30.550	28.614	26.911	25.400	24.050	22.837	21.741	20.746
1,5	ULS	q	---	[kN/m]	100	2.741	2.469	2.246	2.060	1.903	1.687	1.486	1.318	1.177	1.058	0.956	0.867	0.791
		N	Concentric	[kN]	100	40.779	40.734	40.479	40.210	39.928	39.630	39.316	38.984	38.631	38.257	37.859	37.436	36.984
		N	Eccentric	[kN]	100	18.278	18.129	17.975	17.818	17.657	17.493	17.324	17.151	16.973	16.790	16.601	16.406	16.203
		q	---	[kN/m]	300	2.741	2.469	2.246	2.060	1.877	1.639	1.443	1.280	1.143	1.027	0.928	0.843	0.768
		N	Concentric	[kN]	300	39.609	39.609	39.609	39.609	39.609	39.609	39.316	38.984	38.631	38.257	37.859	37.436	36.984
		N	Eccentric	[kN]	300	18.278	18.129	17.975	17.818	17.657	17.493	17.324	17.151	16.973	16.790	16.601	16.406	16.203
		q	---	[kN/m]	600	2.741	2.469	2.246	2.060	1.825	1.594	1.403	1.245	1.112	0.999	0.903	0.819	0.747
		N	Concentric	[kN]	600	38.522	38.522	38.522	38.522	38.522	38.522	38.522	38.522	38.522	38.257	37.859	37.436	36.984
		N	Eccentric	[kN]	600	18.184	18.129	17.975	17.818	17.657	17.493	17.324	17.151	16.973	16.790	16.601	16.406	16.203
	SLS	q	---	[kN/m]	---	3.906	3.047	2.418	1.948	1.590	1.314	1.097	0.925	0.787	0.674	0.582	0.506	0.442
		N	Eccentric	[kN]	---	58.134	52.692	48.193	44.408	41.178	38.390	35.958	33.817	31.918	30.222	28.698	27.320	26.070

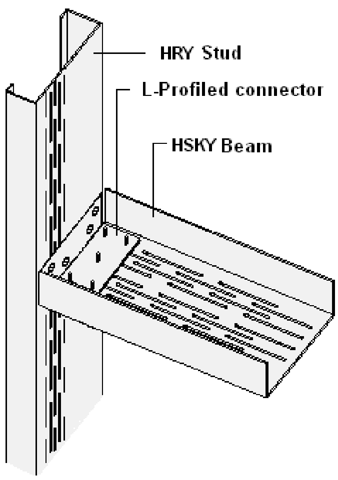
D – Static design of profiles with slotted web

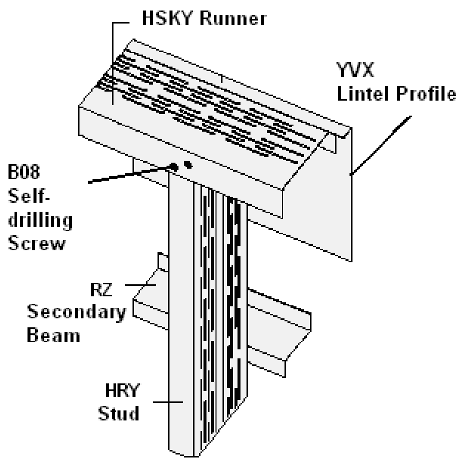
5. Design of Connections

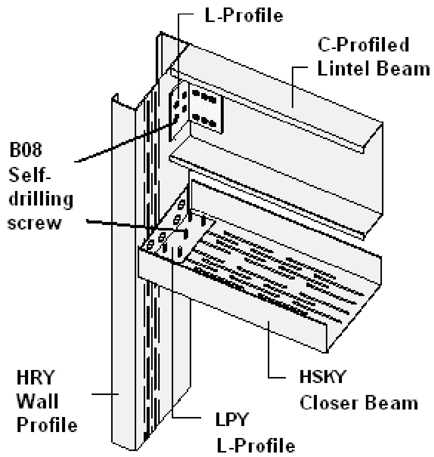
5.1. Type, material and geometry of the fastening element
The connection between the slotted light-gauge profiles can be realized by means of B08 type of self-drilling screws provided by Lindab. The relevant characteristics of the screw are summarized as follows.
B08 self-drilling screw with low head

- Material: carbon steel according to Swedish Standard SIS1370 (T8 quality)
(tensile strength: 8.0kN/screw; shear strength: ~5.2kN/screw/sheared area)
- Surface finish: hot-dip galvanized (12 microns of zinc layer; corrosion class C1 according to EN ISO 12944-2)
- Size: 4.8x16mm (tolerance: 3% in diameter; 5% in length of the screw)
- Drilling capacity: maximum 2x1.5=3.0mm

5.2. Structural details of the connections
Some typical connections can be seen in the next Figures. The connection is generally realized by means of fastenings subjected to shear. The connected members can be fastened with the appropriate number of screws either directly or through L-profiled angle elements.





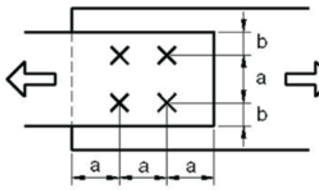


D – Static design of profiles with slotted web

5.3. Static design of the fasteners

Static check of self-drilling screws should be undertaken according to Swedish Code [4], as well as the design of the members themselves are. The safety class 1 is taken into account (see also subchapter 2.3.3.).

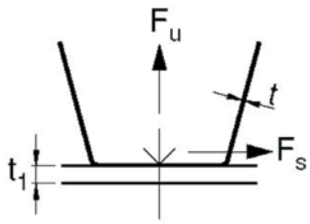
Minimal screw distances:



- From each other: 3d (d is the diameter)
- From the member edge parallel to the force direction: 3d
- From the member edge perpendicular to the force direction: 1.5d

Check of load-bearing capacity

In general, there are two kinds of acting force depending on the load direction for the screw: shearing or tensile force (F_s and F_u). Let the thickness of the sheet under the screw head be ”t”, while the one of the other sheet is ”t_1”. (Because of this distinguishing, it is very important to check the designed position of the screw on site!)



In the function of the direction of the acting load, different failure modes should be taken into account.

In case of shear force (F_s):

- Shearing failure of the screw
- Failure of edge of hole in the sheet
- Screw tilting

In case of tension force (F_u):

- Tensile failure of the screw
- Pull-out of the screw from the supporting sheet
- Pull-through (punching through) failure under the screw head

The resistance values of B08 type self-drilling screws for both shear and tension are tabulated in the next subchapter. The resistances have been determined on the base of laboratory test results and the regulation of the Swedish Code [4].

The application field of the tables is the design of structural profile-to-profile sheared connections (t=1.0-1.2-1.5mm) and profile-to-trapezoidal sheeting, as well (t=0.4-0.5-0.6-0.7mm). This latter use is necessary in case of trapezoidal sheeting applied as cladding.

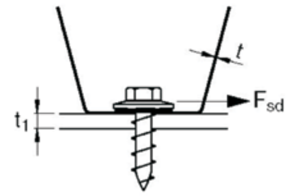
Interaction formula in case of tension and shearing force:

$$\left(\frac{F_u}{F_{ud}}\right)^2 + \left(\frac{F_s}{F_{sd}}\right)^2 \leq 1$$

D – Static design of profiles with slotted web

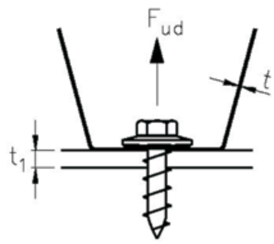
5.4. Design tables for B08 structural self-drilling screw

5.4.1 Shearing resistance (F_s; kN/screw)



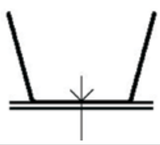
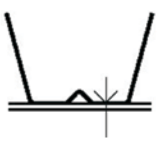
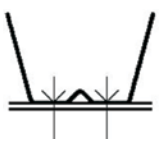
Nominal thickness t_{nom} (mm)	Design thickness t (mm)	Yield strength f_y (N/mm²)	d=4.8mm	
			t_1=t	t_1=2.5t
0.4	0.32	250	**0.28**	**0.61**
0.5	0.41	250	**0.40**	**0.79**
0.6	0.52	250	**0.56**	**0.98**
0.7	0.60	350	**1.00**	**1.61**
1.0	0.93	350	**1.93**	**2.50**
1.2	1.13	350	**2.58**	**3.04**
1.5	1.42	350	**3.63**	**3.82**

5.4.2 Pull-out resistance (F_{ud1}; kN/screw)



Nominal thickness $t_{1,nom}$ (mm)	Design thickness t_1 (mm)	f_y =350 N/mm² d=4.8mm
1.0	0.93	**1.02**
1.2	1.13	**1.38**
1.5	1.42	**1.93**

5.4.3 Pull-through (punching through) resistance (Fud2; kN/screw)

Data for the sheeting under the screw head (d=8mm)				
Nominal thickness t_{nom} (mm)	Yield strength f_y (N/mm²)			
0.4	250	**0.36**	**0.32**	**0.25**
0.5	250	**0.46**	**0.41**	**0.32**
0.6	250	**0.57**	**0.52**	**0.40**
0.7	350	**0.95**	**0.85**	**0.66**
1.0	350	**1.46**	**1.32**	**1.03**
1.2	350	**1.78**	**1.60**	**1.25**

D – Static design of profiles with slotted web

References

In accordance with the above-mentioned basis, the following design standards are referred in this Design Guide:

[1] MSZ 15020 – 86: Design of load bearing structures of buildings. General rules.

[2] MSZ 15021/1 – 86: Design of load bearing structures of buildings. Design loads for buildings.

[3] MSZ 15021/2 – 86: Design of load bearing structures of buildings. Stiffness requirements.

[4] StBK-N5: Swedish Code for Light-Gauge Metal Structures, Swedish Institute of Steel Construction, 1982.

[5] BSK94: Regulations for Steel Structures, Swedish Institute of Steel Construction, 1994.

Further references:

[6] Thöyrä, T.: **Strength of Slotted Steel Studs**, Licentiate Thesis, Royal Institute of Technology, Department of Structural Engineering, TRITA-BKN. Bulletin 6, 2001.

[7] Norlin, B.: **Ofullständig samverkan i flerskitsbalkar av trä**. Del av kompendium i lättbyggnad. Teknisk Rapport, 1997.

E
PROPOSED CONSTRUCTION SOLUTIONS (DRAWING LIBRARY)

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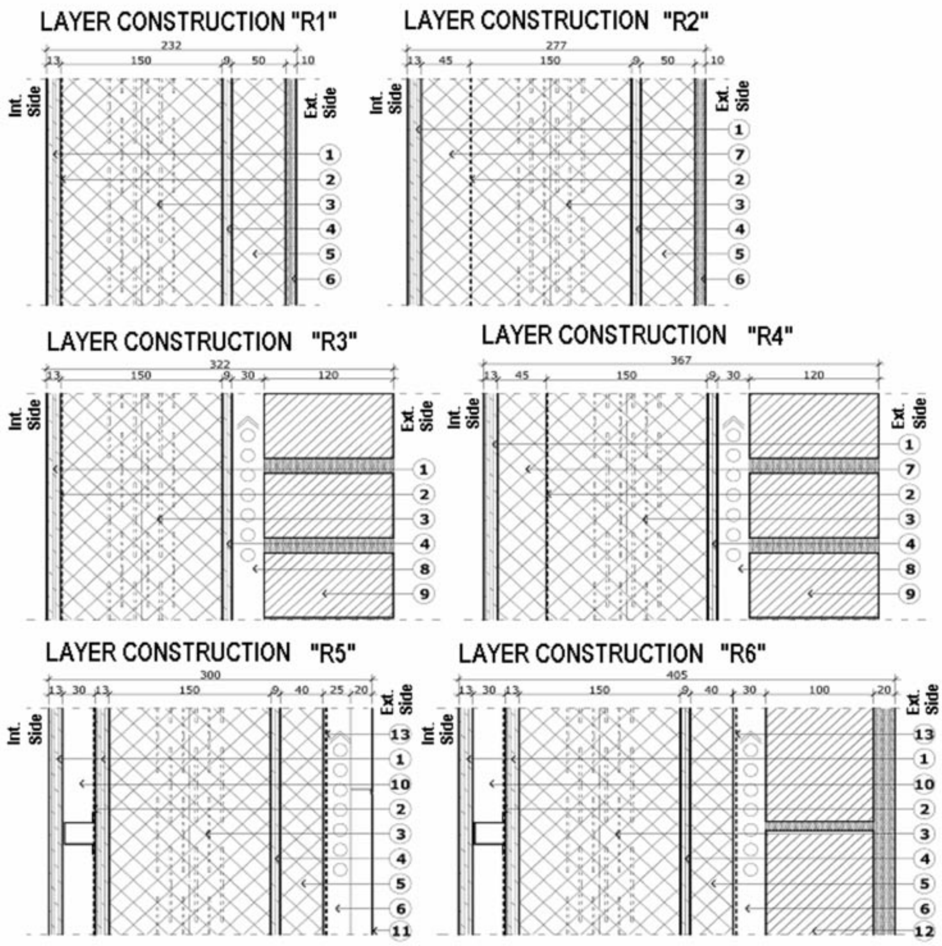
E – Proposed construction solutions (drawing library)

1. Exterior Wall Construction made of Slotted Profiles

1.1. Layer constructions

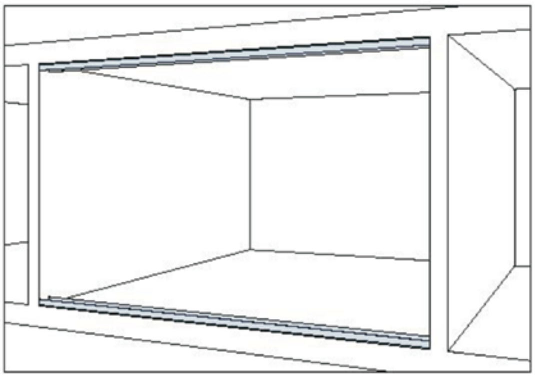


No.	DESCRIPTION	BUILDING MATERIALS
1	Internal cladding board	15-18 mm fire resistant gypsum board; (1-2)x12,5 mm gypsum board; 16 mm V.100 G.E1 impregnated wooden chipboard; 12-15 mm OSB board; BETONYP board;
2	Vapour barrier layer	Vapour tight foil (S_d>50 m)
3	Studs + Insulation	120-150-200 mm LINDAB slotted stud HRY-C + glass wool or rock wool insulation
4	External cladding board	6-12-15 mm OSB board, BETONYP board, 12,5-15 mm gypsum fibre board; 9,5 mm water-proof gypsum board; 16 mm V.100 G.E1 impregnated wooden chipboard
5	Additional external insulation	3-6 cm polystyrene foam; 4-6 cm faced mineral wool + wind-tight foil + ventilated air space
6	External plaster (mortar)	Textile glass net + skin plaster; 15-25 mm coarse or scoured plaster, scratch coat
7	Additional internal insulation	4-5 cm polystyrene foam
8	Ventilated air space	
9	Façade brick wall	Frost resistant façade brick (clinker)
10	Installation gap provided by spacers (secondaries)	Lindab hat or Z-profiles
11	Lightweight mounted façade cladding	E.g. Lindab façade wall cassette cladding
12	Additional brick wall	10 cm partition wall brick, 12 cm hollow brick, etc.

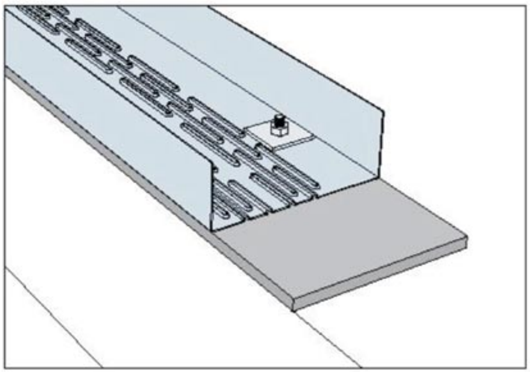
E – Proposed construction solutions (drawing library)

1.2. Constructional details, erection proposals

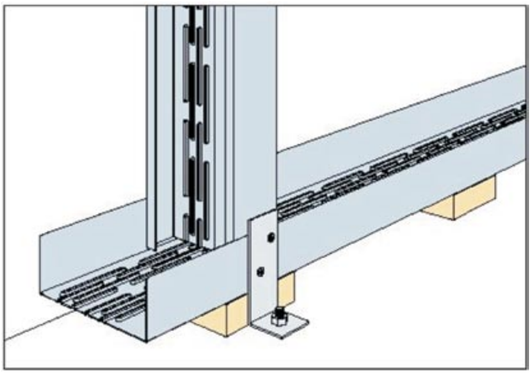
1.2.1. Fixing HSKY runner to support, anchoring



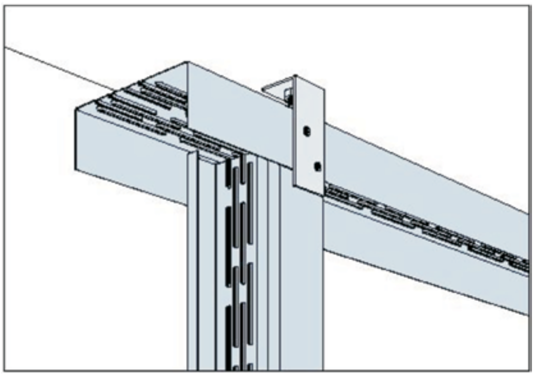
HSKY runner should be fixed by every 400mm to the cleaned base (on the roof and on the floor)



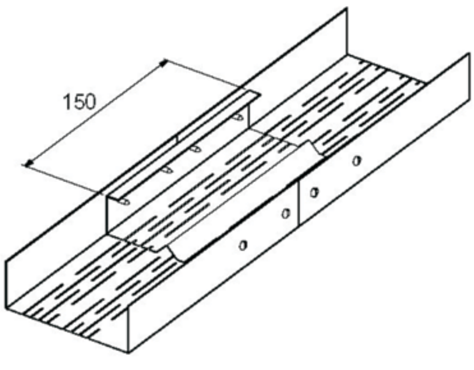
Between **HSKY** runner and the floor base the **PD10** polyethene sealant strip must be placed! Do not apply the screw in the slots.



In case of uneven, rough base wooden wedges and steel angles can be used for levelling and fixing. The gap between **HSKY** runner and the base must always be filled in by insulation!



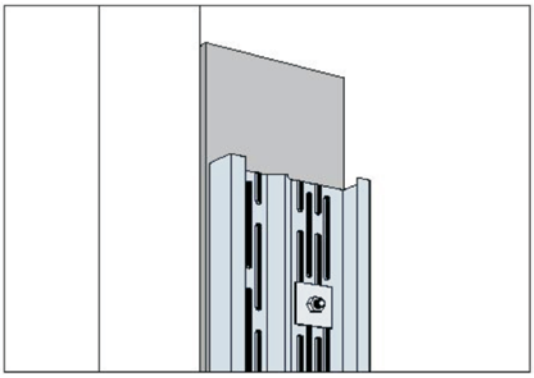
Fixing of upper HSKY runner can be solved by steel angle, as well. It is better to hide the horizontal flange of the angle in the wall.



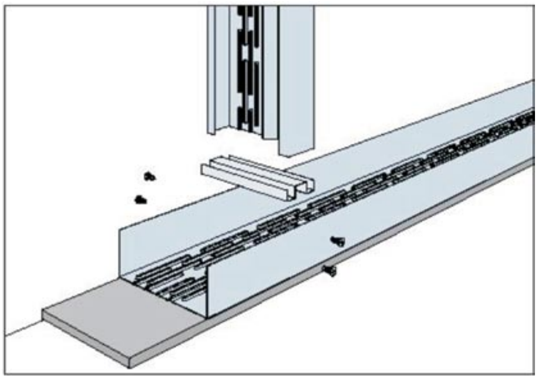
The connection of **HSKY** runners can be solved by using splices made of **HRY** profiles

E – Proposed construction solutions (drawing library)

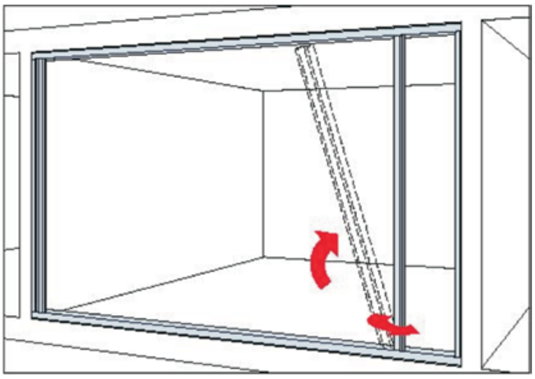
1.2.2. Fixing HRY stud to HSKY runner



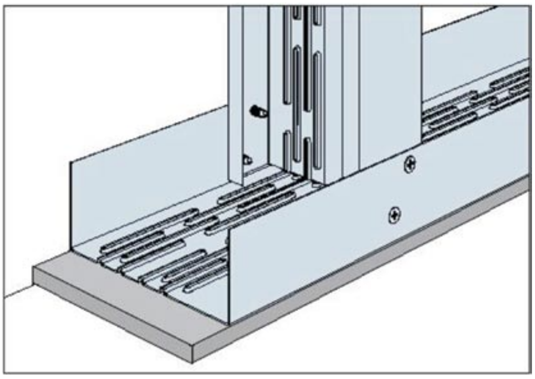
Between the end **HRY** stud and the base the **PD10** sealant strip must be used. Fixing should be made in every 300-400mm.



In case of compression studs it is necessary to place the **AÄ** end stiffener piece into the **HRY** profile before fixing to **HSKY** runner.

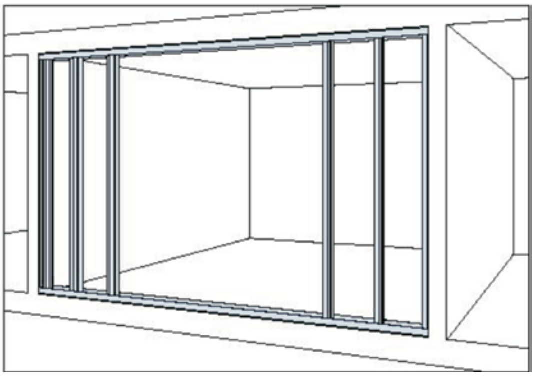


After placing the end profiles, the intermediate **HRY** studs can be positioned into the runners starting from the edge.

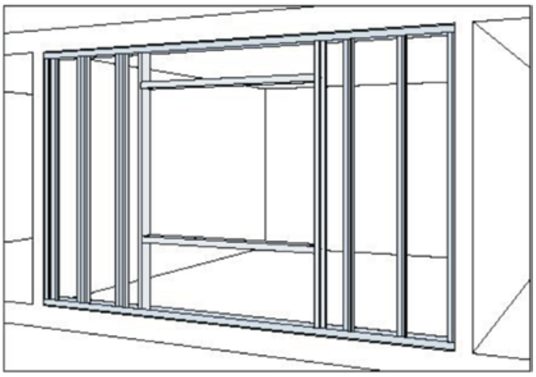


HRY studs should be fixed to the flange of the **HSKY** runner by 2 pcs of **B08** structural self-drilling screws.

1.2.3. Openings

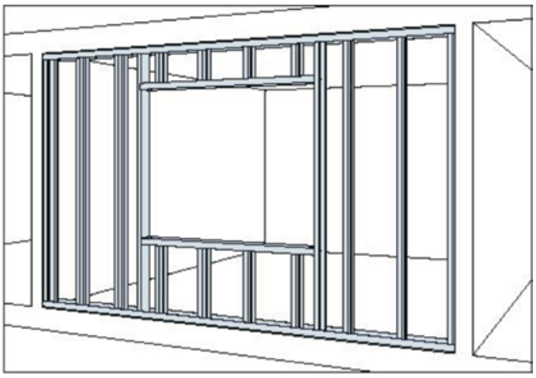


At the edge of the opening the **HRY** studs (generally with higher thickness) should be placed as the flanges are out of the opening

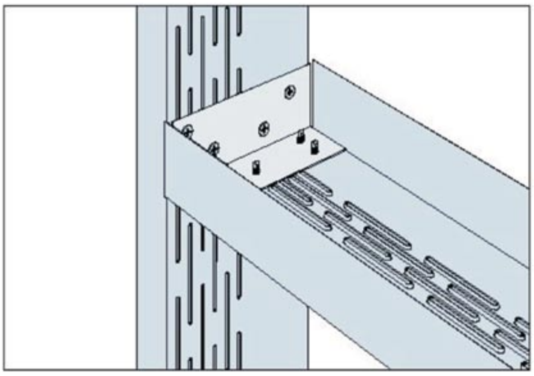


Upper and lower edge of the opening can be provided by **HSKY** profiles placed as the flanges are out of the opening.

E – Proposed construction solutions (drawing library)

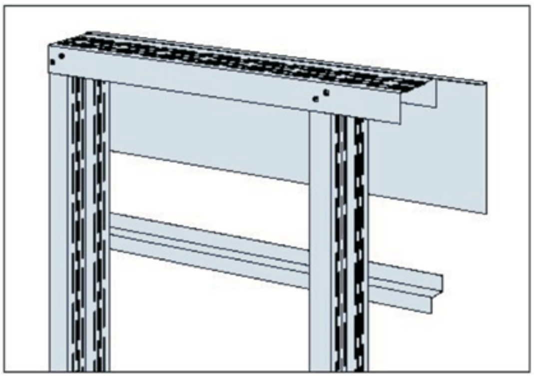


Then the placing of intermediate shorter **HRY** studs is followed under and above the opening.

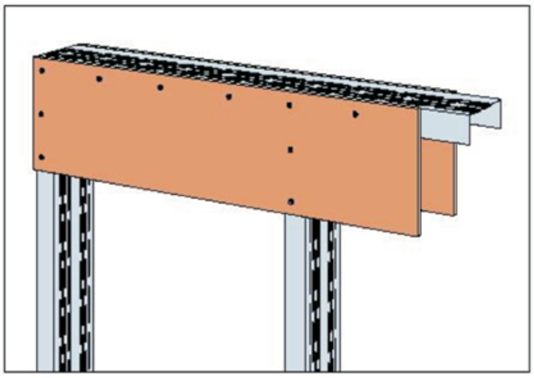


The connection between the **HRY** studs and the upper/lower **HSKY** profile around the opening can be solved by means of **LPY** L-profiled connection pieces screwed.

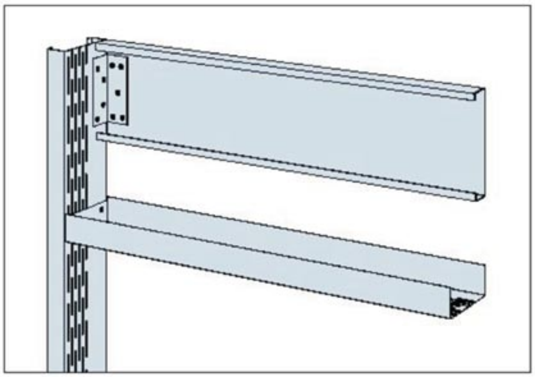
1.2.4. Lintel beams



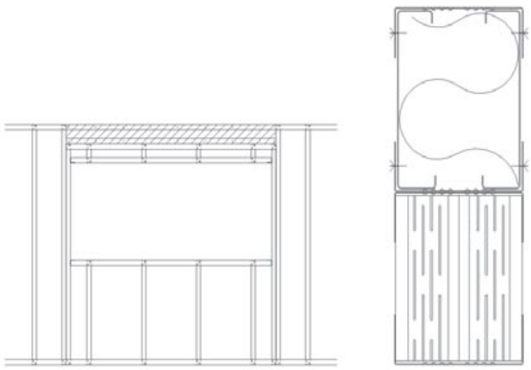
The simplest way of lintel beam is realized by means of L-profile **YVX** that works only together with the screwed board, in case of opening width of 600-2100mm.



Alternatively, the lintel beam can be made of stronger boards (solid wood, plywood, OSB etc.) on both sides in case of opening width of 600-2100mm).



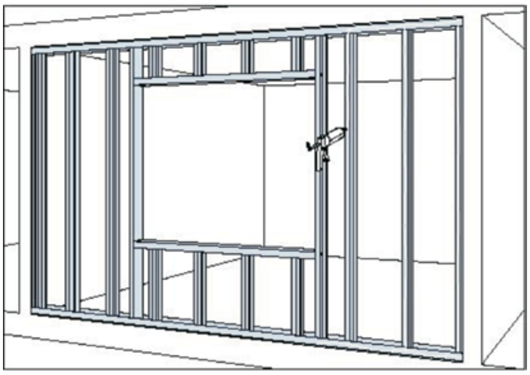
In case of higher opening width (>2100mm) standard **C-profiles** can be used, connected by screwed L-angles **LPY**.

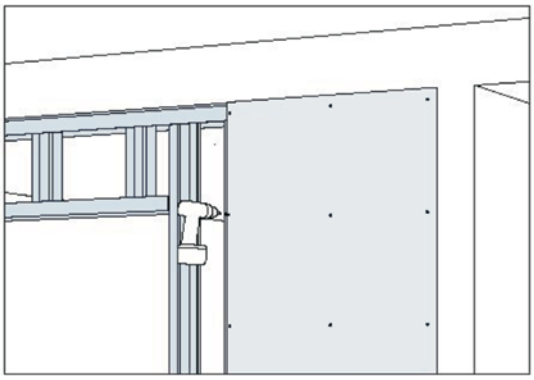


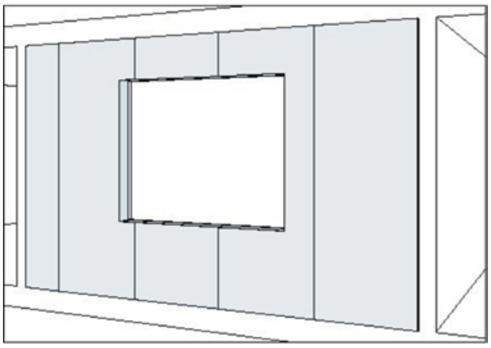
For even higher openings (>>2100mm), the lintel beam can be a box section made of **C- and HSKY profiles.**

E – Proposed construction solutions (drawing library)

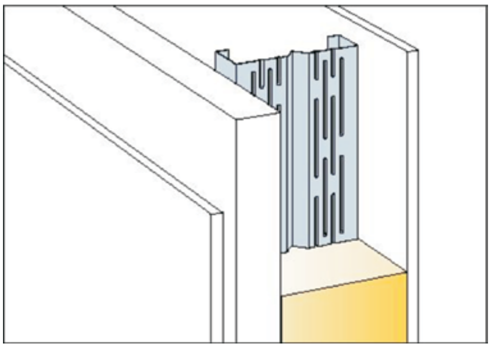
1.2.5. External board cladding

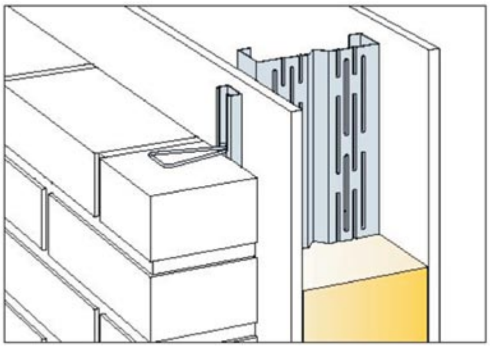

Applying plaster board glue to the studs and runners in order to temporarily fix the boards.

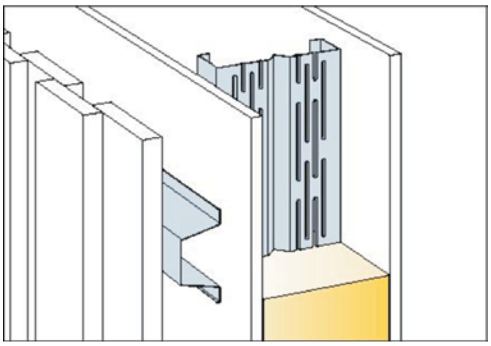

Fastening the plaster boards with plaster board screws to the lightweight steel frame.

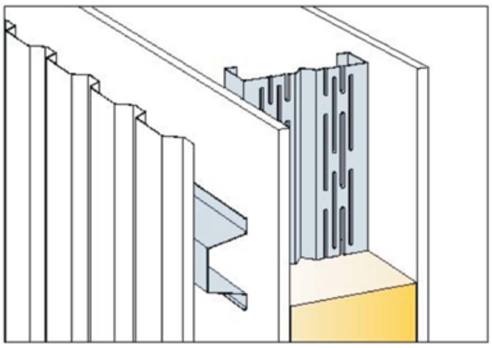

Covering the rest of the infill wall with plaster board until complete cladding.

Alternative external façade claddings:


Additional insulation + plaster, mortar (R1; R2)

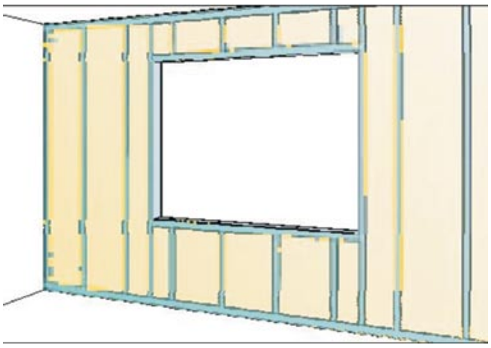

Façade brick wall (R3, R4)


Lightweight mounted façade (e.g. wood) (R5)

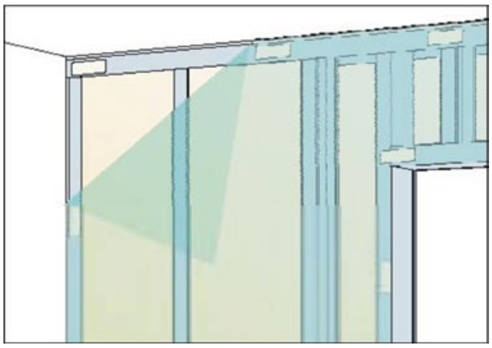

Simple trapezoidal sheeting (R5)

E – Proposed construction solutions (drawing library)

1.2.6. Insulation and vapour barrier foil

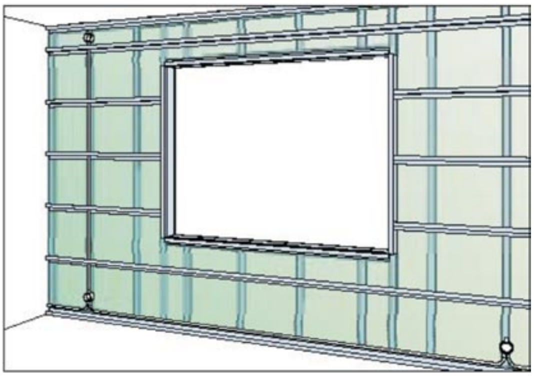


Placing the mineral wool insulation inside the wall, by filling every space.

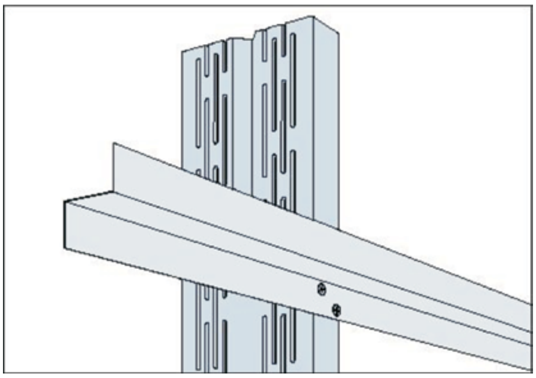


Fastening the plastic vapour barrier foil with double sided adhesive tape. Important that the plastic foil should be tight with no rips!

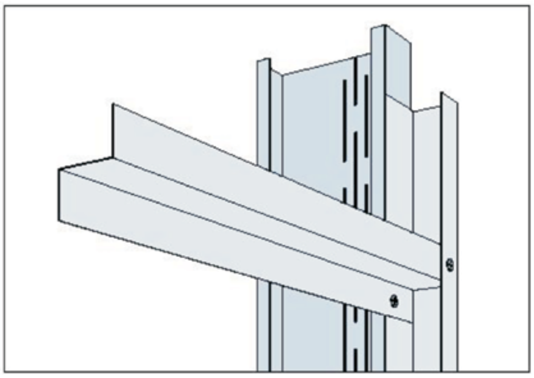
1.2.7. Szerelő réteg kialakítása (vezetékek, szerelvények számára)



To create an installation layer secondary (spacer) profiles (**RZ** or hat) should be used.



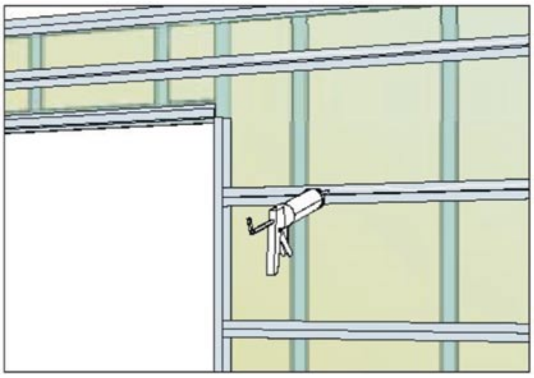
Connection of **HRY** stud and **RZ** spacer profile with 2 pcs of **B08** self-drilling screws.



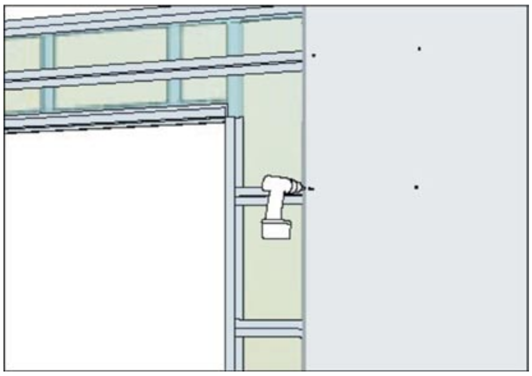
Connection of **HRY** stud, **RZ** spacer profile and **RCY** edge profile around openings.

E – Proposed construction solutions (drawing library)

1.2.8. Internal board cladding

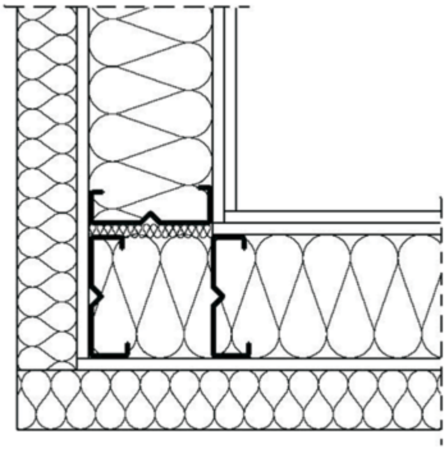


After the electrical installation are placed, applying board glue to the **RZ** spacer profiles is followed.

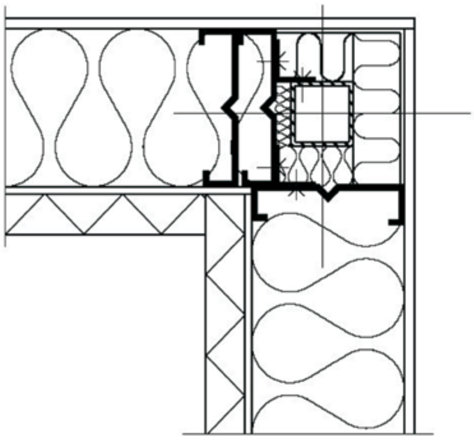


Fastening the plaster boards with plaster board screws to the lightweight steel frame.

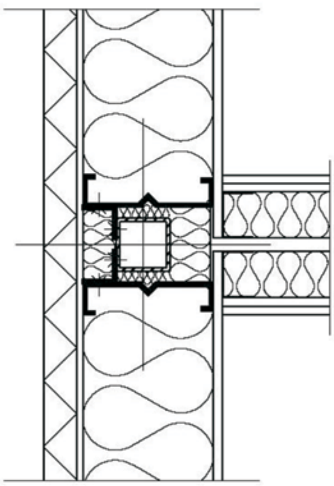
1.2.9. Wall connections



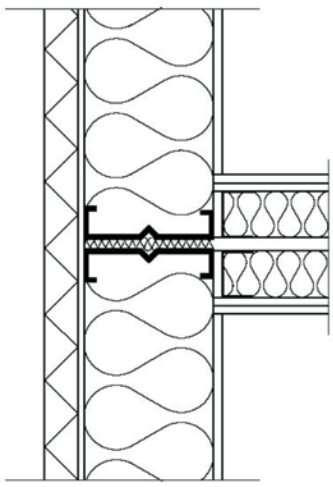
Wall corner detail #1.
(horizontal section)



Wall corner detail #2:
in case of hot-rolled steel primary column inside the wall (horizontal section).



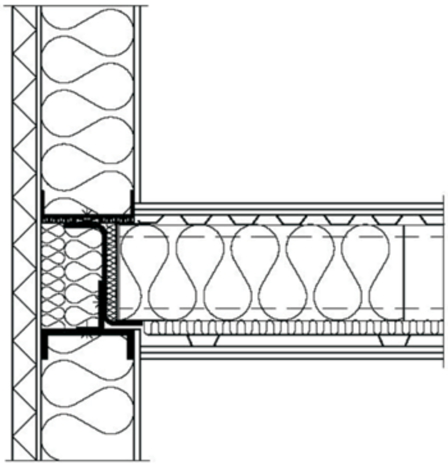
Wall T-connection #1:
between two apartments
(horizontal section)



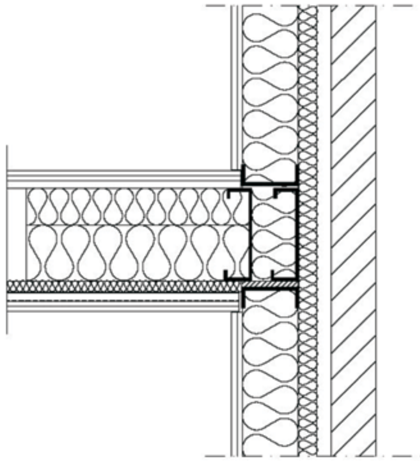
Wall T-connection #2:
case of hot-rolled steel primary column inside the wall (horizontal section)

E – Proposed construction solutions (drawing library)

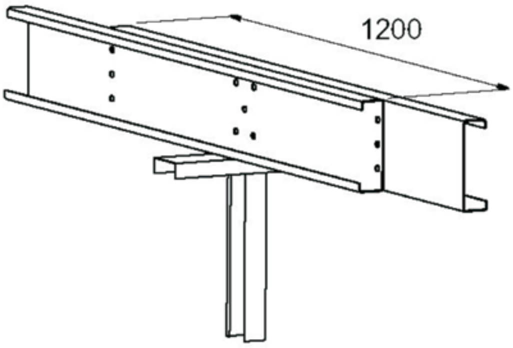
1.2.10. Floor connections



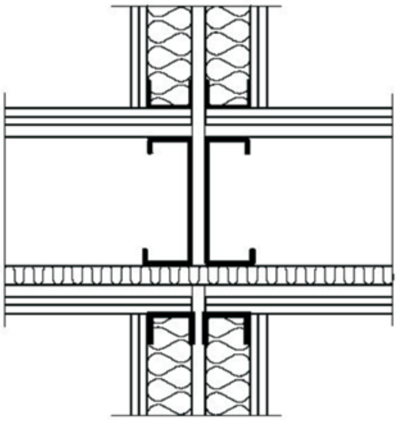
Exterior wall – floor connection #1.
(vertical section)



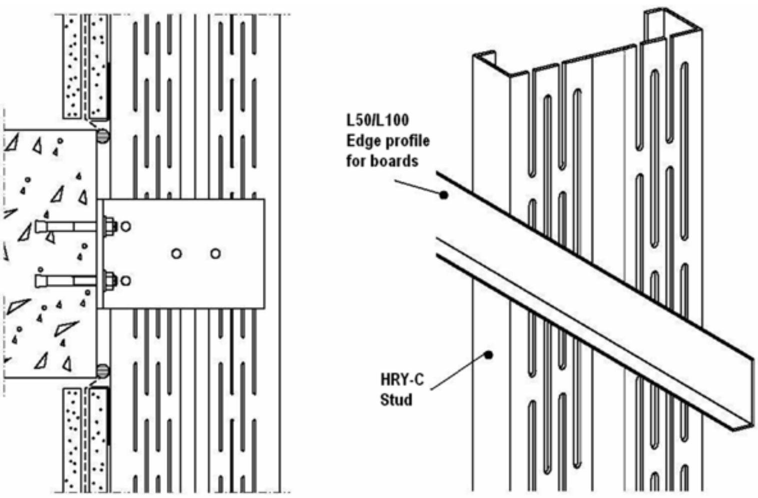
Exteoir wall – floor #2.
(vertical section)



Intermediate wall – floor beam connection
(3D view).



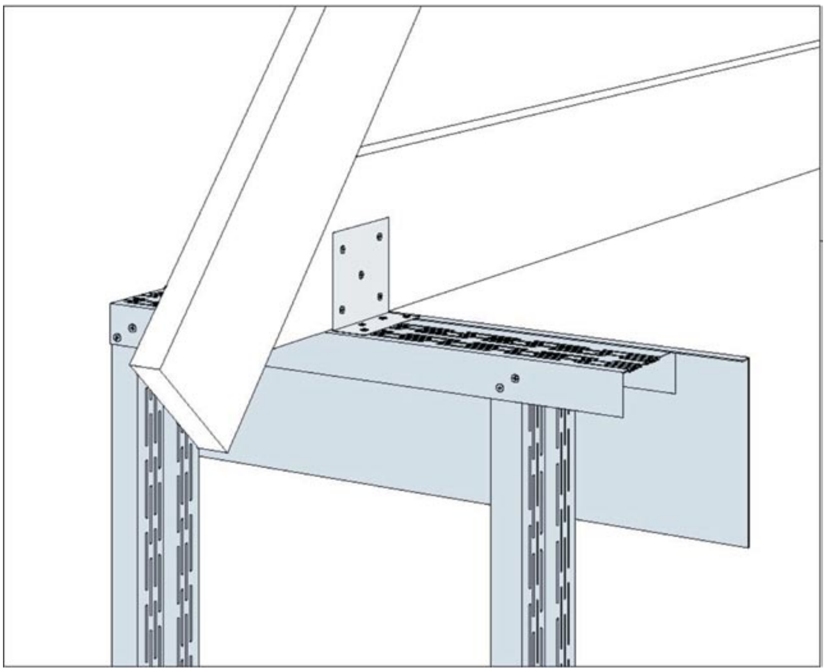
Doubled partition wall – floor connection between
apartments (vertical section)



Exterior curtain wall – Reinforced concrete floor slab connection
(vertical section and 3D view)

E – Proposed construction solutions (drawing library)

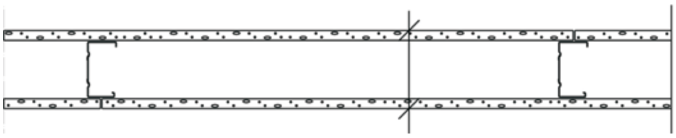
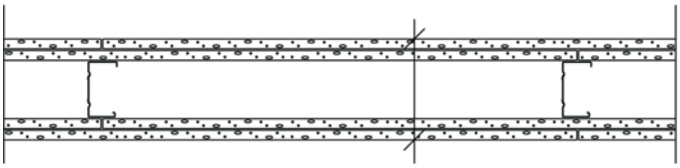
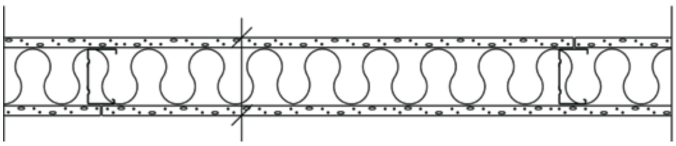
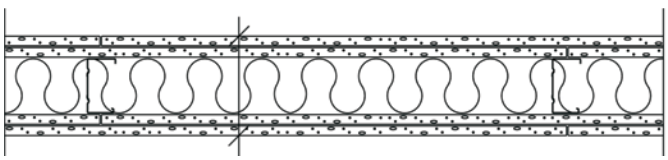
1.2.11. Connection to lightweight roof structure



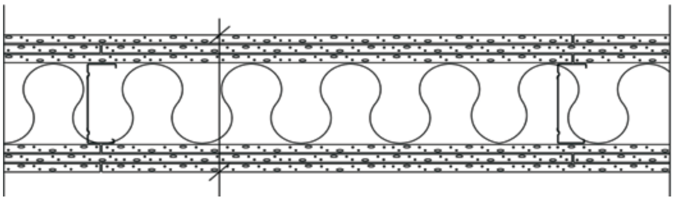
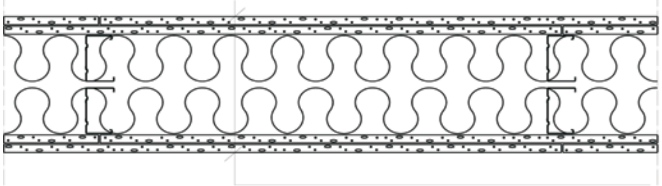
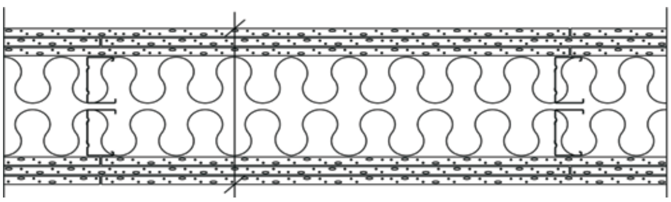
Load-bearing exterior wall – wooden truss roof girder connection.

E – Proposed construction solutions (drawing library)

2. Layer Constructions of Partition Walls

WALL TYPE	CROSS-SECTION OF THE WALL	L_g=45 cm	L_g=60 cm
E70/70 101		R'_w = 34 dB $R'_{w \cdot C50-3150}$=32 dB T_h = 0.5 hour H_{max} = 4400 mm	R'_w = 34 dB $R'_{w \cdot C50-3150}$=32 dB T_h = 0.5 hour H_{max} = 3600 mm
E95/95 101	Cladding: 2x1x12.5 mm gypsum board	R'_w = 35 dB $R'_{w \cdot C50-3150}$=33 dB T_h = 0.5 hour H_{max} = 5800 mm	R'_w = 35 dB $R'_{w \cdot C50-3150}$=33 dB T_h = 0.5 hour H_{max} = 5000 mm
E70/70 202		R'_w = 42 dB $R'_{w \cdot C50-3150}$=39 dB T_h = 1.0 hour H_{max} = 4600 mm	R'_w = 43 dB $R'_{w \cdot C50-3150}$=40 dB T_h = 1.0 hour H_{max} = 4000 mm
E95/95 202	Cladding: 2x2x12.5 mm gypsum board	R'_w = 44 dB $R'_{w \cdot C50-3150}$=41 dB T_h = 1.0 hour H_{max} = 6300 mm	R'_w = 44 dB $R'_{w \cdot C50-3150}$=41 dB T_h = 1.0 hour H_{max} = 5500 mm
E70/70 101 + 70 mm insulation		R'_w = 37 dB $R'_{w \cdot C50-3150}$=32 dB T_h = 0.5 hour* H_{max} = 4400 mm	R'_w = 40 dB $R'_{w \cdot C50-3150}$=36 dB T_h = 0.5 hour* H_{max} = 3600 mm
E95/95 101 + 95 mm insulation	Cladding: 2x1x12.5 mm gypsum board	R'_w = 40 dB $R'_{w \cdot C50-3150}$=36 dB T_h = 0.5 hour* H_{max} = 5800 mm	R'_w = 42 dB $R'_{w \cdot C50-3150}$=36 dB T_h = 0.5 hour* H_{max} = 5000 mm
E120/120 101 + 120 mm insulation		R'_w = 42 dB $R'_{w \cdot C50-3150}$=37 dB T_h = 0.5 hour* H_{max} = 6600 mm	R'_w = 43 dB $R'_{w \cdot C50-3150}$=38 dB T_h = 0.5 hour* H_{max} = 5500 mm
E70/70 202 +70 mm insulation		R'_w = 50 dB $R'_{w \cdot C50-3150}$=44 dB T_h = 1.0 hour** H_{max} = 4600 mm	R'_w = 50 dB $R'_{w \cdot C50-3150}$=44 dB T_h = 1.0 hour** H_{max} = 4000 mm
E95/95 202 +95 mm insulation	Cladding: 2x2x12.5 mm gypsum board	R'_w = 50 dB $R'_{w \cdot C50-3150}$=43 dB T_h = 1.0 hour** H_{max} = 6300 mm	R'_w = 50 dB $R'_{w \cdot C50-3150}$=45 dB T_h = 1.0 hour** H_{max} = 5500 mm
E120/120 202 +120 mm insulation		R'_w = 52 dB $R'_{w \cdot C50-3150}$=44 dB T_h = 1.0 hour** H_{max} = 6500 mm	R'_w = 53 dB $R'_{w \cdot C50-3150}$=44 dB T_h = 1.0 hour** H_{max} = 5700 mm

E – Proposed construction solutions (drawing library)

FAL TÍPUSA	VÁLASZFAL METSZETE	L_g=45 cm	L_g=60 cm
E120/120 303 +120 mm insulation	 Cladding: 2x3x12.5 mm gypsum board	R'_w = 55 dB $R'_{w*C50-3150}$=48 dB T_h = 1.5 hour H_{max} = 6800 mm	R'_w = 56 dB $R'_{w*C50-3150}$=48 dB T_h = 1.5 hour H_{max} = 6000 mm
DD70/70 202 +140 mm insulation	 Cladding: 2x12x12.5 mm gypsum board	R'_w = 63 dB $R'_{w*C50-3150}$=55 dB T_h = 1.0 hour H_{max} = 3600 mm	R'_w = 63 dB $R'_{w*C50-3150}$=55 dB T_h = 1.0 hour H_{max} = 3100 mm
DD70/70 303 +140 mm insulation	 Cladding: 2x3x12.5 mm gypsum board	R'_w = 65 dB $R'_{w*C50-3150}$=58 dB T_h = 1.5 hour H_{max} = 3700 mm	R'_w = 65 dB $R'_{w*C50-3150}$=60 dB T_h = 1.5 hour H_{max} = 3200 mm

Remarks:

- Acoustic parameters:
  – R'_w weighted air-borne sound isolation (noise reduction) value can only be achieved in case of correct erection, air-tight sealants at all connection, both on the surface and edges. The fittings are to be chosen to suit the requirements from the plasterboard manufacturers' manuals.
  – $R'_{w,C50-3150}$ is the air-borne sound isolation (noise reduction) in the low frequency range (50-3150 Hz).
- Fire resistance values T_h are valid in case of the following insulation::
  * EI60 fire class of rock wool (density ≥ 30 kg/m^3)
  ** EI90 fire class of rock wool (density ≥ 30 kg/m^3).
- The maximum allowable height of the partition walls H_{max} is determined in the tables according to Swedish Standards (StBK-N5:1982; BSK94) and professional customs, such as:
  – In ultimate limit state (ULS), uniformly distributed surface load of 0.35 kN/m^2 is taken into account (possible wind load in generally closed internal rooms with some openings);
  – In ultimate limit state (ULS), uniformly distributed line load of 1.00 kN/m, acting horizontally in mid-height of the wall (Hmax/2), this load case is independent from the previous one;
  – In serviceability limit state (SLS), uniformly distributed line load of 0.50 kN/m, acting horizontally in mid-height of the wall (Hmax/2), maximum deflection of H/300 is considered.

Notes

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60
de ani

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