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UNIVERSITY OF TECHNOLOGY

TIMBER ENGINEERING - VSM196

LECTURE 8 –

TIMBER-FRAMED WALLS,
BEARING STRESSES, SLS,
SETTLEMENT

SPRING 2020

Topic

- Timber-framed walls, Bearing stresses, SLS, Settlement

- [DoTS: Chapter 3 (3.1.4) and Chapter 7 (7.2.1)]

Content

- Wall and construction types of timber buildings
- Assembly of light frame timber walls
- Design of timber-framed wall in ULS and SLS

- Exercises S1

Intended Learning Outcomes of this lecture

- You know different construction systems for timber buildings
- You can choose adequate wall systems for timber buildings
- You can determine the capacity of timber in compression perp. to grain
- You can calculate the vertical deformation of walls and timber members

Overview

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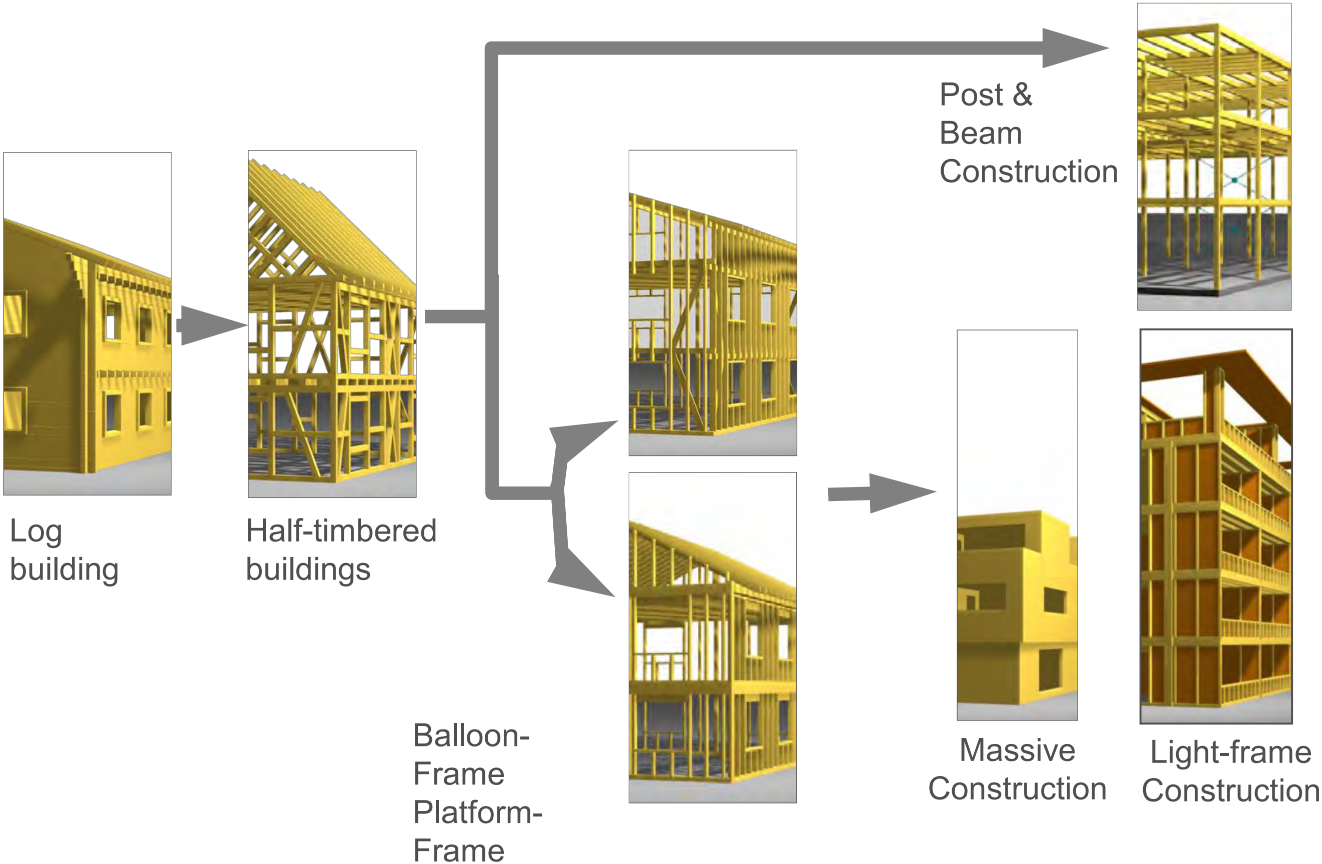
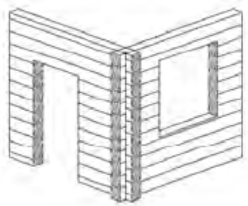
Wall and construction types

Construction types in timber

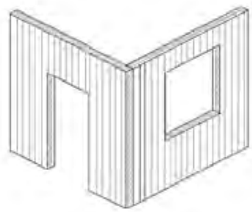


Common load bearing systems

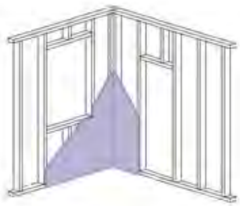
- Load-bearing walls



Log



CLT (or X-LAM)



Timber frame

- Post and beam system
- typically used for multi-storey buildings

Load-bearing walls

- No columns are in the system, only the walls

- The walls carry both vertical and horizontal load

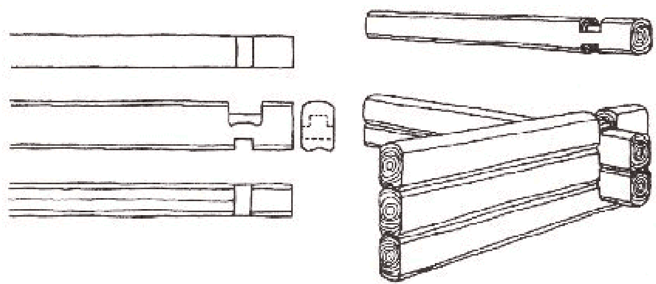
- Diaphragm action typically used for stabilization (bracing). (Sheathing, such as OSB, plywood or gypsum necessary in the case of timber frames)

- The sheathing material is also needed for fire resistance and sound insulation. Gypsum (inside) is the dominant material as both the fire, noise and resistance to be met.

Log Houses

Log houses

Corner profile



Log houses

- Examples of traditional log houses

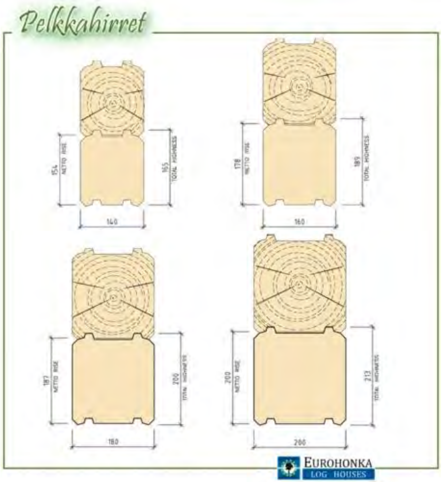
Log houses

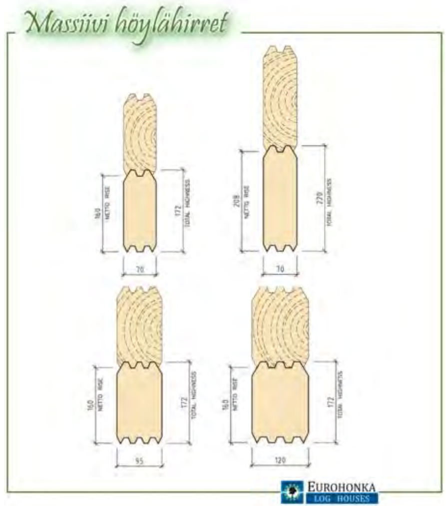
- Examples of modern log house

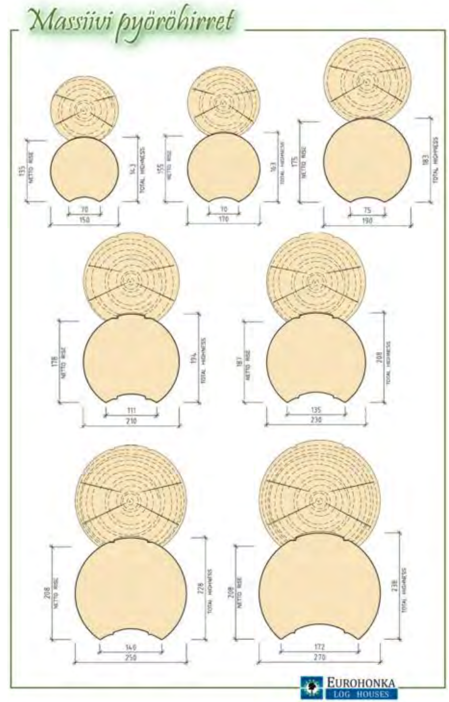
Blockbau, holzbaum.ch

Log houses

- Examples of modern log house



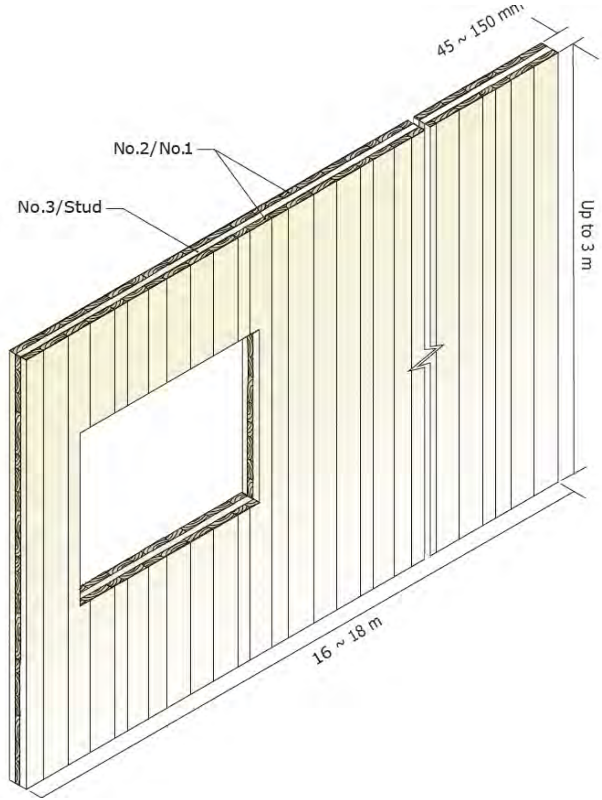




CLT Systems

CLT Systems

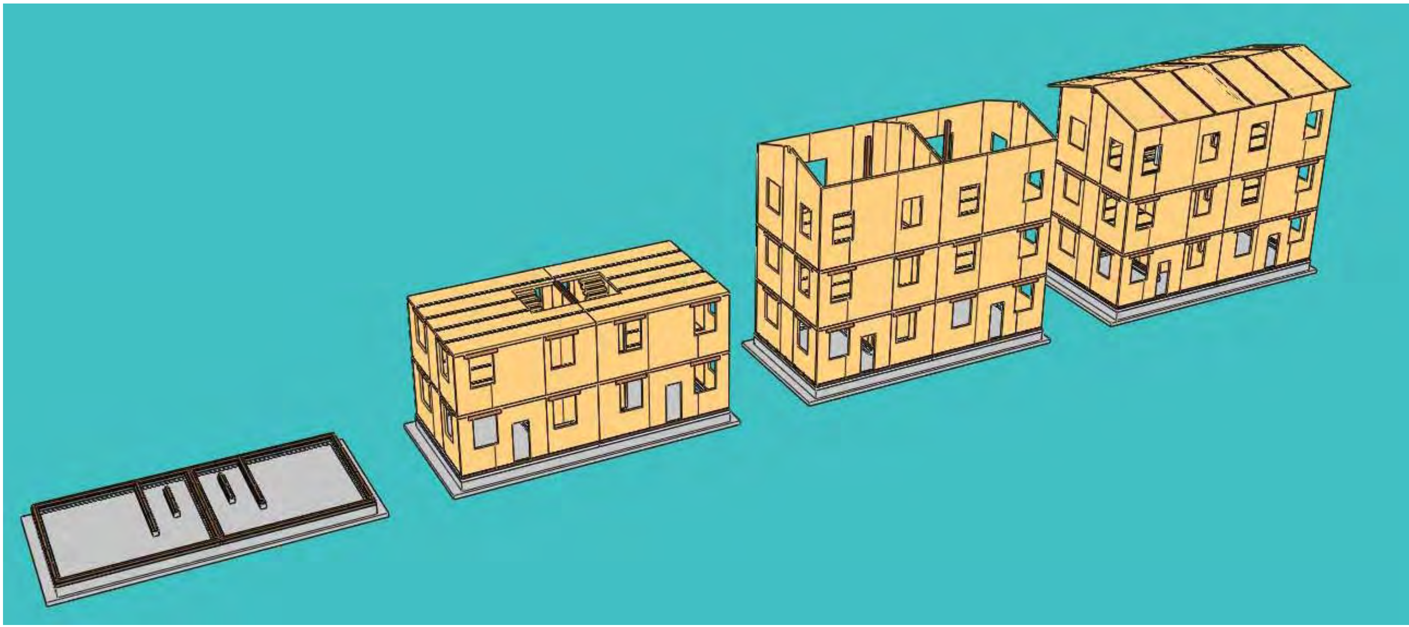
- Typical dimensions



CLT Systems

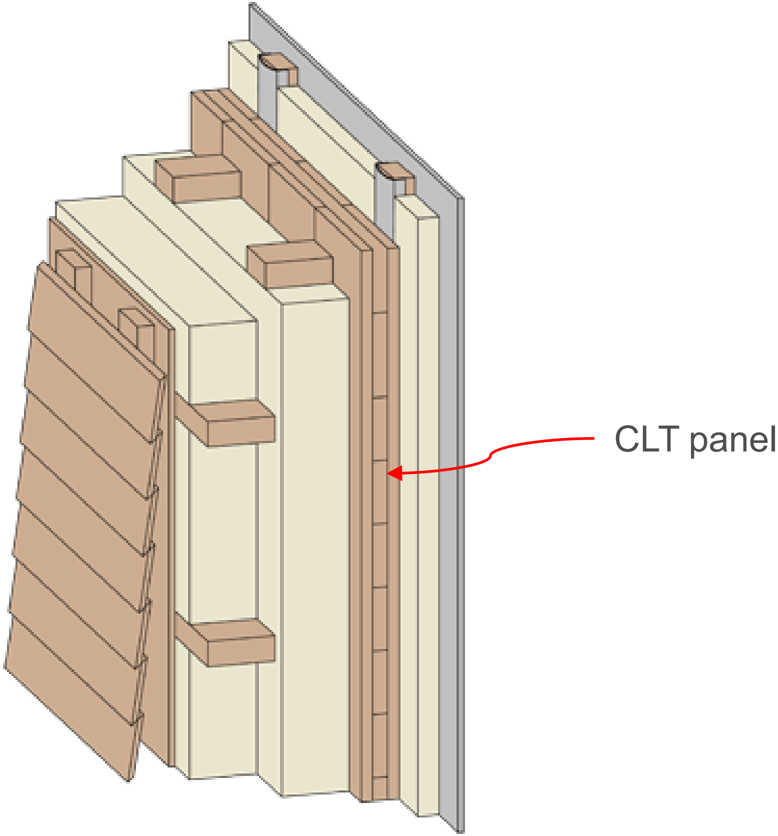
CLT Systems

- Construction phases



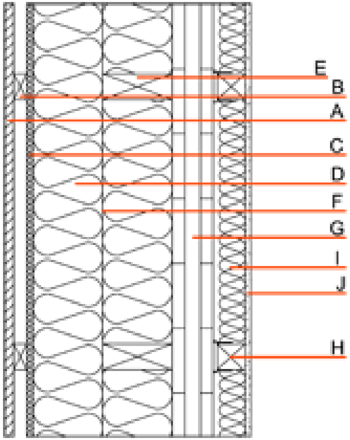
CLT Systems

- wall ”anatomy”



CLT Systems

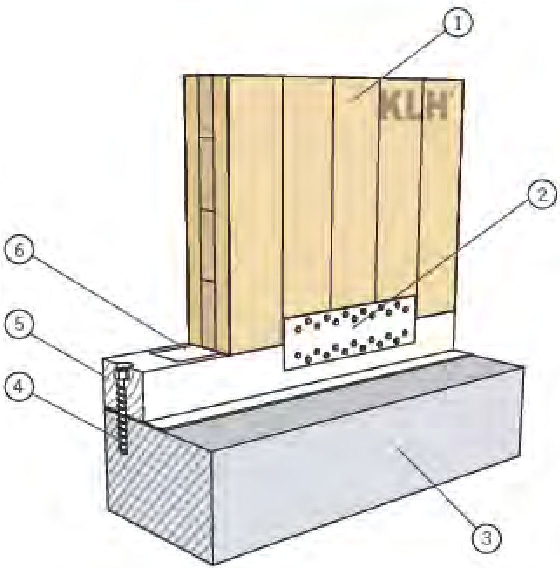
- wall ”anatomy”



	Thickn.	Building material
A	20.0	external wall cladding, e.g. pine, larch, thermowood, acetylated wood, etc
B	30.0	spruce wood battens offset (30/60) - ventilation
C	15.0	fibreboard (MDF)
D	160.0	finger-jointed solid construction timber cross; (60/160; c/c=600mm, typ.)
E	160.0	finger-jointed solid construction timber (60/160; c/c=600mm, typ.)
F	*	Insulation material
G	*	cross laminated timber ≥ 94,0; at least 3-layers, top layer at least 30mm)
H	80.0	spruce wood Battens on resilient clips (50/80; c/c=600mm, typ.)
I	*	Insulation material
J	12.5	gypsum plasterboards with improved properties at high temperatures (fire) or gypsum fibre board

CLT Systems

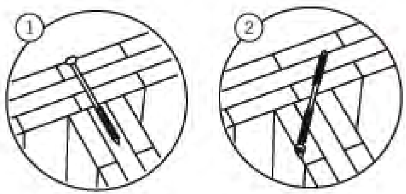
- some typical joint details:
  - Wall-Concrete Connection



1. KLH wall panel according to static requirements
2. E.g. BMF perforated plate for shear connection between KLH wall and sill
3. Concrete component (wall, ceiling, concrete slab)
4. Concrete screws for shear force transmission between sill and concrete
5. Oak or larch sill laid in mortar bed – with the entire surface resting on the base
6. Install joint tape, if necessary

CLT Systems

- some typical joint details:
  - Wall-Wall Connection
  - Ceiling-Wall Connection

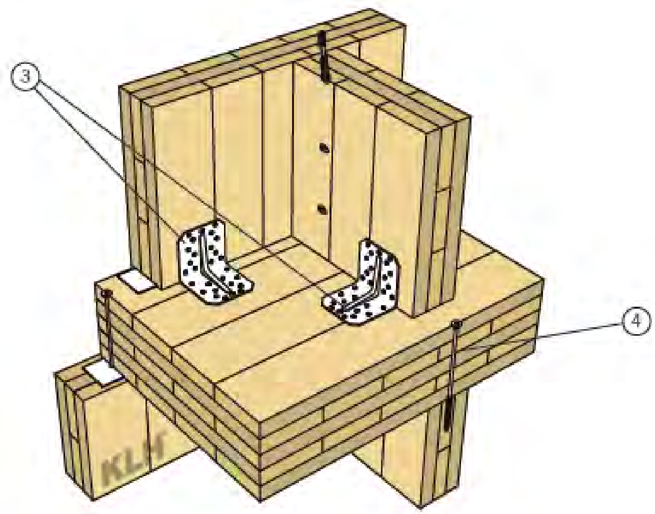


(1) Cross wall connection – screw connection from the outside

(2) Cross wall connection – screw connection from the inside

(3) Shear force transmission along the joint and tension anchorage of walls – e.g. BMF angle bracket – type, distance according to static requirements

(4) Screw connection of ceiling with walls according to static requirements



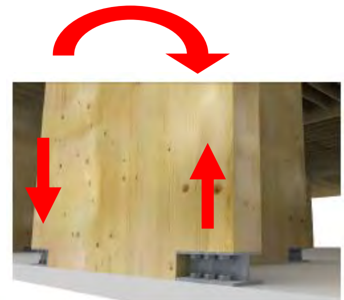
Post-and-beam system

Post-and-beam system

- TRÄ-8

Post-and-beam system
Floor with span up to 8 m
Moelven

Bracing unit: taking of overturning moment



Post-and-beam system

- Timber wall bracing

Post-and-beam system

Post-and-beam system

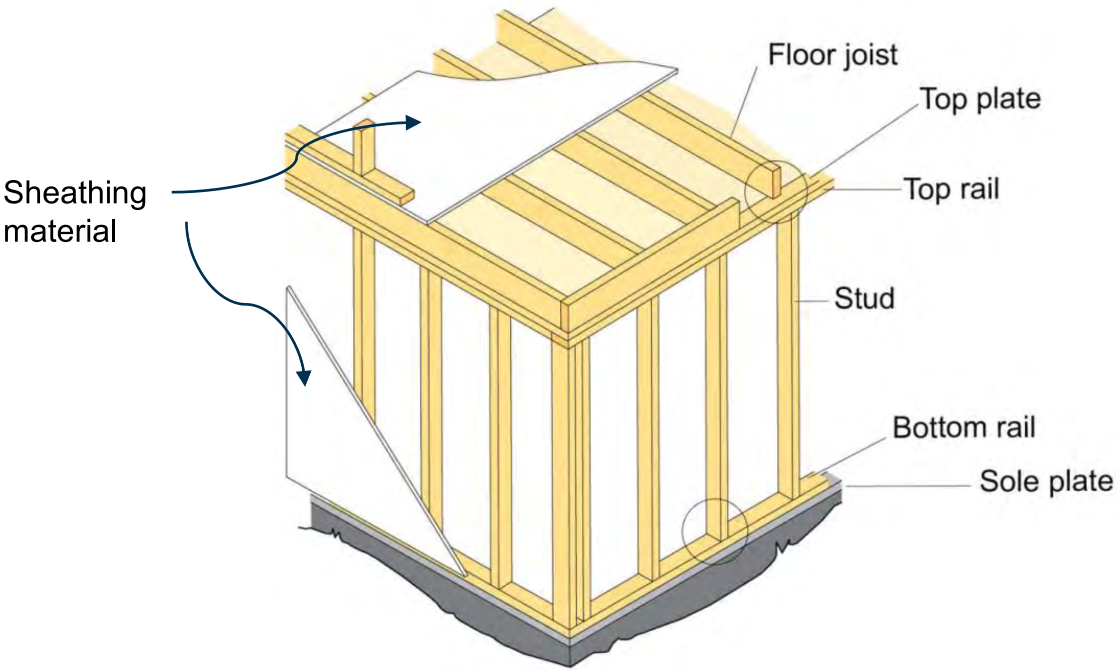
Post-and-beam system

- Concrete wall bracing

Timber frame systems

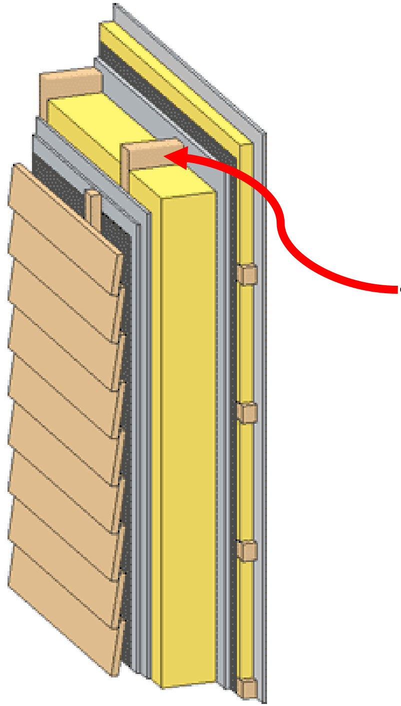
Timber frame systems

Timber frame systems



Timber frame systems

- wall ”anatomy”



Typical Stud Thicknesses, mm²

120 × 45

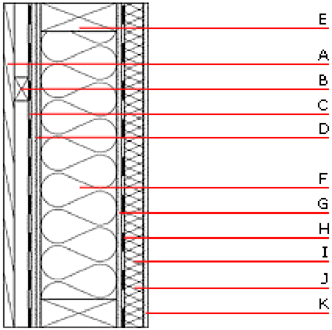
145 × 45

195 × 45

220 × 45

Timber frame systems

- wall ”anatomy”



	Thickn.	Building material
A	24.0	• external wall cladding, e.g. pine, larch, thermowood, acetylated wood, etc
B	30.0	• spruce wood battens offset (30/50; 30/80) - ventilation
C		• wind barrier
D	20.0	• gypsum fibre board (2x10 mm)
E	*	• finger-jointed solid construction timber (c/c=600mm, typ.)
F	*	• Insulation material
G	12.5	• gypsum fibre board
H		• vapour barrier sd≥ 2m
I	*	• spruce wood cross battens (a=400) or battens offset)
J	*	• Exchangeable layer
K	12.5	• gypsum fibre board or gypsum plasterboards with improved properties at high temperatures (fire)

Timber frame systems

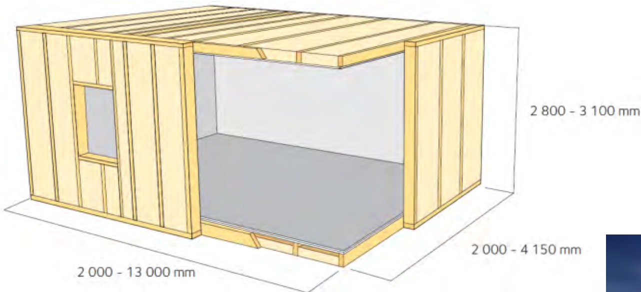
- on site construction of walls

Timber frame systems

- prefabricated walls

Timber frame systems

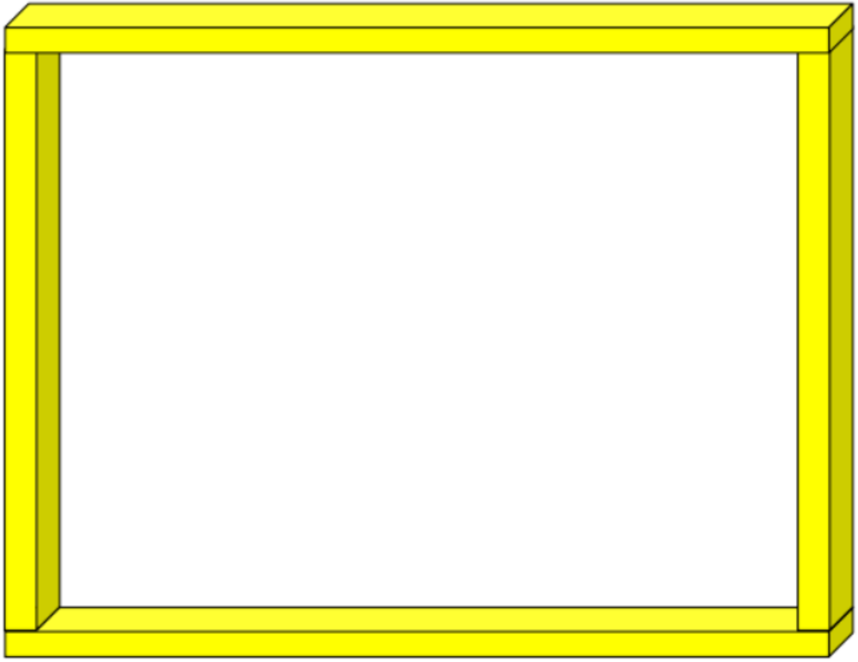
- prefabricated volume modules



Timber framed walls

Timber framed walls

Timber framed walls



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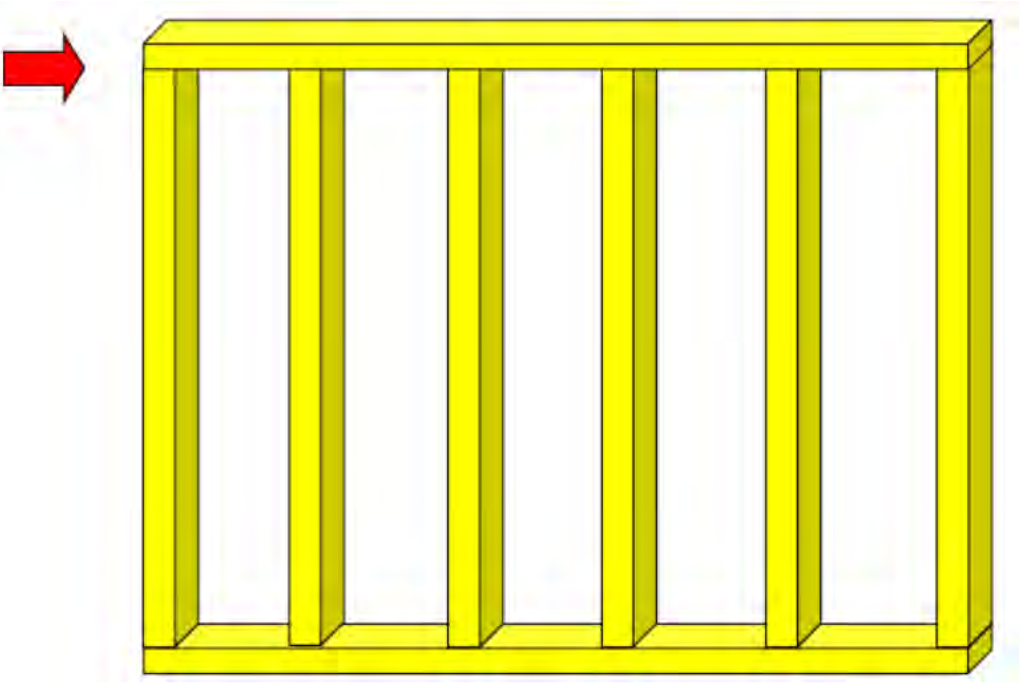
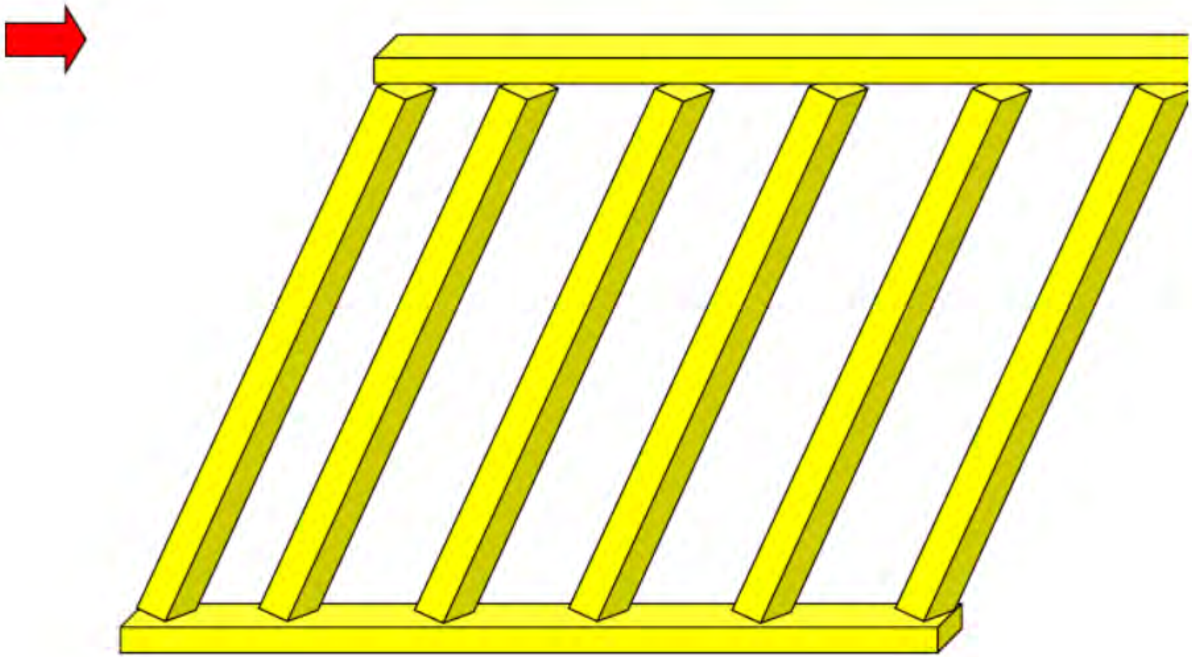
Timber framed walls

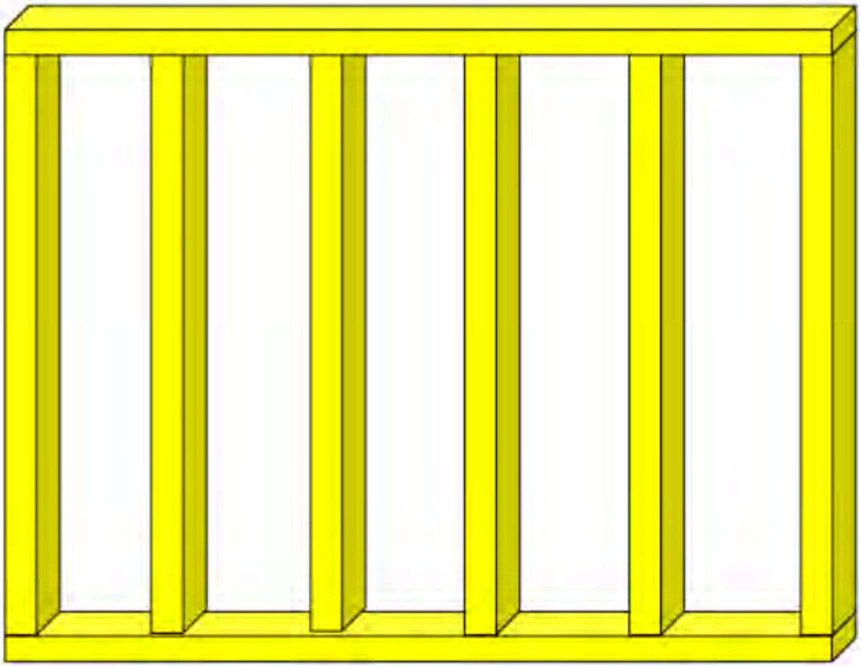
- Horizontal bottom & top plates and vertical studs are nailed together



Timber framed walls

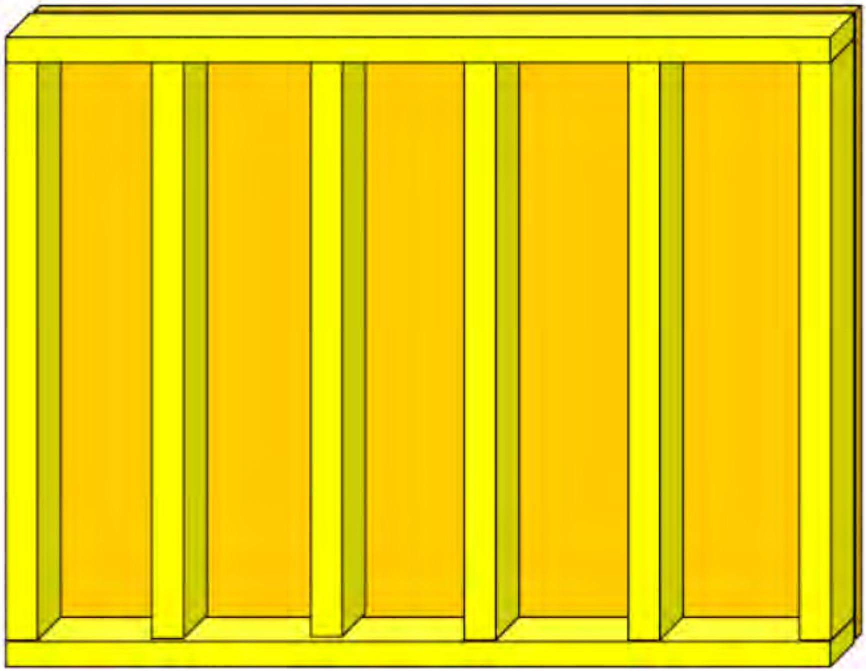


Timber framed walls

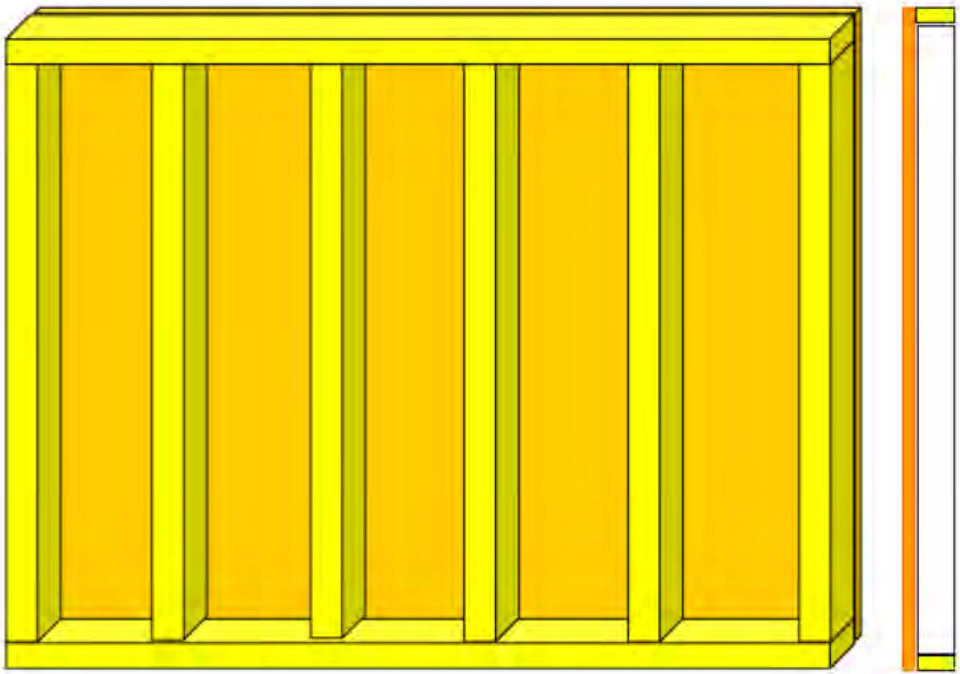


Timber framed walls

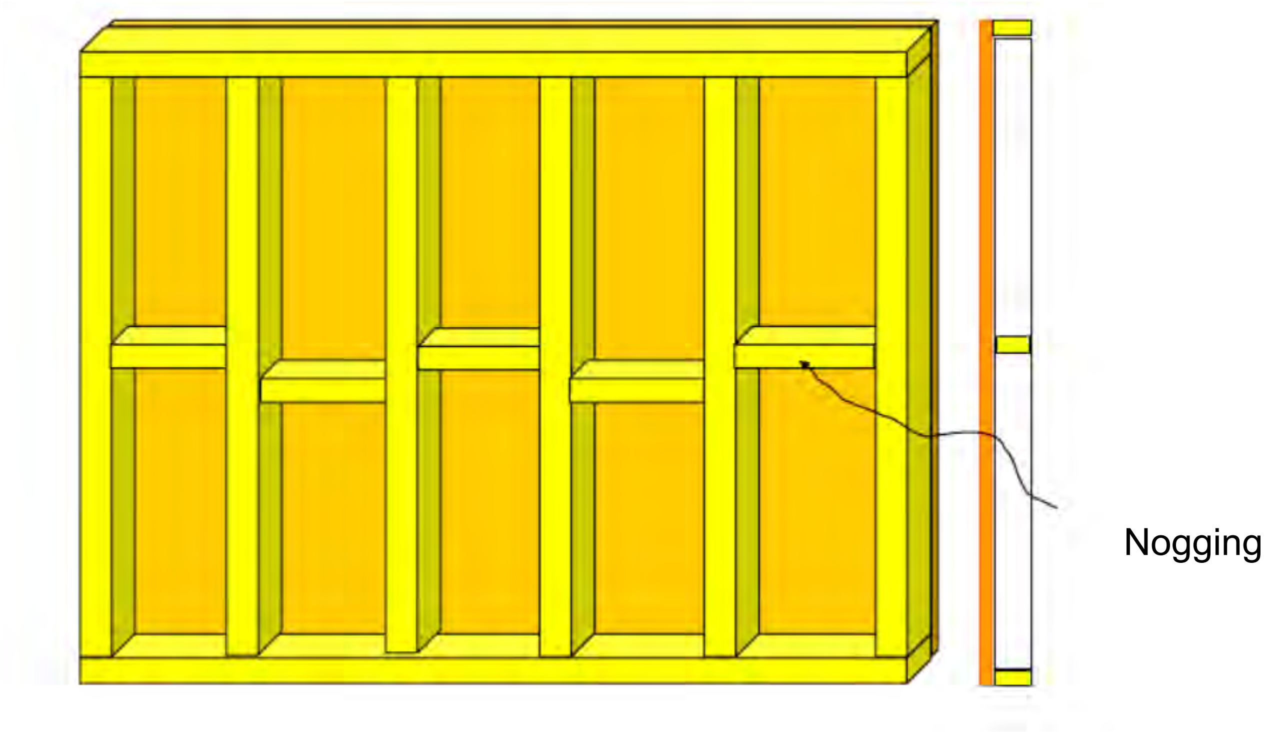
- Structural sheet, nailed at close distances



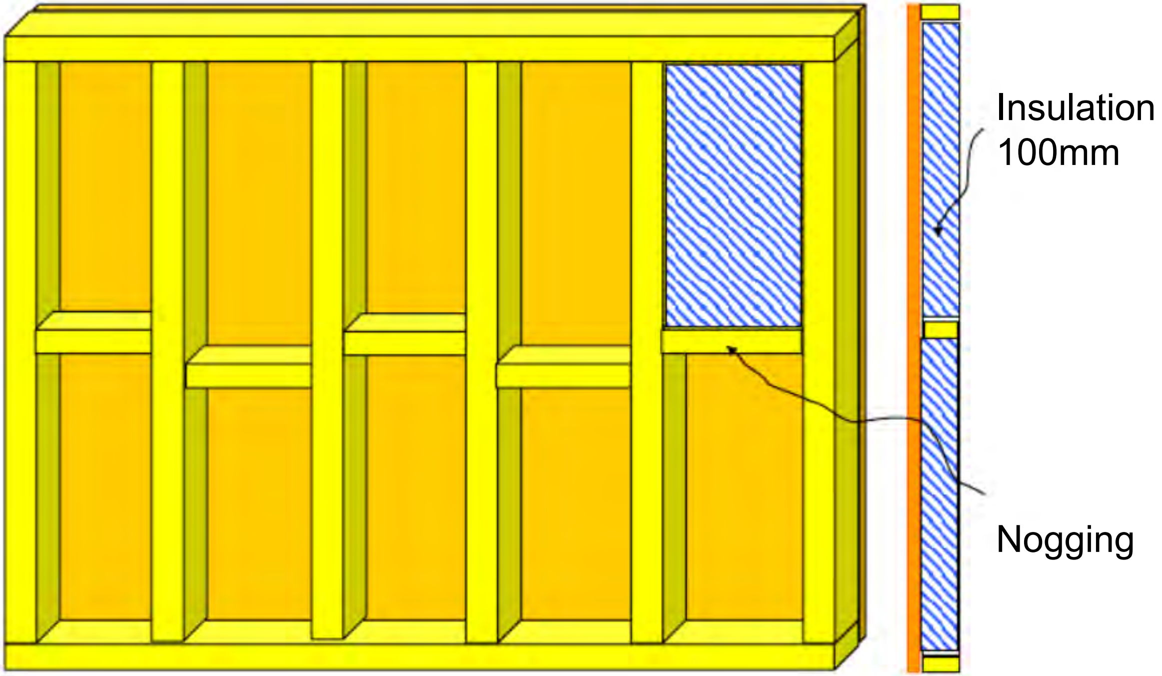
Timber framed walls



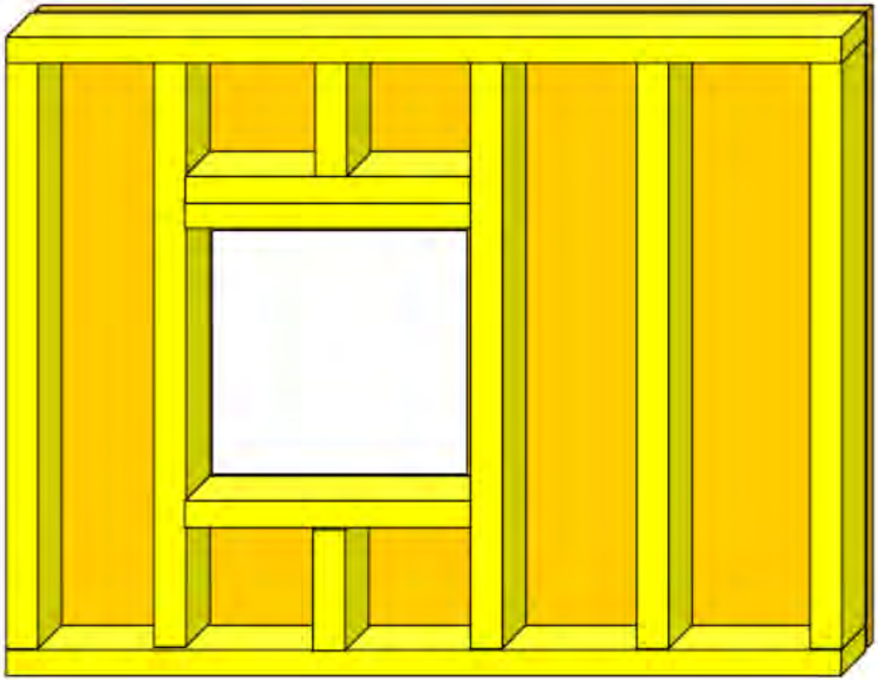
Timber framed walls



Timber framed walls

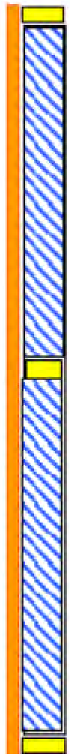


Timber framed walls



Timber framed walls

outside



Inside

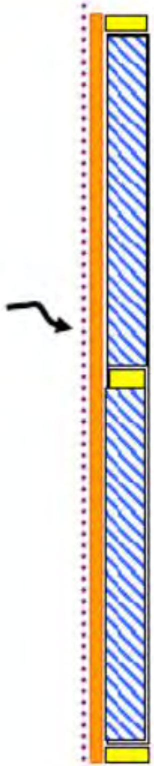
Keep it dry

Timber framed walls

outside

Inside

Moisture
barrier



Keep it dry

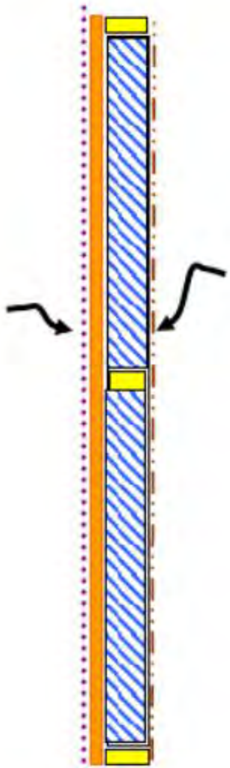
Timber framed walls

outside

Inside

Moisture
barrier

Vapor barrier



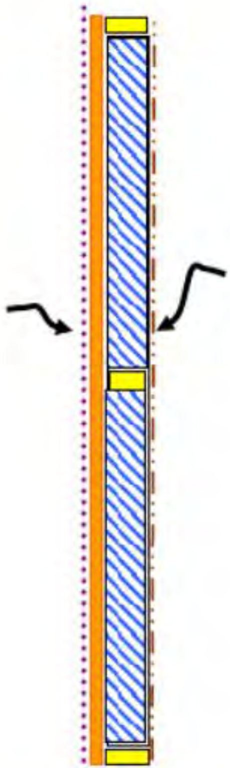
Keep it dry

Timber framed walls

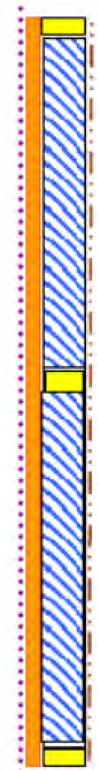
outside

Inside

Moisture barrier



Vapor barrier

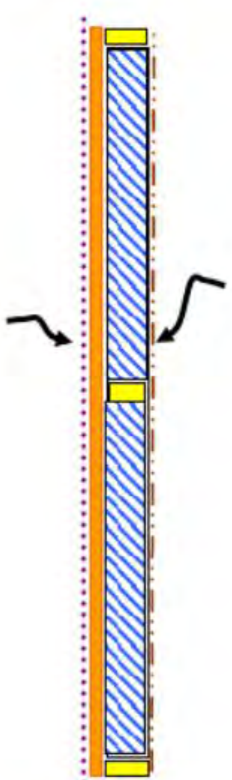


Keep it dry

Timber framed walls

outside

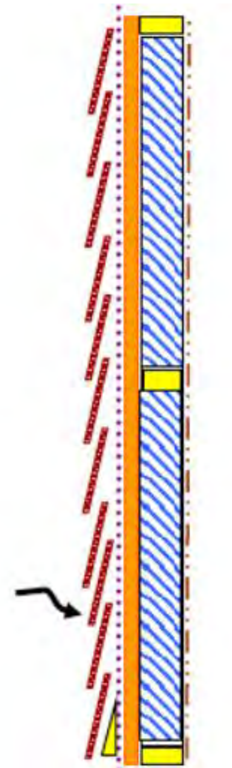
Inside



Moisture barrier

Vapor barrier

Weather proof layer, timber boarding, tiles



Keep it dry

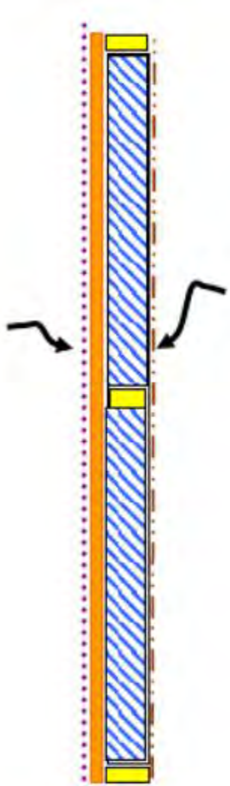
Timber framed walls

outside

Inside

Moisture barrier

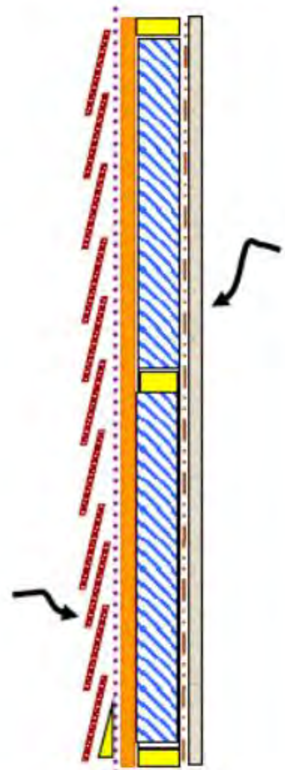
Vapor barrier



Keep it dry

Plaster board

Weather proof layer: timber boarding, tiles



Finished wall

Timber framed walls

1 Top plate

2 Diagonal brace

3 Jack stud (over)

4 Lintel

5 Head trimmer

6 Bottom plate

7 Common stud

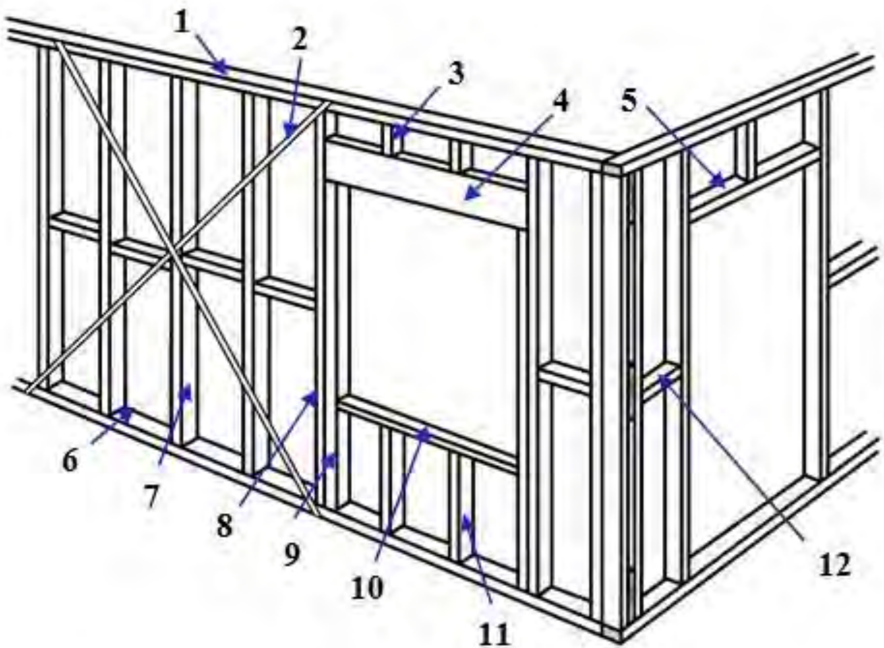
8 Jamb stud

9 Secondary jamb stud

10 Sill trimmer

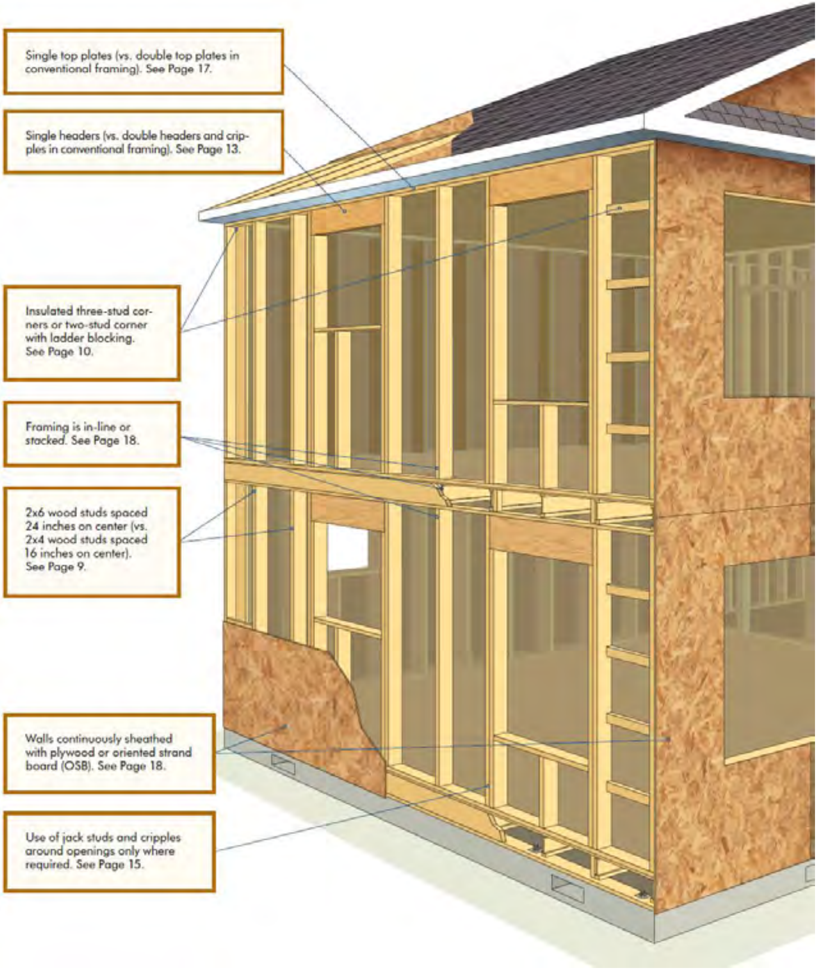
11 Jack stud (under)

12 Nogging



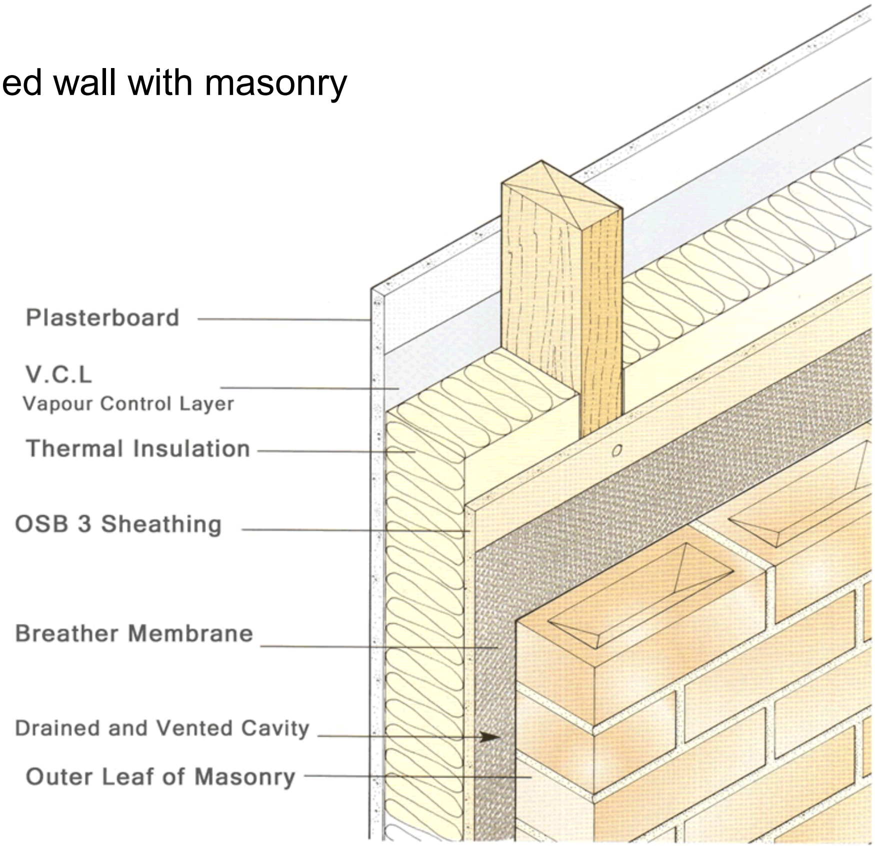
Timber framed walls

Timber framed walls



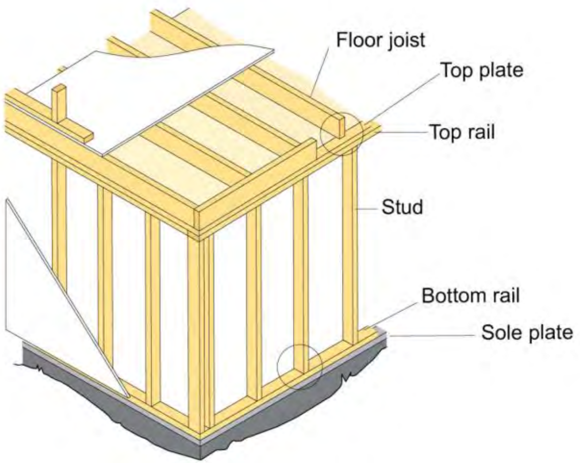
Timber framed walls

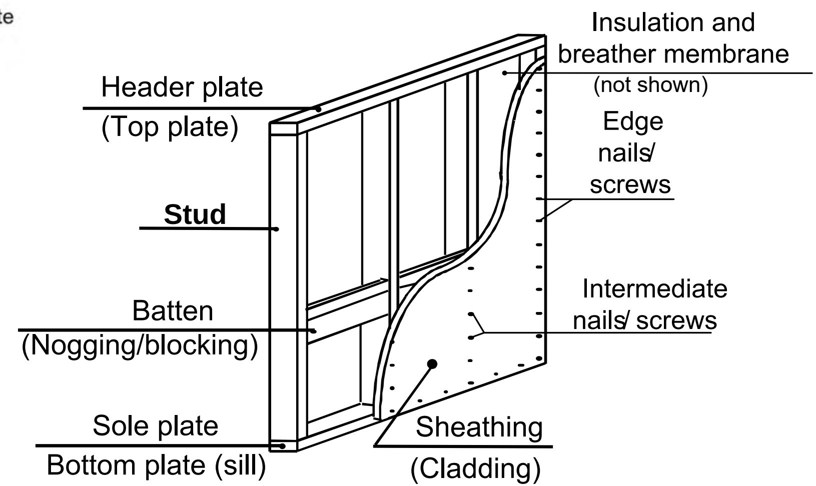
- Timber framed wall with masonry



Design of timber-framed walls with timber studs

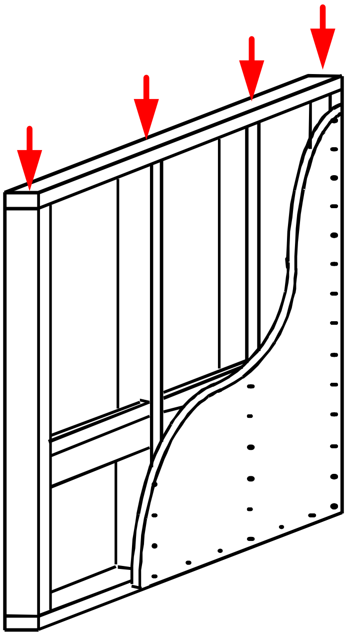
Timber framed walls

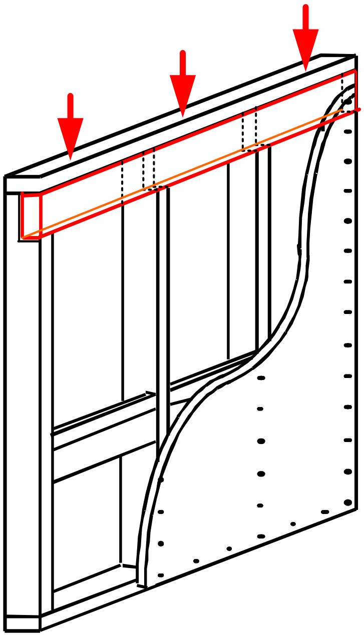




Timber framed walls

- Concentrated loads should be located directly over the studs. If located in the span area of the header plate, all studs should include a load-bearing beam





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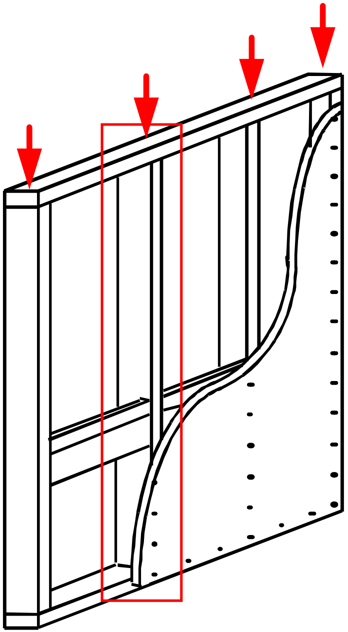
Design of wall studs - ULS

- EC5 - 6.3
- Relative slenderness

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi}\sqrt{\frac{f_{c,0,k}}{E_{0.05}}}$$

and

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi}\sqrt{\frac{f_{c,0,k}}{E_{0.05}}}$$



Design of wall studs - ULS

- If $\lambda_{rel,z} \leq 0{,}3$ and $\lambda_{rel,y} \leq 0{,}3$ then

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$ Eq 6.19

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$ Eq 6.20

- In all other cases

$$\frac{\sigma_{c,0,d}}{k_{c,y} f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$ Eq 6.23

$$\frac{\sigma_{c,0,d}}{k_{c,z} f_{c,0,d}} + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$ Eq 6.24

Design of wall studs - ULS

- with

$$k_{c,y} = \frac{1}{k_y + \sqrt{k_y^2 - \lambda_{rel,y}^2}}$$

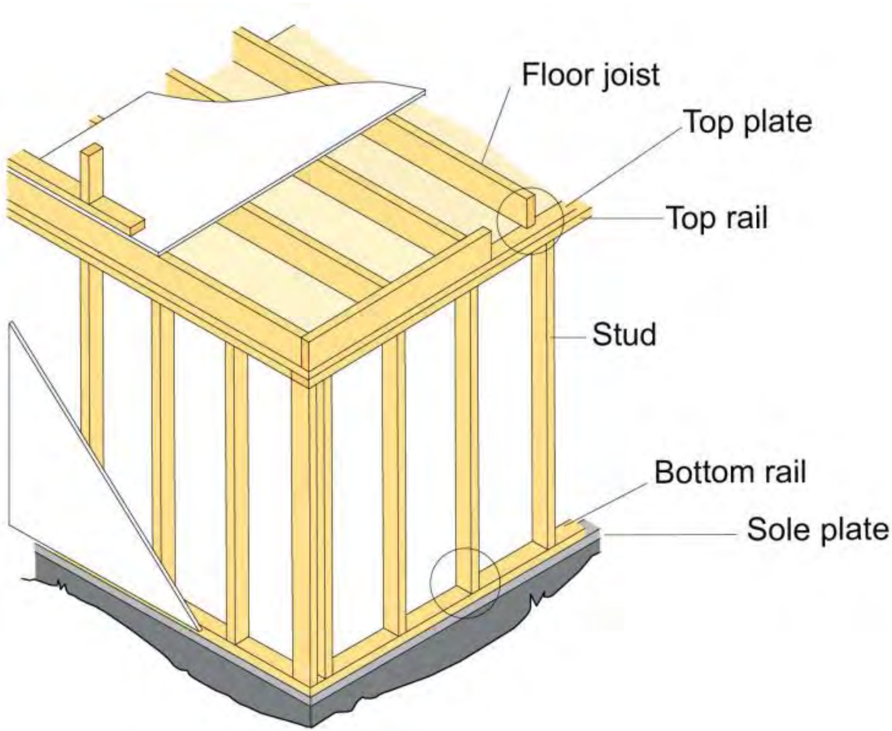
$$k_{c,z} = \frac{1}{k_z + \sqrt{k_z^2 - \lambda_{rel,z}^2}}$$

$$k_y = 0{,}5\left(1 + \beta_c\left(\lambda_{rel,y} - 0{,}3\right) + \lambda_{rel,y}^2\right)$$

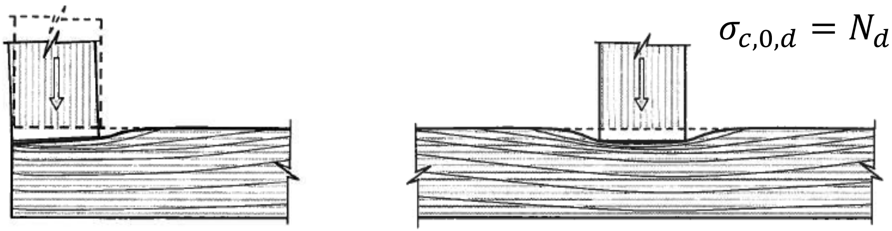
$$k_z = 0{,}5\left(1 + \beta_c\left(\lambda_{rel,z} - 0{,}3\right) + \lambda_{rel,z}^2\right)$$

$$\beta_c = \begin{cases} 0{,}2 & \text{for solid timber} \\ 0{,}1 & \text{for glued laminated timber and LVL} \end{cases}$$

Top and sole rail in a wall



Design of sole rail in a wall - ULS



$\sigma_{c,0,d} = N_d/A$

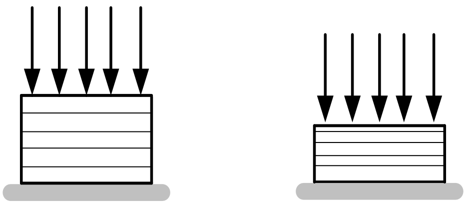
- The top and sole rail provide lateral restraint to the ends of the studs and function as a bearing members

$$\sigma_{c,90,d} \leq k_{c,90} f_{c,90,d}$$ EC 5, Eq. 6.3

- Sheathing is assumed not to contribute to distribution of the load from the studs to the sole plate

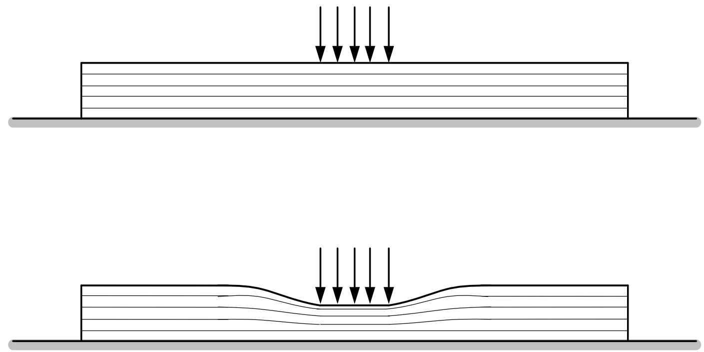
Compression ⊥ to grain

- Deformation and size effect



a) b)

$$\sigma_{c,90} = \frac{N}{A}$$

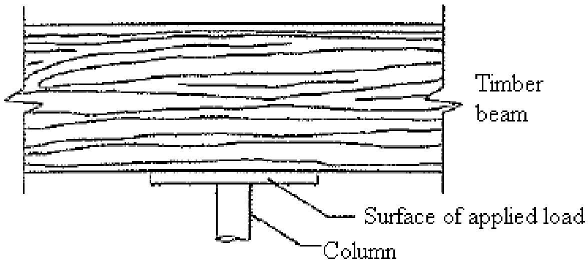


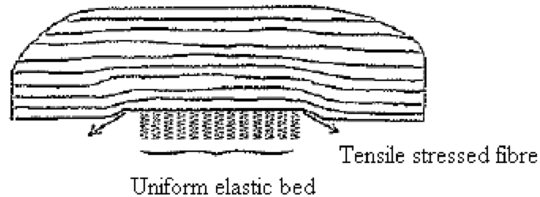
a)

b)

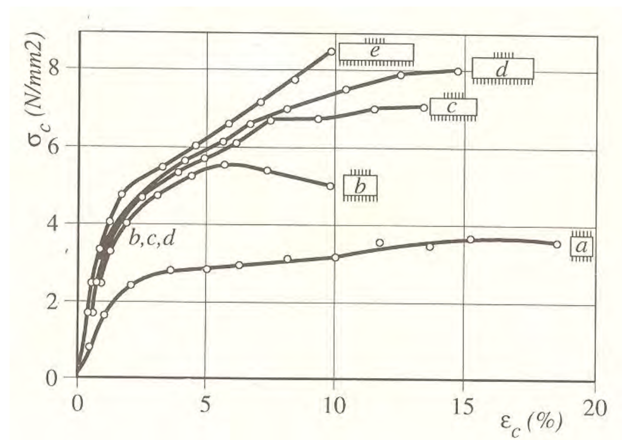
DoTS 7.2.1

Compression ⊥ to grain

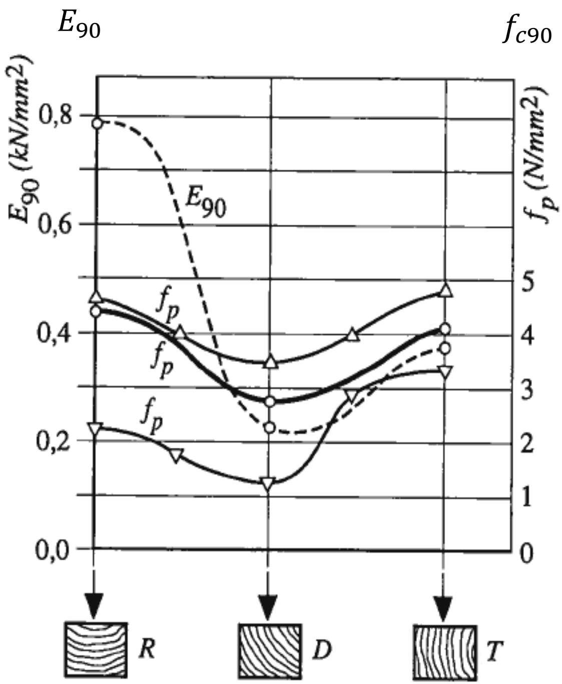


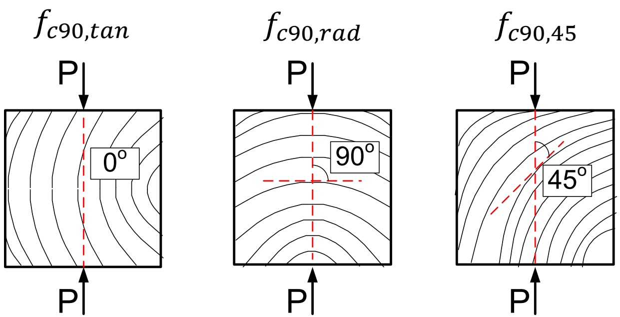


- Strength increases for longer non-loaded timber parts due to the fact that adjacent parts prevent deformation



Compression ⊥ to grain





$$f_{c90,tan} : f_{c90,rad} : f_{c90,45} \approx$$
$$1 : 0{,}8 : 0{,}6$$

Compression perpendicular to grain

6.1.5 Compression perpendicular to the grain

(1)P The following expression shall be satisfied:

$$\sigma_{c,90,d} \leq k_{c,90} f_{c,90,d} \tag{6.3}$$

with:

$$\sigma_{c,90,d} = \frac{F_{c,90,d}}{A_{ef}} \tag{6.4}$$

where:

$\sigma_{c,90,d}$ is the design compressive stress in the effective contact area perpendicular to the grain;

$F_{c,90,d}$ is the design compressive load perpendicular to the grain;

A_{ef} is the effective contact area in compression perpendicular to the grain;

$f_{c,90,d}$ is the design compressive strength perpendicular to the grain;

$k_{c,90}$ is a factor taking into account the load configuration, the possibility of splitting and the degree of compressive deformation.

The effective contact area perpendicular to the grain, A_{ef}, should be determined taking into account an effective contact length parallel to the grain, where the actual contact length, ℓ, at each side is increased by 30 mm, but not more than a, ℓ or $\ell_1/2$, see Figure 6.2.

Compression perpendicular to grain

6.1.5 Compression perpendicular to the grain

A_{ef} is the effective contact area in compression perpendicular to the grain;

The effective contact area perpendicular to the grain, A_{ef}, should be determined taking into account an effective contact length parallel to the grain, where the actual contact length, ℓ, at each side is increased by 30 mm, but not more than a, ℓ or $\ell_1/2$, see Figure 6.2.

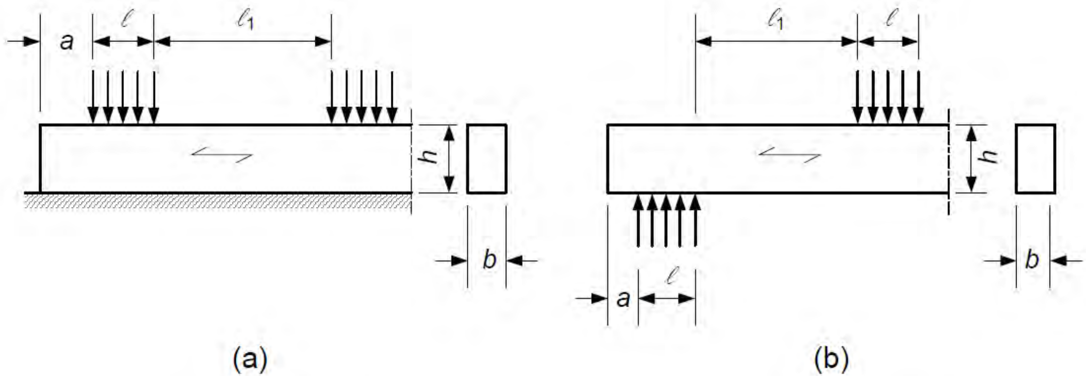


Figure 6.2 – Member on (a) continuous and (b) discrete supports

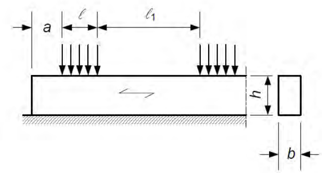
Compression perpendicular to grain

6.1.5 Compression perpendicular to the grain

$k_{c,90}$ is a factor taking into account the load configuration, the possibility of splitting and the degree of compressive deformation.

(2) The value of $k_{c,90}$ should be taken as 1,0 unless the conditions in the following paragraphs apply. In these cases the higher value of $k_{c,90}$ specified may be taken, with a limiting value of $k_{c,90}$ = 1,75.

(3) For members on continuous supports, provided that $\ell_1 \geq 2h$, see Figure 6.2a, the value of $k_{c,90}$ should be taken as:

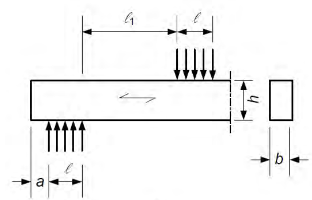


– $k_{c,90}$ = 1,25 for solid softwood timber

– $k_{c,90}$ = 1,5 for glued laminated softwood timber

where h is the depth of the member and ℓ is the contact length.

(4) For members on discrete supports, provided that $\ell_1 \geq 2h$, see Figure 6.2b, the value of $k_{c,90}$ should be taken as:



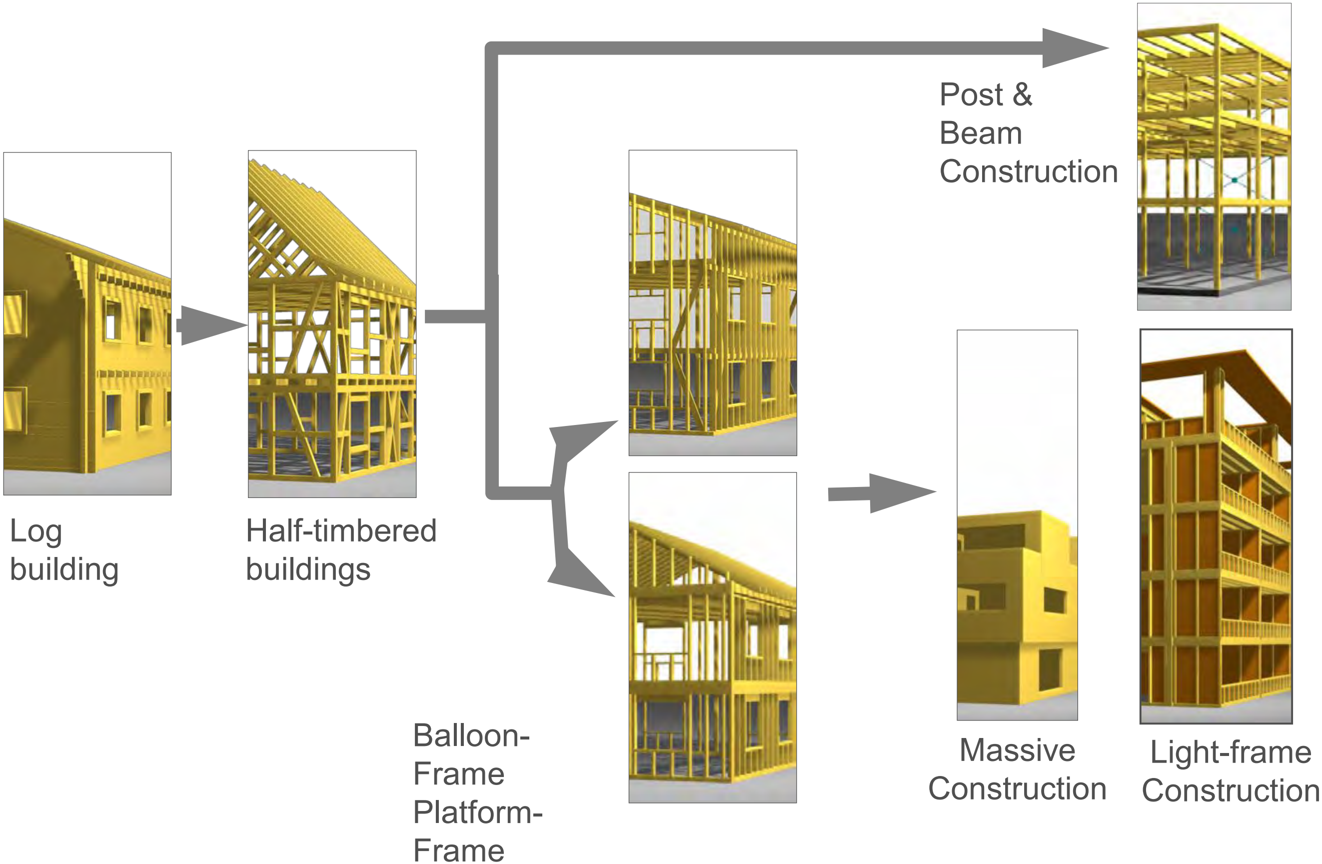
– $k_{c,90}$ = 1,5 for solid softwood timber

– $k_{c,90}$ = 1,75 for glued laminated softwood timber provided that $\ell \leq$ 400 mm

where h is the depth of the member and ℓ is the contact length.

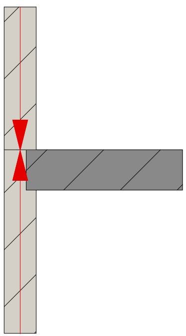
Construction Types

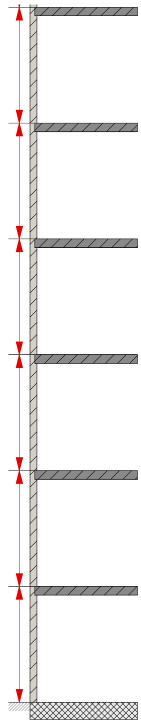
Construction types



Construction types

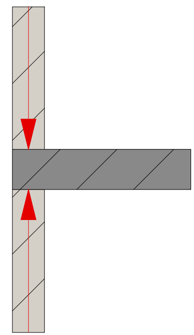
- «Balloon» Frame

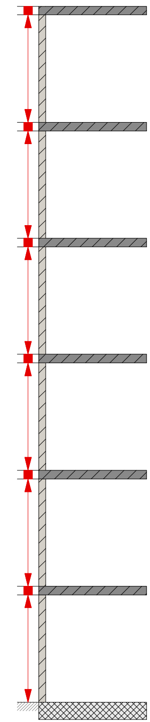




- Small deformations
- Little creep
- High capacity

- «Platform» Frame



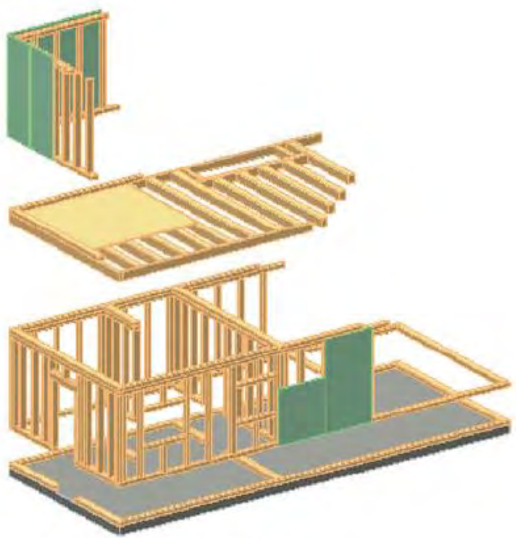


- Large deformations
- Considerable creep
- Low resistance

Source: Philipp Zumbrunnen

Construction types

- Platform and Balloon construction for timber frame



„platform frame“

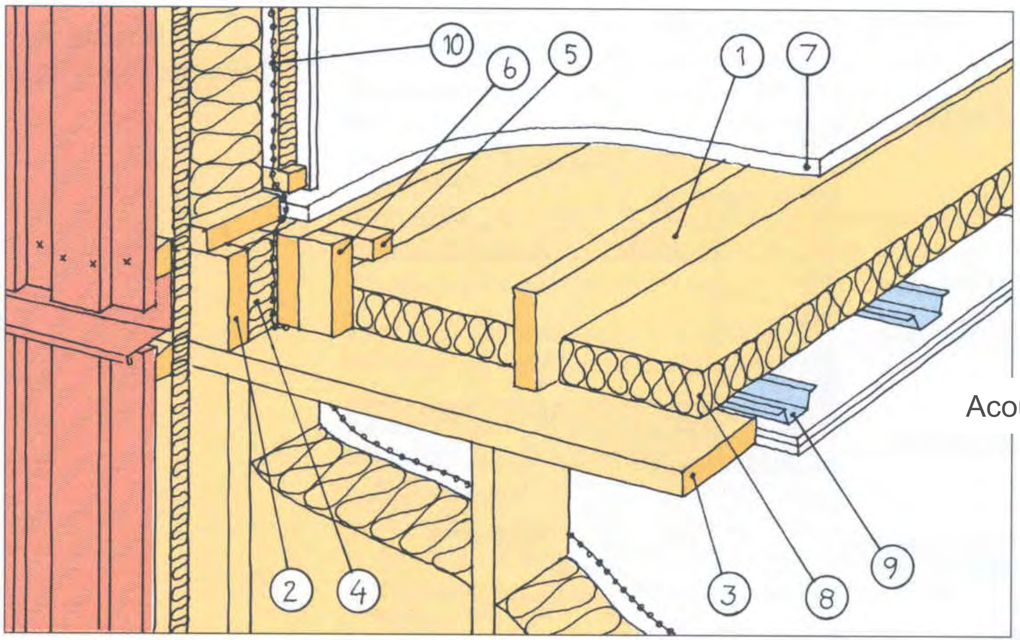
„balloon frame“

Construction types

- Platform frame on the top of concrete ground floor/basement

Construction types

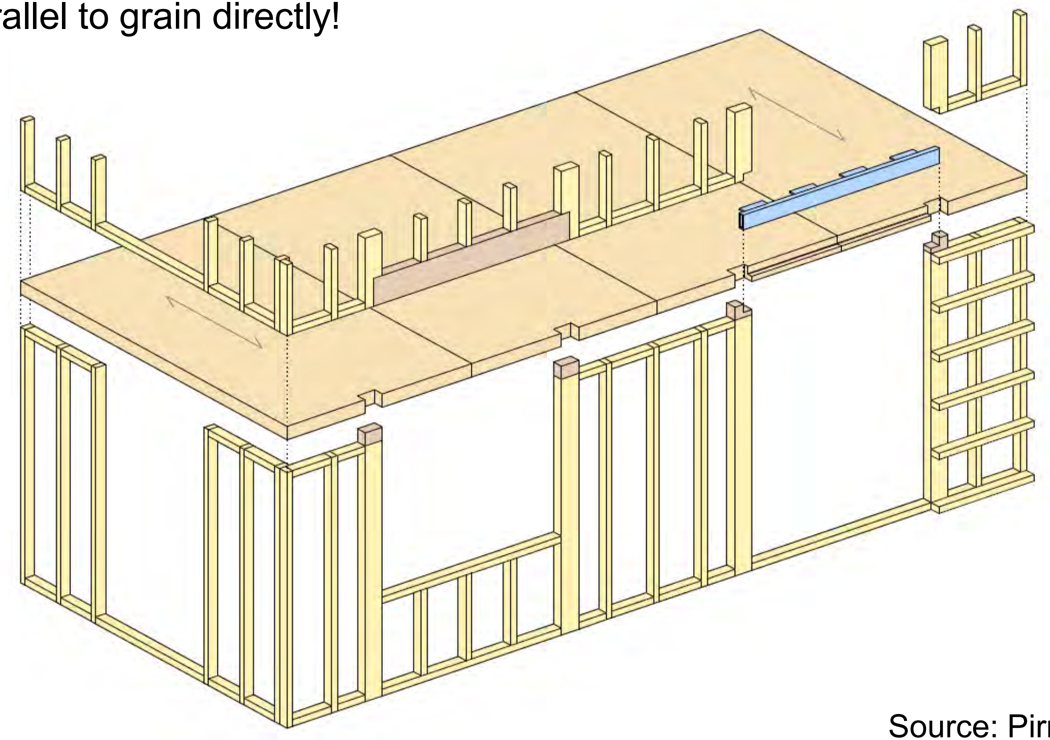
- connection between wall and floor in platform frame construction



Acoustic panels

Timber-frame systems

- Transfer high and concentrated loads by compression parallel to grain directly!



Source: Pirmin Jung

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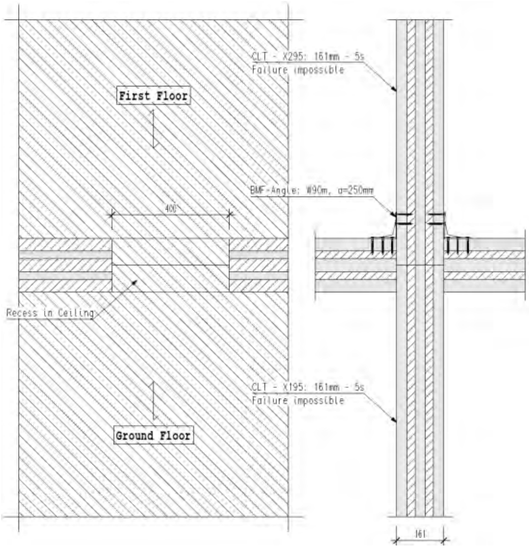
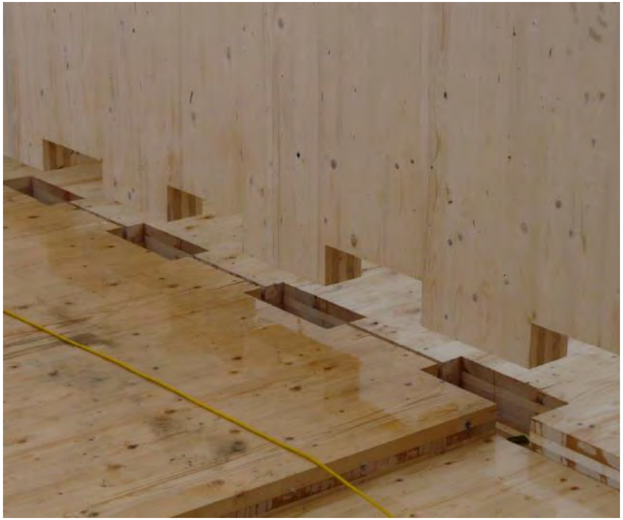
Vertical load transfer

- Special construction possibilities for CLT





Source: Pirmin Jung

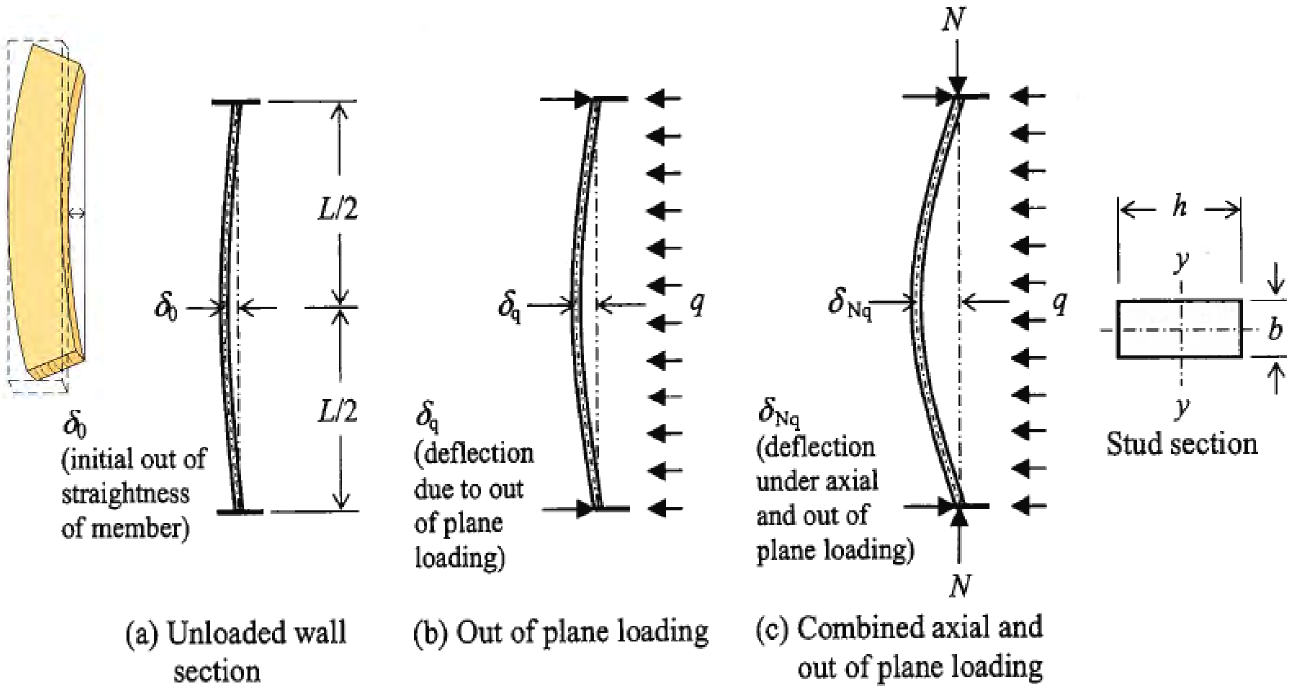
SLS (deformations)

Not considered in the code!

Some design methodologies are proposed in this lecture

DoTS 7.2.1

Out of plane deflection of load-bearing studs



- $\delta_0 \leq L/500$ for all timber and wood products

Out of plane deflection of load-bearing

Studs

- Stud subjected to axial design load N_d

$$\alpha = \left(\frac{1}{1 - N_d/P_E}\right) \qquad P_E = \frac{\pi^2 E_{0.05}(bh^3/12)}{L^2}$$

- Stud subjected to out of plane loading q_d

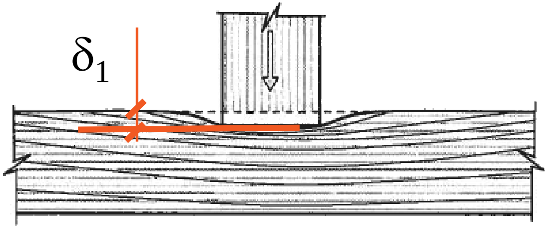
$$\delta_q = \frac{5 q_d L^4}{384 E_{o,m} I} + 1.2\,\frac{q_d L^2}{8 G_{0,m} A}$$

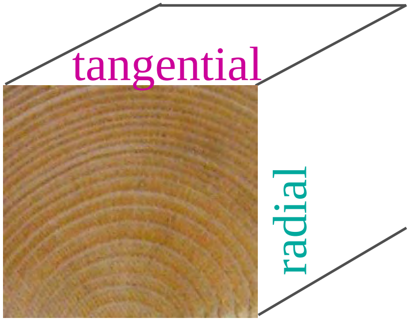
- Increase in instantaneous deformation of the lateral deflection of the wall under the critical characteristic combination of loading

$$\delta_{char,inst} = \alpha \cdot \left(\frac{N_{char}}{P_E}\delta_0 + \delta_{q,inst}\right)$$

STDtoEC5- Ex 5.7.8

Vertical settlement of the sole plate in a wall

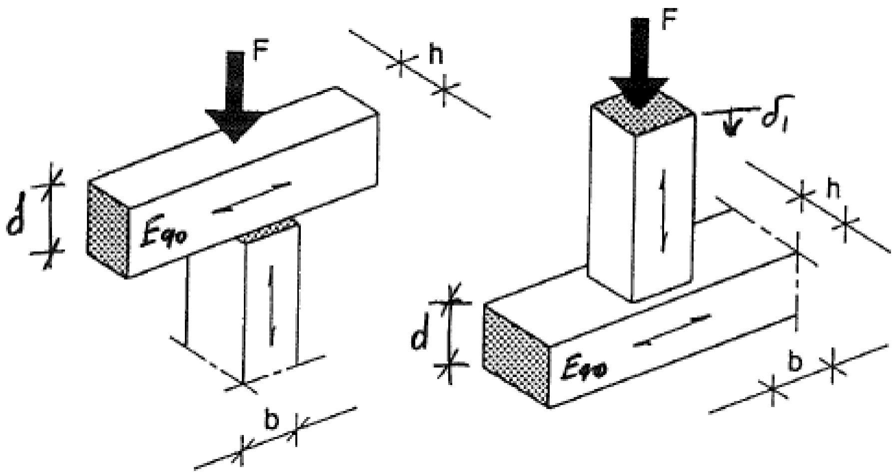




$$\delta_1 = \frac{qd}{AE_{90}}$$

- where:
  - δ_1 is the deformation perpendicular to the grain
  - q is the magnitude of the applied load perpendicular to the grain
  - d is the depth of the horizontal plate
  - A is the loaded area of the horizontal plate
  - E_{90} is the modulus of elasticity perpendicular to the grain of the horizontal plate

Deformation due to pressure (settlement)



$$\delta_1 = \frac{F \cdot d}{A \cdot E_{d,90}} = \frac{F \cdot d\left(1 + k_{def}\right)}{b \cdot h \cdot E_{mean,90}}$$

Deformation due to pressure

- Laboratory tests at Chalmers – February 2009

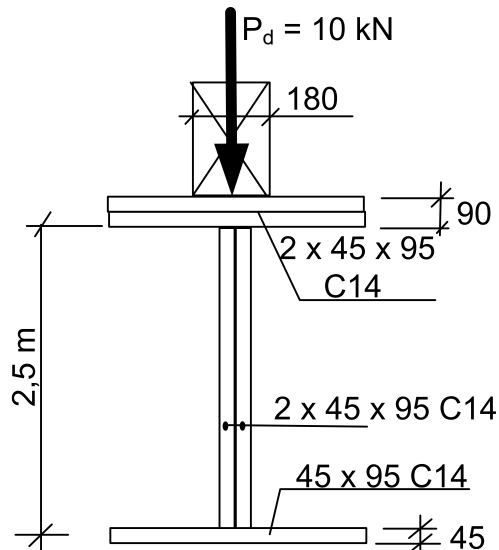
$$\delta_1 = \frac{F \cdot d}{A \cdot E_{d,90}}$$

Mean values from 10 specimens

Deflection from testing [mm] Mean from both supports	Deflection from eq. $\boldsymbol{\delta_1}$ [mm]	% of testing result/$\boldsymbol{\delta_1}$
$\boldsymbol{P_1/2}$ = 0,947 kN and 1,814 kN		
0,199	0,048	414%
0,337	0,092	366%

Example S1 Vertical settlements

- Outside wall structure was made of double top plate 45 x 95 mm, C14, double vertical studs 45 x 95, C24 and ground plate, 45 x 95 mm C14 on top of the concrete slab. Wall is a support of a large truss.
  The design load in SLS from the truss is $P_d = 10kN$.
  Medium-term duration. Service class 1.
  The structure was assembled at 17% MC.
- What was the vertical settlement of the structure as a result of drying to 10% MC?
- Assume that the top plates were sawn in radial direction and loaded in tangential direction.
  The bottom plate was loaded in radial direction.
- $\alpha_t = 0{,}002$
- $\alpha_r = 0{,}001$
- $\alpha_t = 0{,}0001$



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