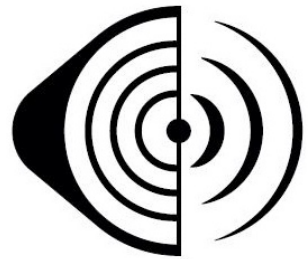
Lund University 191213

Acoustics in wood constructions

Content

- Introduction – expected constructions with wood, today and in future
- Why wood?
- How do we meet an increased demand?
- Subjective evaluation and wood buildings
- **Various building systems**
  - **Evaluation of different building systems**
- **Acoustic challanges for different building systems**
- **Acoustic challanges in different type of buildings (residential / offices / schools)**
- **Examples**
- Calculation and control
- Future
- Others / questions



Who am I?

Boverket

LUNDS UNIVERSITET

SILENT TIMBER BUILD

OPTIWOOD ?

Why Wood – advantages?

Environment – We have more forest than we use – must be utilized

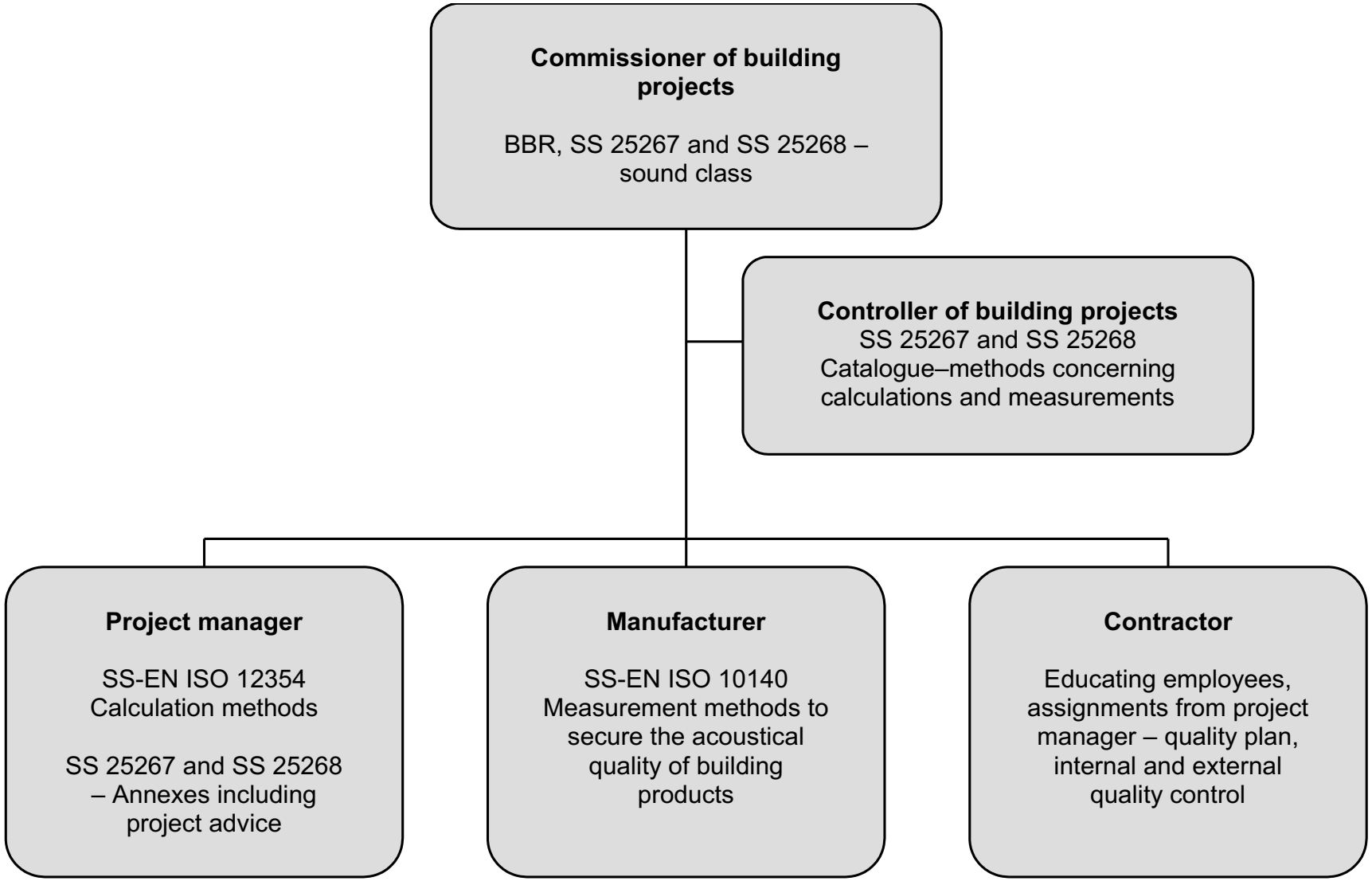
Working Environment and transport – Can be build in factories and facilitate transport

Can be designed very light – use existing foundations

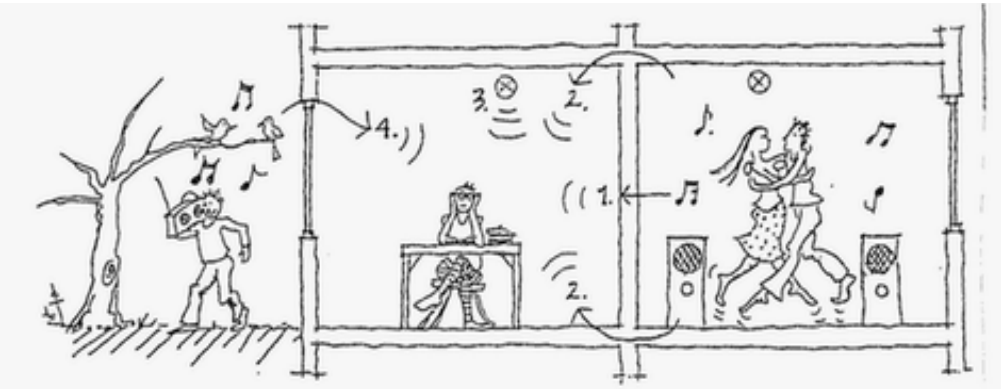
How do we meet an increased demand?

- Education
- research
- Interest and committment
- Think new …….. We must challange more than normal

Building Acoustics - Regulations



Sound insulation



- Sound insulation / sound reduction index, R

  Should be as <u>high</u> as possible

- Impact sound level, L_n

  Should be as <u>low</u> as possible

Sound reduction value

Different measures

R_w

R'_w

D_{nTw}

$D_{nTw}+C_{50\text{-}3150}$

R_A

R'_A

$R_{A,tr}$

R'_w+C

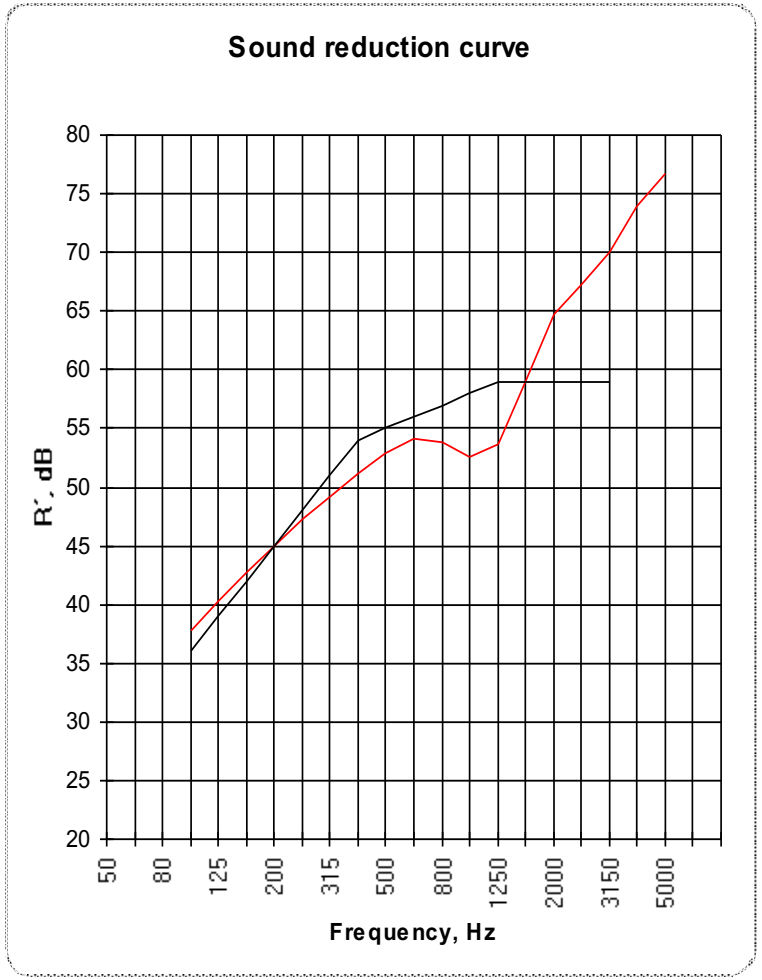
$R'_w+C_{50\text{-}3150}$

R'_w+C_{tr}

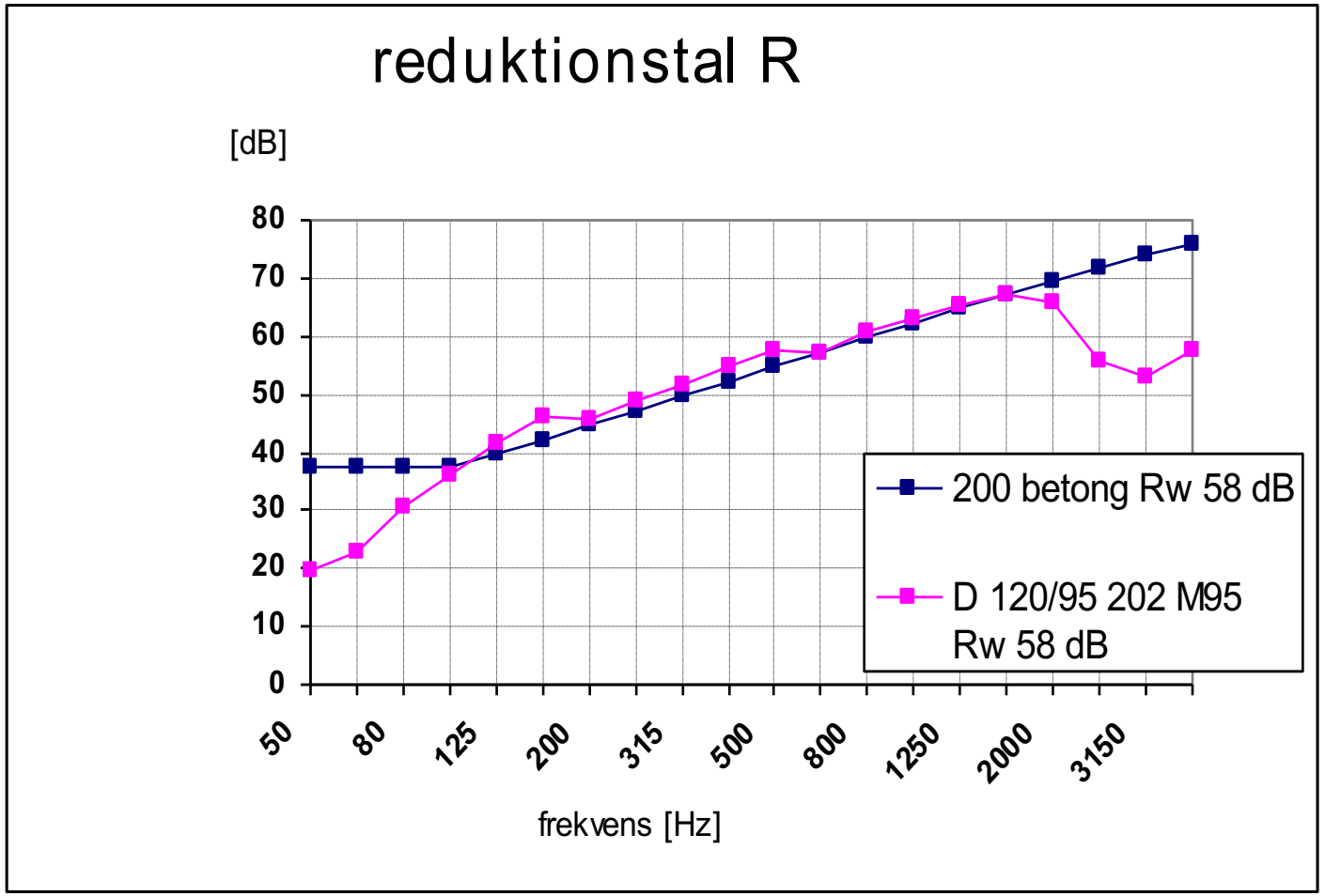
$R'_w+C_{tr,50\text{-}3150}$

$R'_w+C_{tr,50\text{-}5000}$

etc.



Same value, Rw – different shapes



Impact sound level

Different measures

L_n

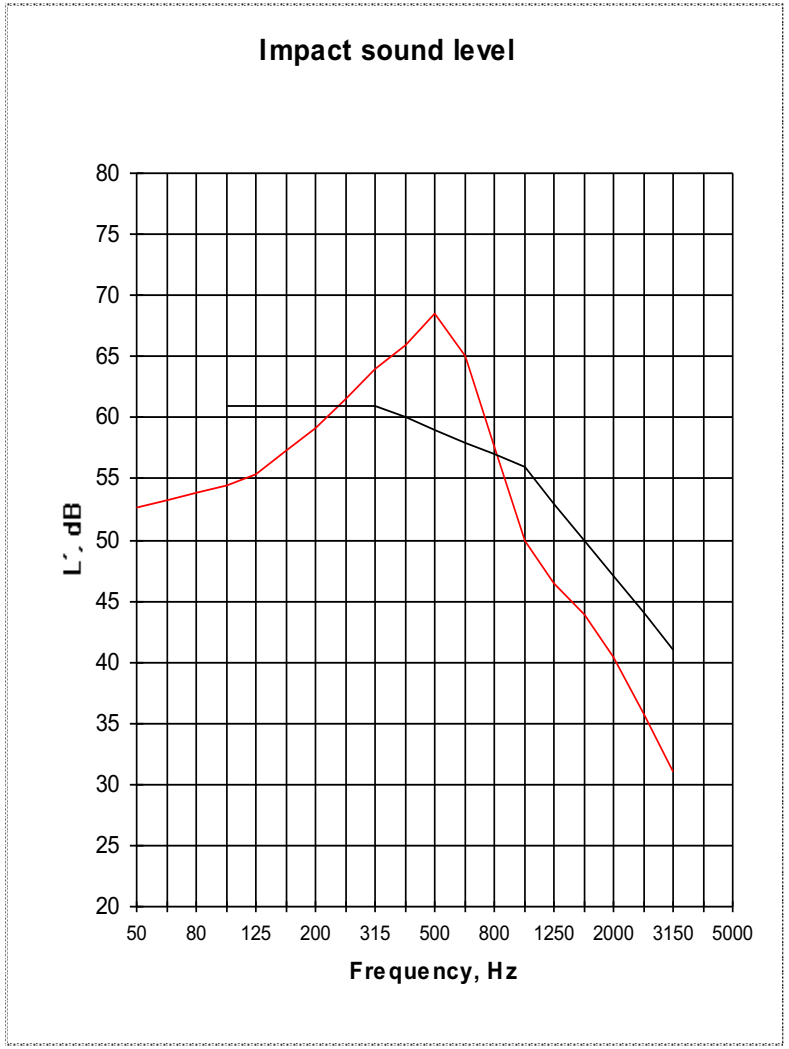
$L'_{n,w}$

$L'_{n,w} + C_I$

$L'_{n,w} + C_{I,50\text{-}2500}$

$L'_{nT,w}$

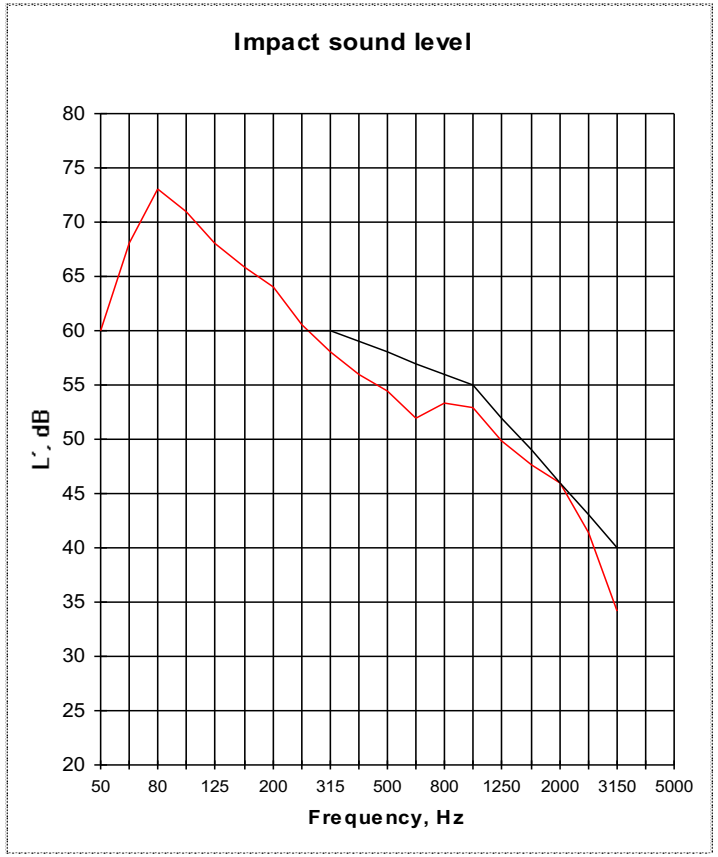
$L'_{nT,w} + C_{I,50\text{-}2500}$



Same value but different shapes

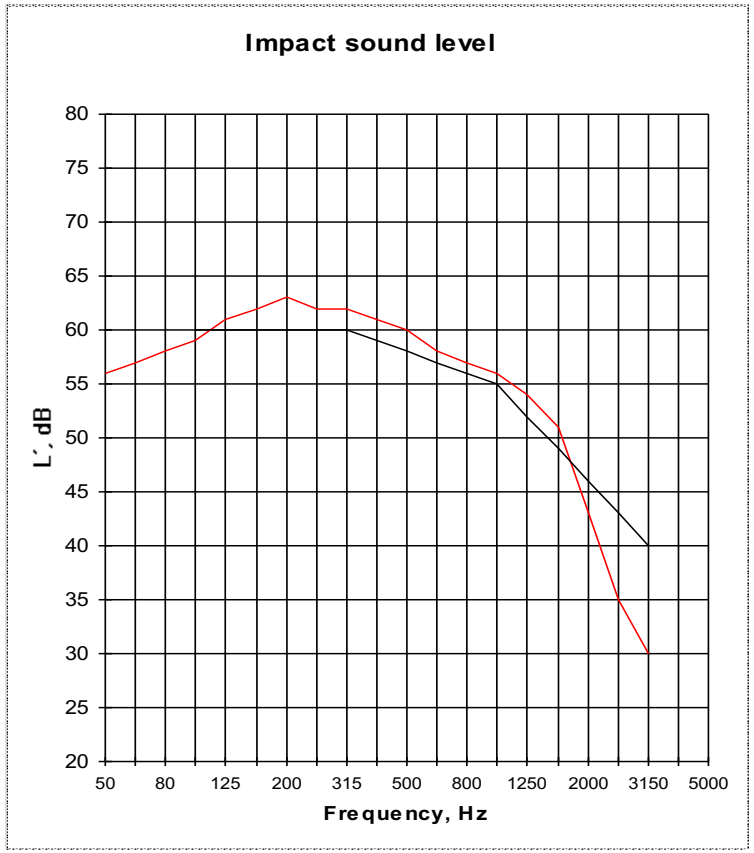
Lnw =58 dB

Lnw+C50-2500 = 62 dB

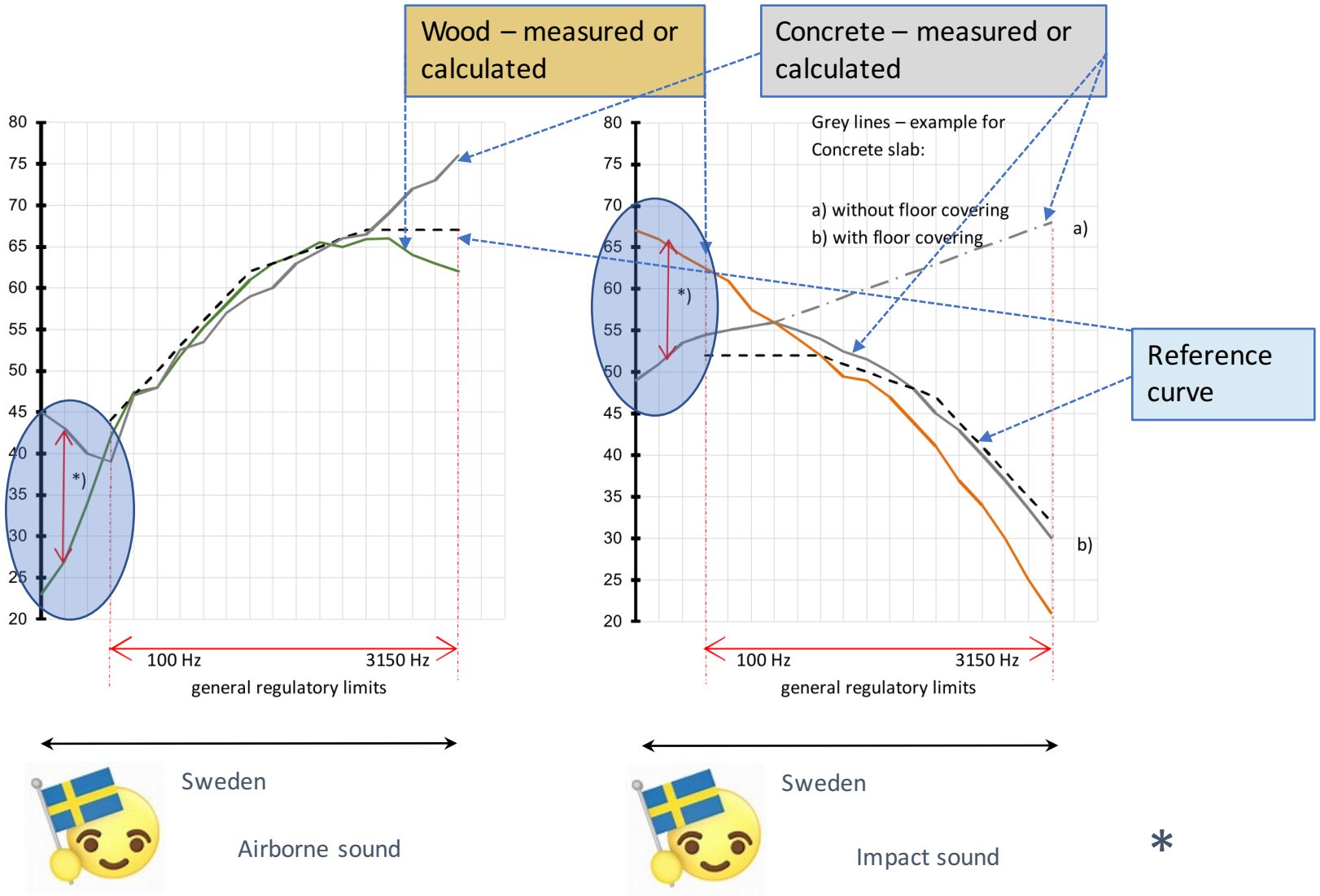


Lnw =58 dB

Lnw+C50-2500 = 57 dB



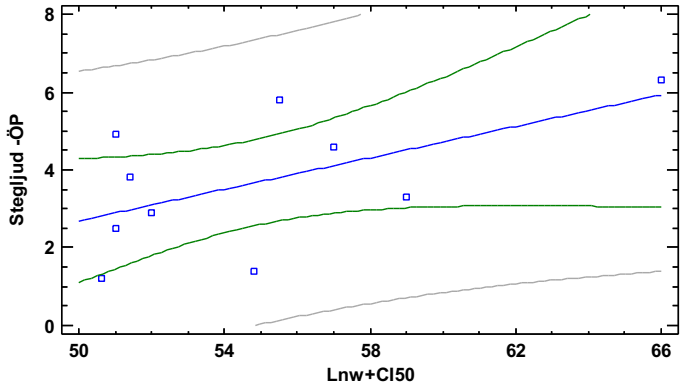
Lightweight – Wood as building material



Importance of low frequency range

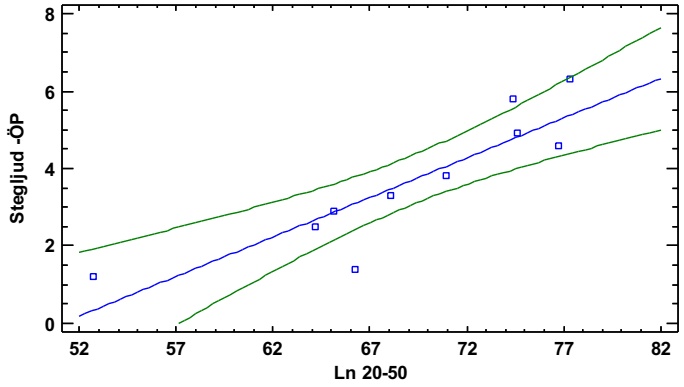
- Impact sound, coefficient of determination for different ranges?

50 Hz -3150 Hz, ISO 717



R^2 = 32%

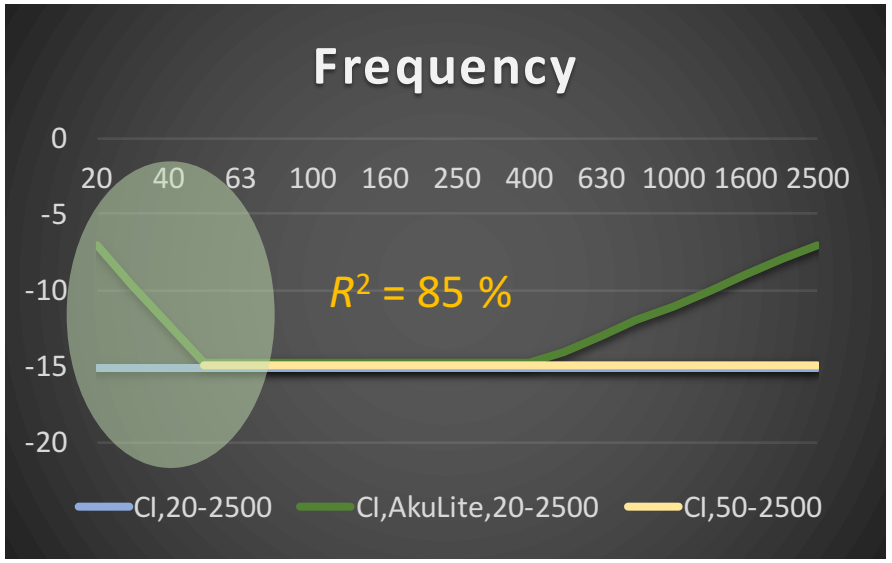
20-50 Hz only



R^2 = 78%

Importance of low frequency range

- Impact sound – Overview of results



Single number	R^2	Frequency range [Hz]
$L'_{nT,w}$	0,38	100-3150
$L'_{nT,w} + C_{I,100-2500}$	0,48	100-3150
$L'_{nT,w} + C_{I,50-2500}$	0,58	50-3150
$L'_{nT,Bodlund}$	0,58	50-1000
$L'_{nT,Hagberg}$	0,63	50-3150
$L'_{nT,Fasold}$	0,56	50-5000
$L'_{n,w} + C_{I,AkuLite,20-2500}$	0,56	20-3150
$L'_{nT,w} + C_{I,AkuLite,20-2500}$	0,57	20-3150

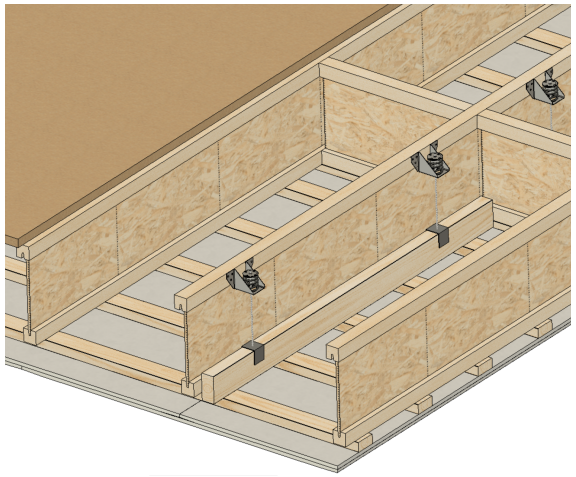
- Airborne sound 50 or 100 HZ ?

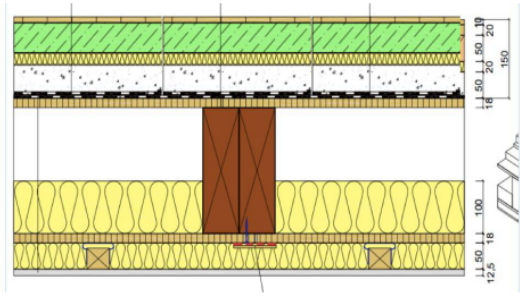
Different building systems

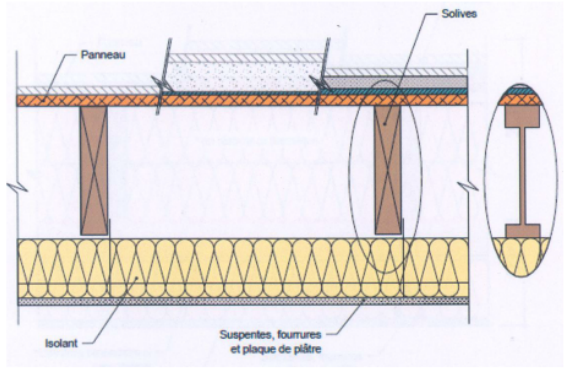
- CLT – growing fast and a volume increasing from 7.000 m^3 till 200.000 m^3 in few years it will be more! The manufacturer will ”sell”.
- Beam sytems – very good if correctly manufactured
- Combination beam system and CLT
- CLT and concrete (hybrid)

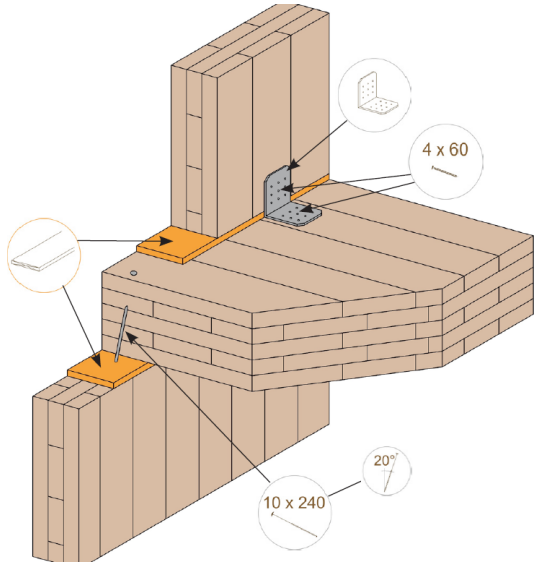
Different building system

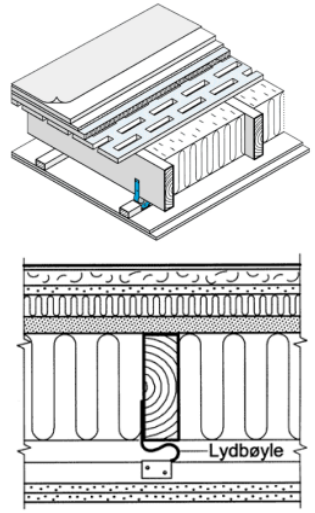
Flat elements
or ”on site”



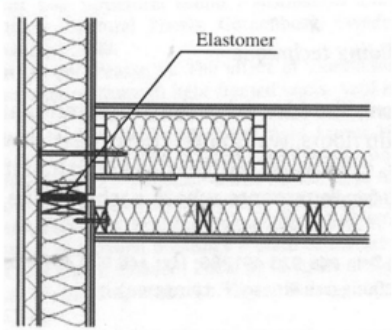


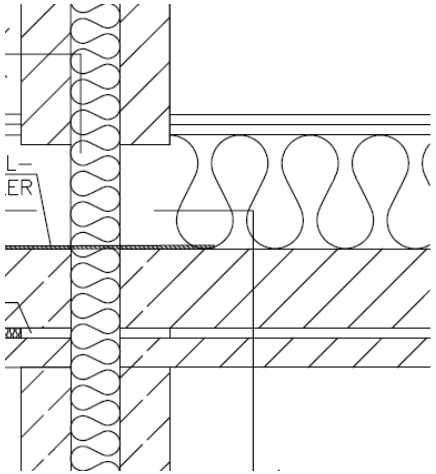






Volumes

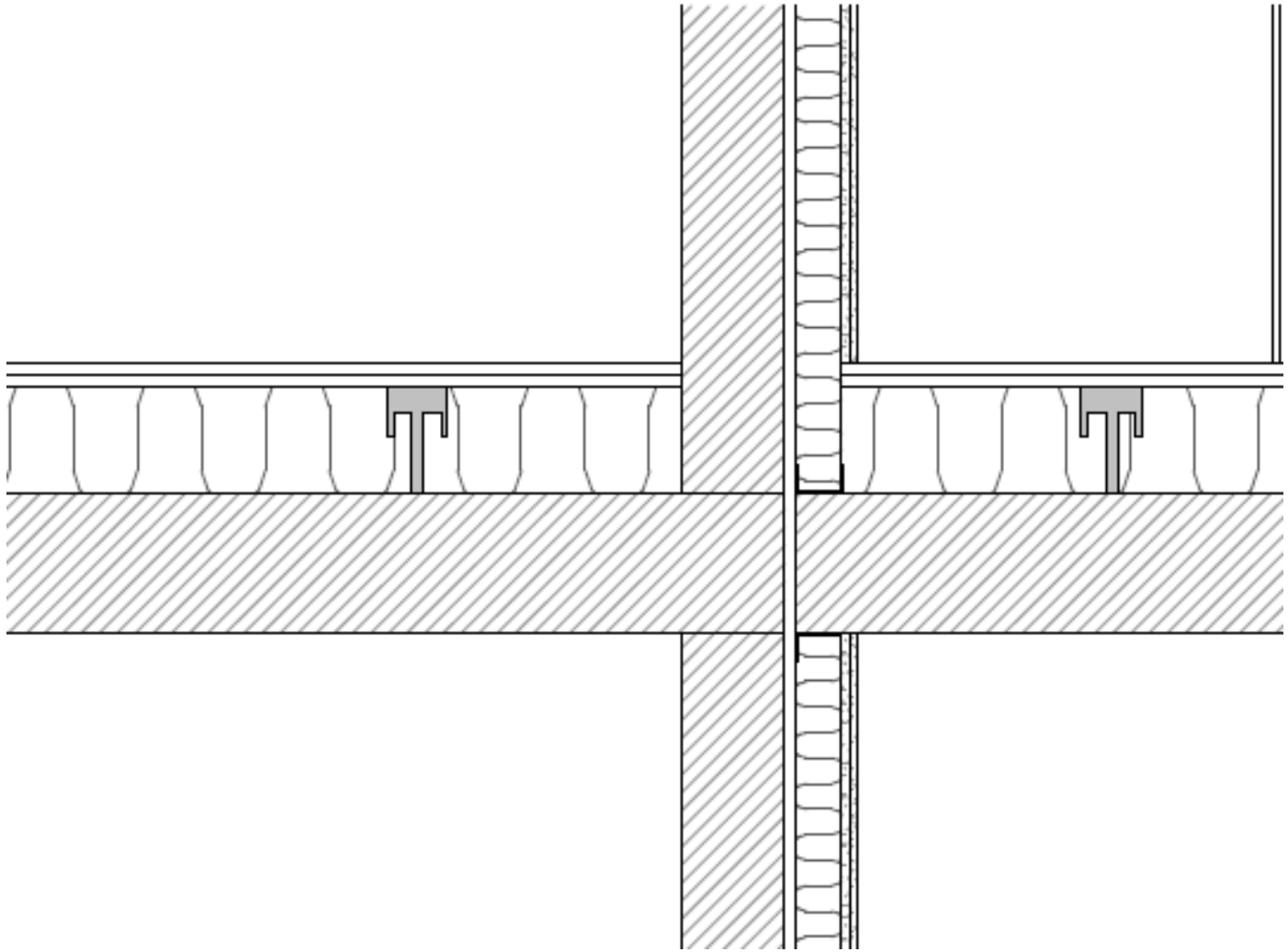




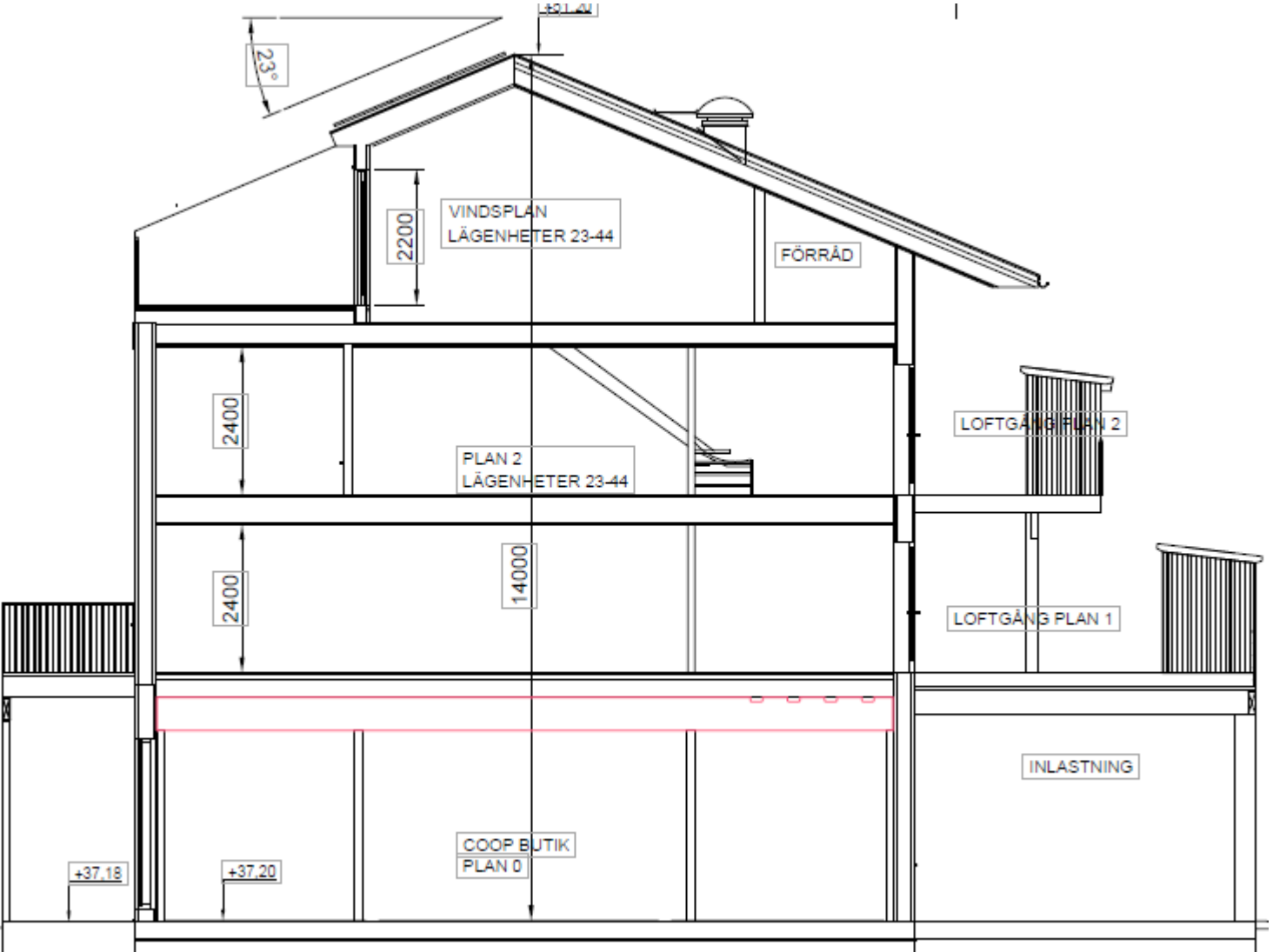
Challenges (Opportunities?) for different systems

- Optimise with regard to sound in order to ”make a project”. Sound classes must be ”questioned” for specific applications
- Added storeys – huge potential
- CLT – can take high loads ➔ can be high buildings (flanking transmission?)
- Raise the ”wood feeling” (fire?)
- Efficient building methods and processes

Principal solution (CLT with raised upper floor)



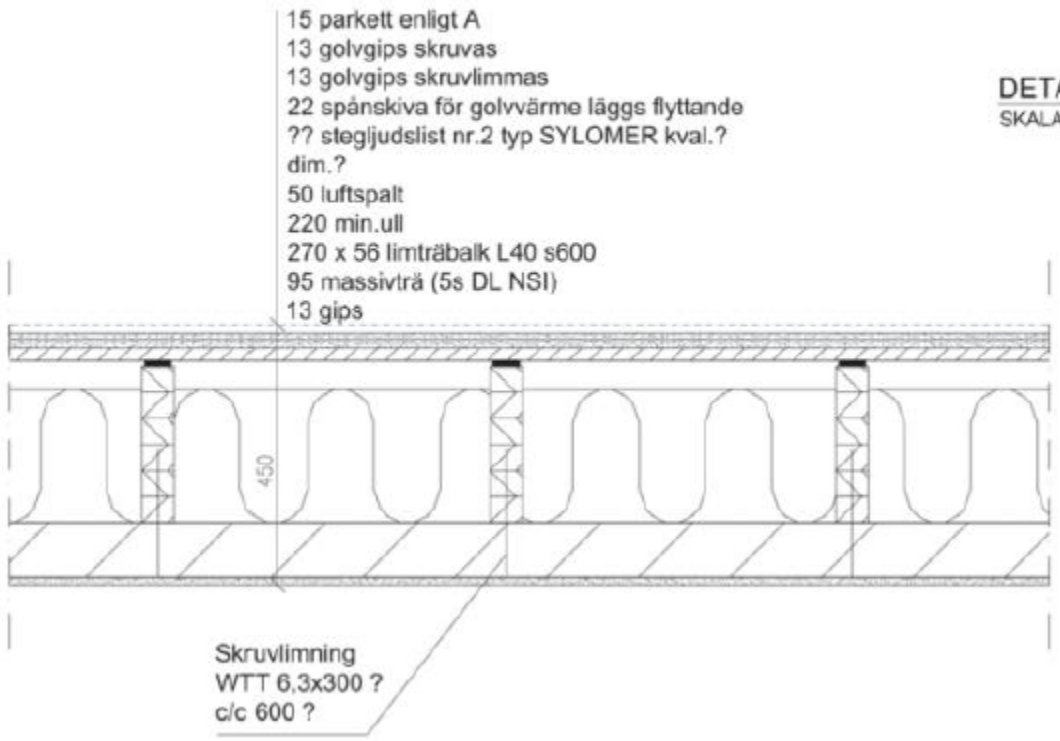
Project with 160 mm CLT i the bottom



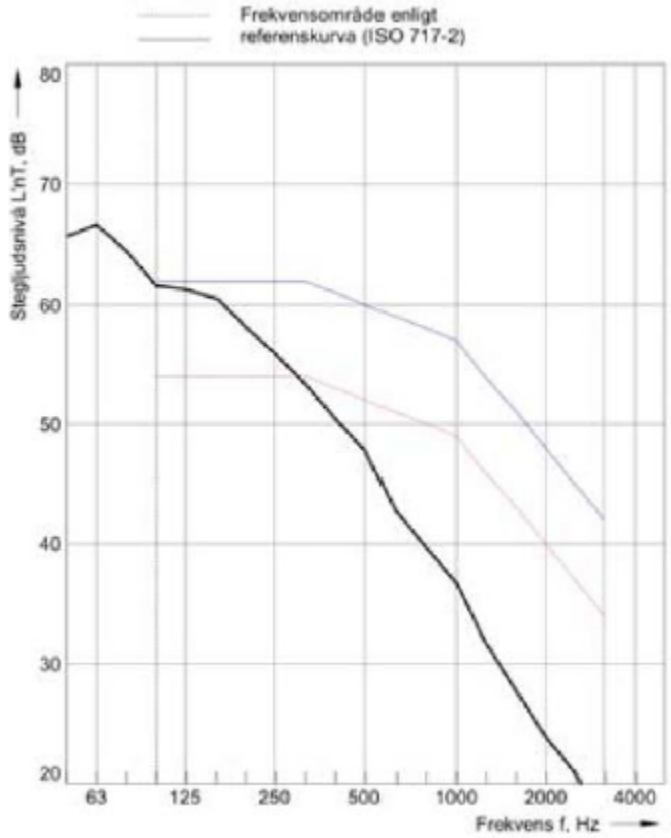
Idea from developer

Project with 160 mm CLT i the bottom

Förändringsförslag (princip)



DETALJ 7
SKALA 1:20



$L'_{n,w}+C_{I,50\text{-}2500} = 57$ dB
$(C_{I,50\text{-}2500} = 6$ dB$)$

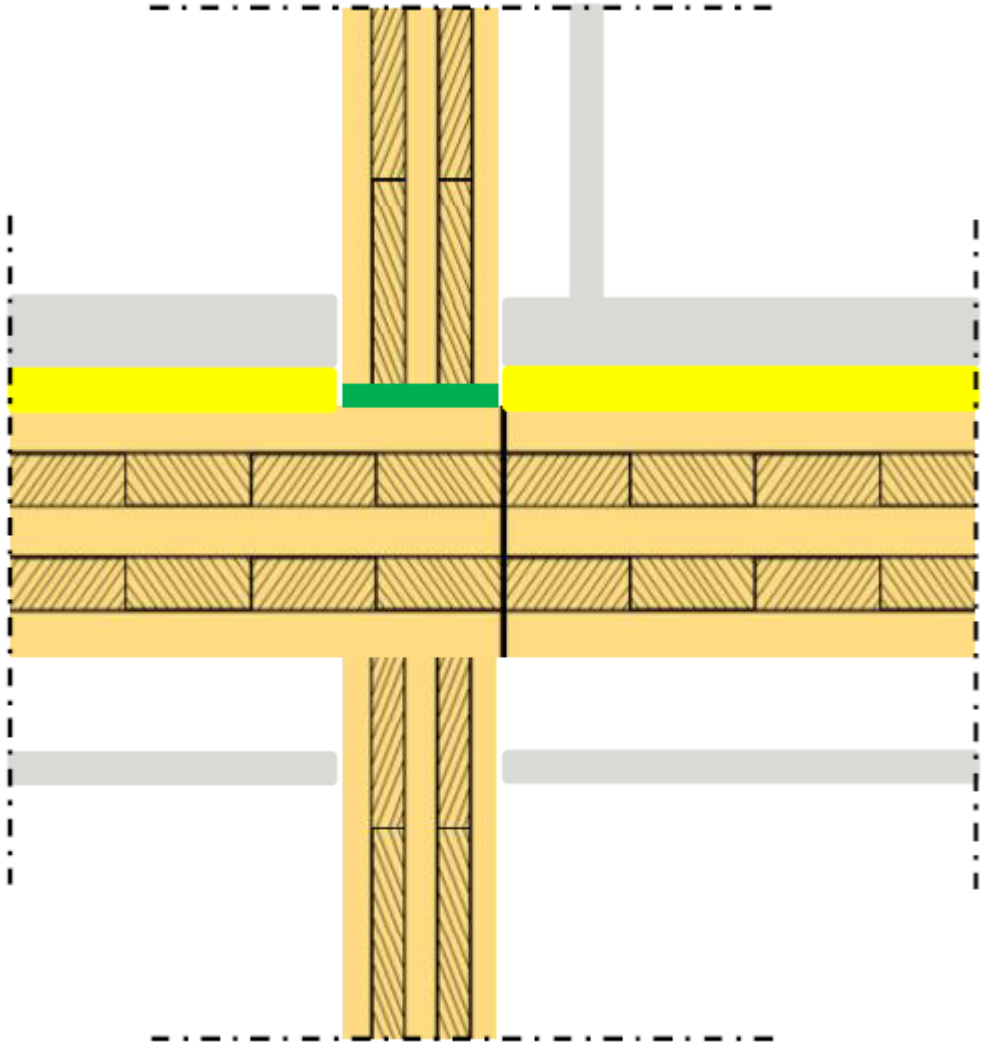
Mätt ljudnivåskillnad $D_{nT,w,50}$ mellan utrymmen [dB]				
Nr	Skiljeyta	Mätriktning	Mätvärde [dB]	Kommentar
D1	Lägenhet 24 allrum nedre plan till lägenhet 23 allrum nedre plan	Horisontell	58	
D2	Lägenhet 24 allrum nedre plan till lägenhet 2 allrum	Vertikal	52	
D3	Lägenhet 24 allrum nedre plan till lägenhet 25 allrum nedre plan	Horisontell	57	
D4	Lägenhet 24 allrum/sovrum övre plan till lägenhet 23 allrum/sovrum övre plan	Horisontell	56	

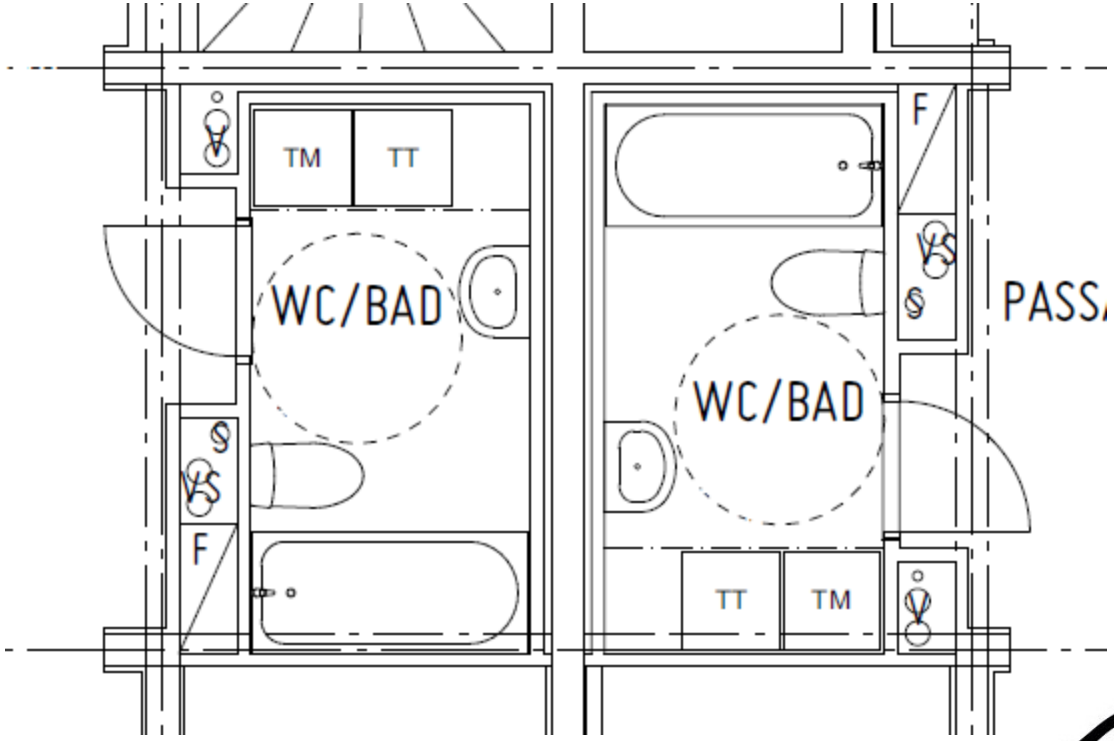
Tabell 4

Mätt stegljudsnivå $L_{nT,w,50}$ i utrymme [dB]				
Nr	Skiljeyta	Mätriktning	Mätvärde [dB]	Kommentar
I1	Lägenhet 24 allrum nedre plan till lägenhet 23 allrum nedre plan	Horisontell	41	
I2	Lägenhet 24 allrum nedre plan till lägenhet 2 allrum	Vertikal	54	
I3	Lägenhet 23 allrum nedre plan till lägenhet 1 allrum	Vertikal	56	

Cederhusen

Challenges

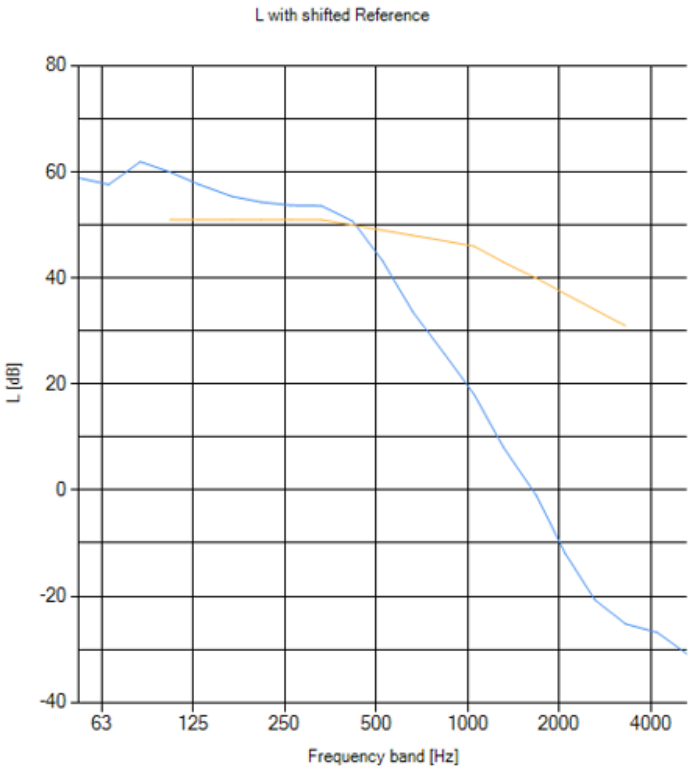




Challenges

Vertical sound insulation (Calculatis)

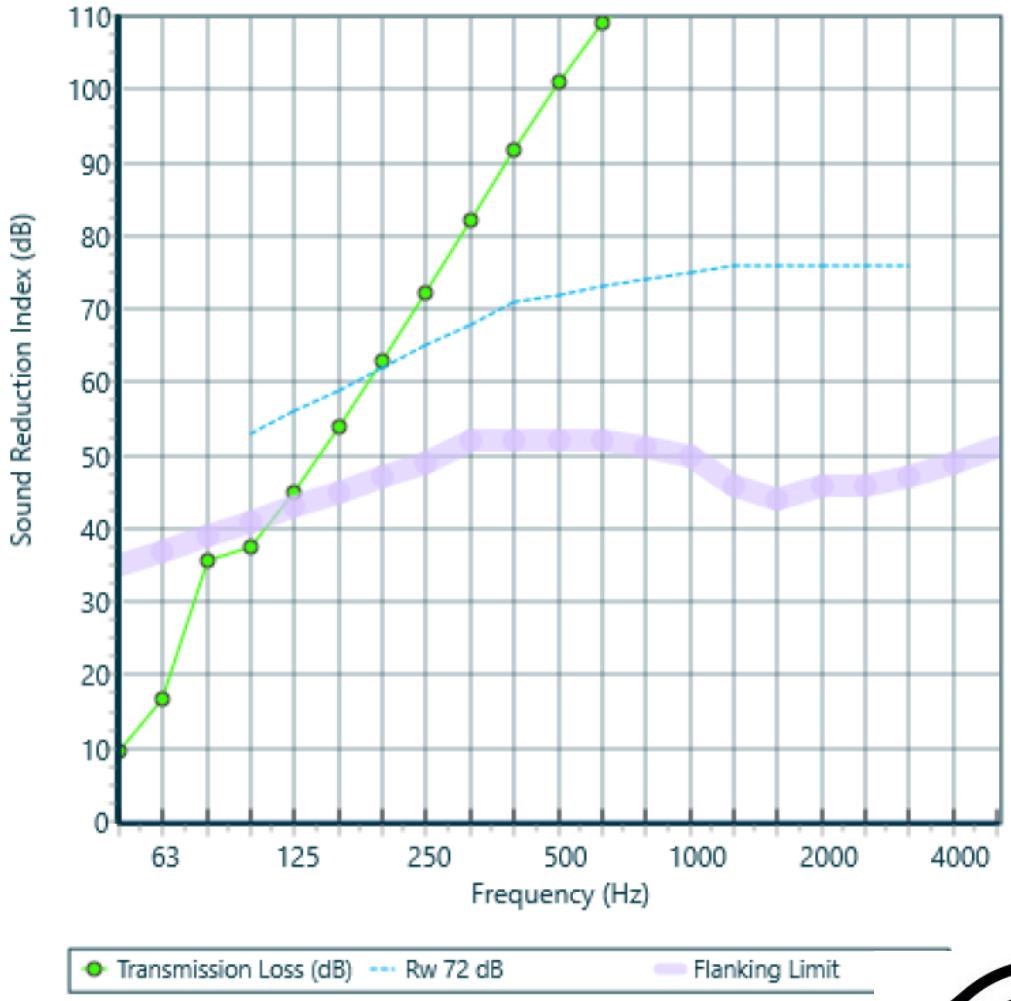
L_{nw}	49 dB
C_I	0 dB
$C_{I,50\text{-}2500}$	4 dB



R_w	70 dB
C	-5 dB
C_{tr}	-13 dB
$C_{50\text{-}3150}$	-8 dB
$C_{50\text{-}5000}$	-7 dB

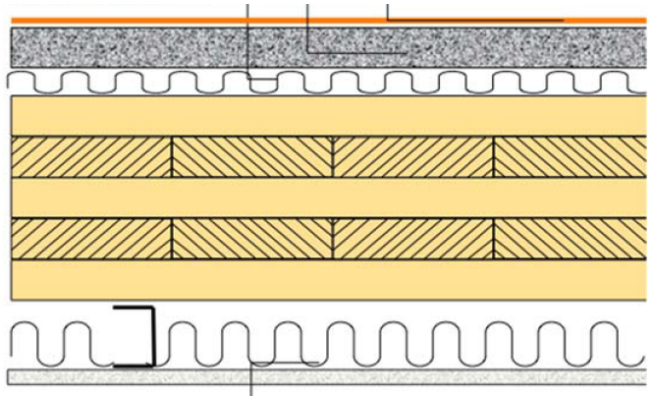
$D_{nTw,50}$ ca 52 dB (flank - mätningar)

Bathroom – bathroom (Insul)

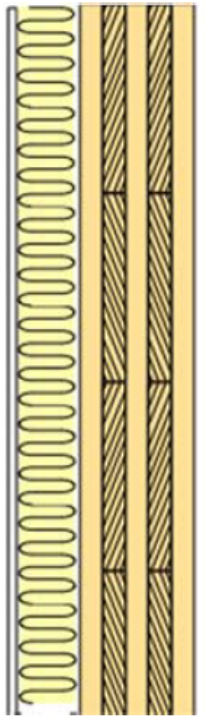


$C_{50\text{-}3150}$ = -21 dB

Student dwellings in Norway



40+
30+
140+
100 (divided)



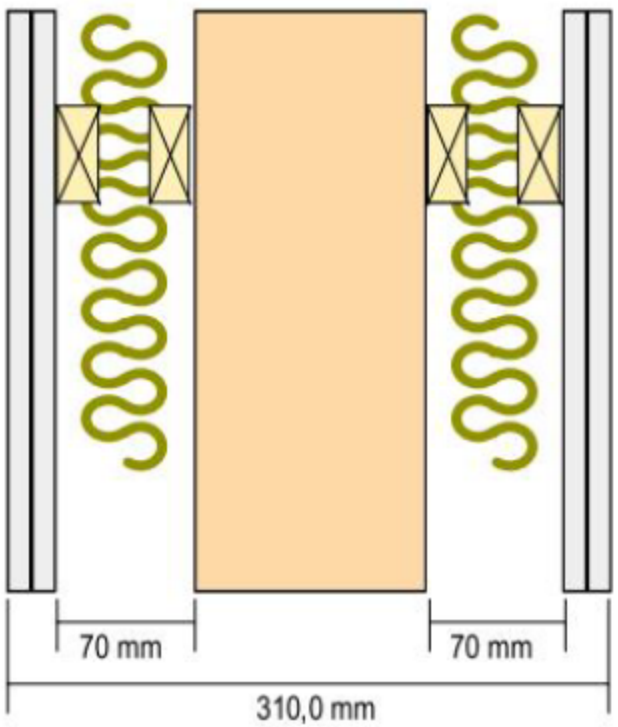
15+95+120

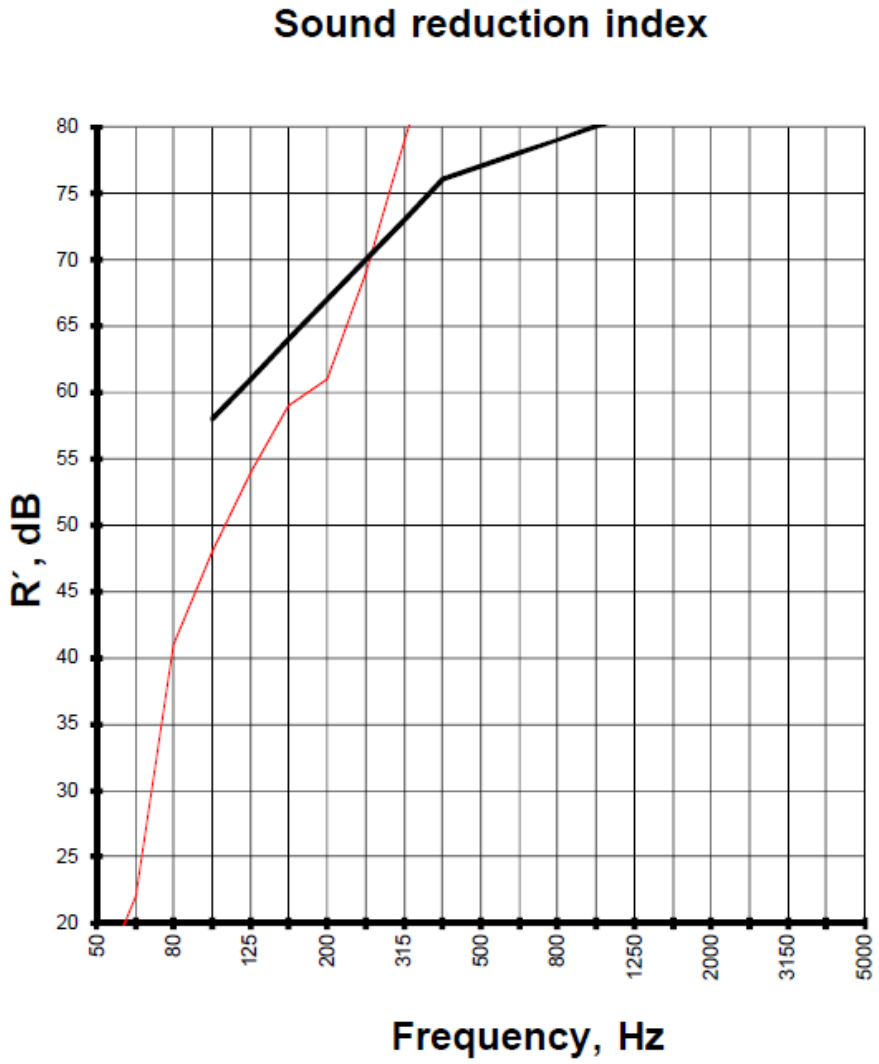
Vert
$R_{w,ber}$ = 67 dB $L_{nw,ber}$ = 51 dB
$R'_{w,mät}$ = 56 dB $L'_{nw,mät}$ = 53 dB

Hor
$R_{w,ber}$ = 56 dB
$R'_{w,mät}$ = 54-58 dB

Junction:
6mm Rothoblaas (Xylofon) both above and under floor structure

CLT in Sundbyberg



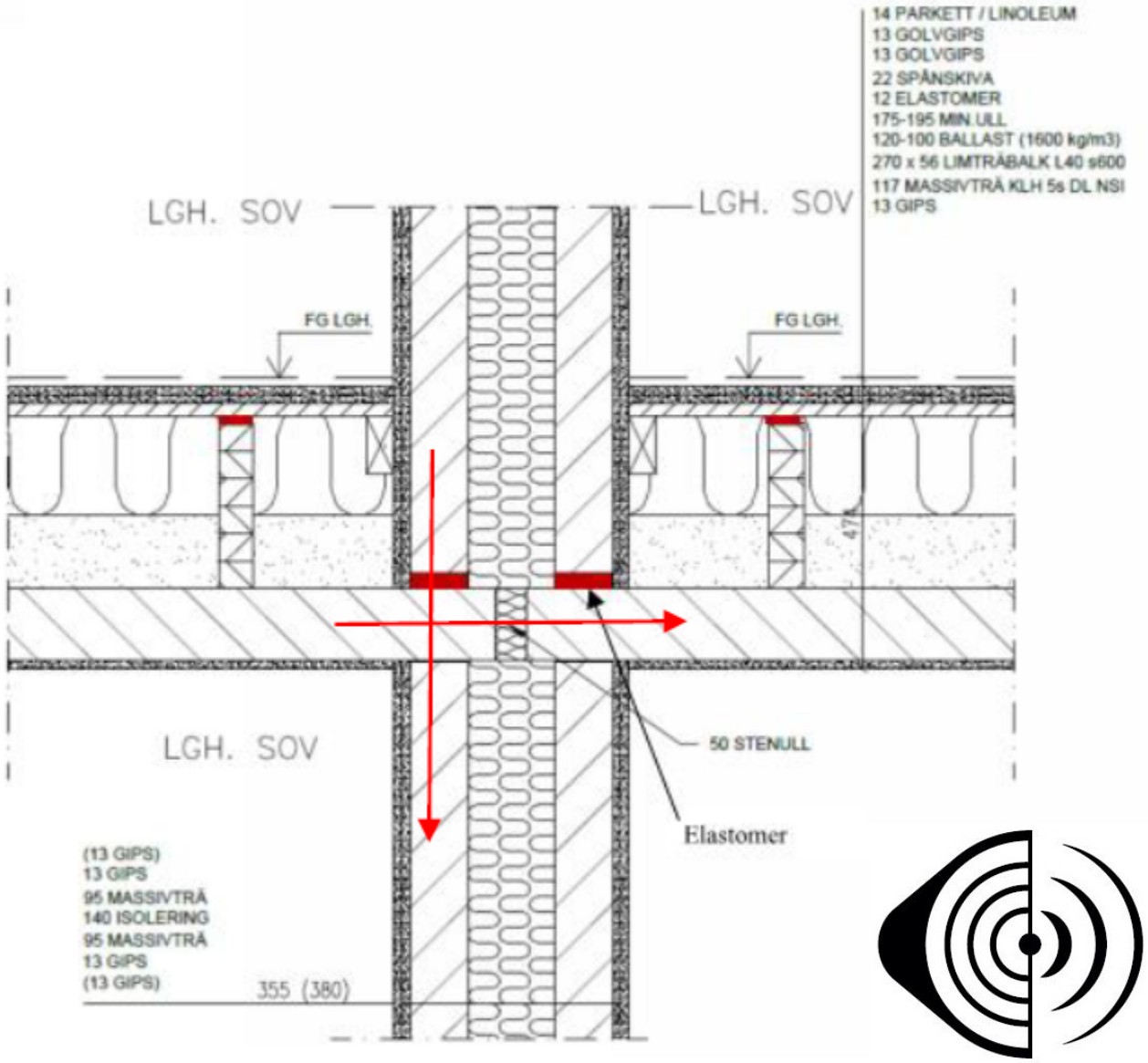


R_w ($C_{50\text{-}3150}$) = 77 (-24) dB

➔

That means it will BBR for other dwellings with no margin

6 storeys with double wall structure



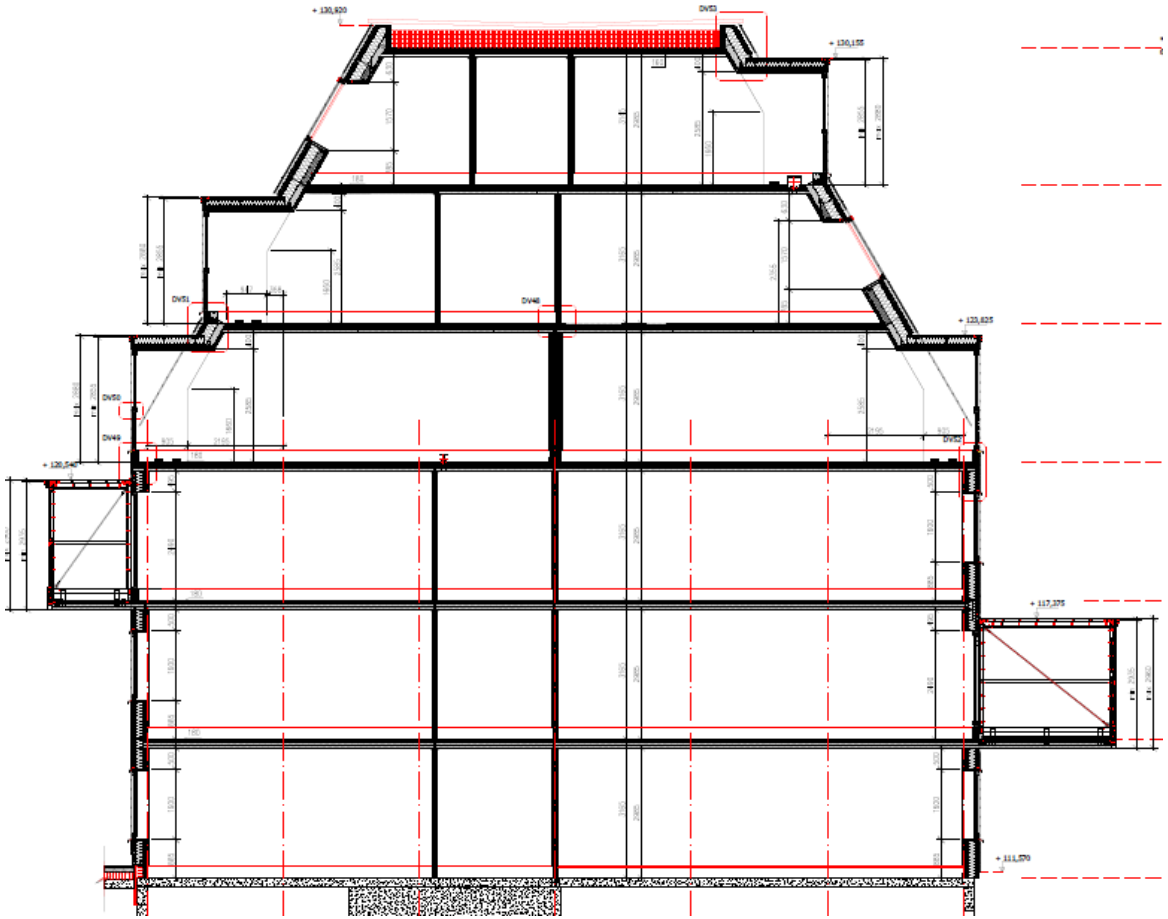
6 storeys with double wall structure

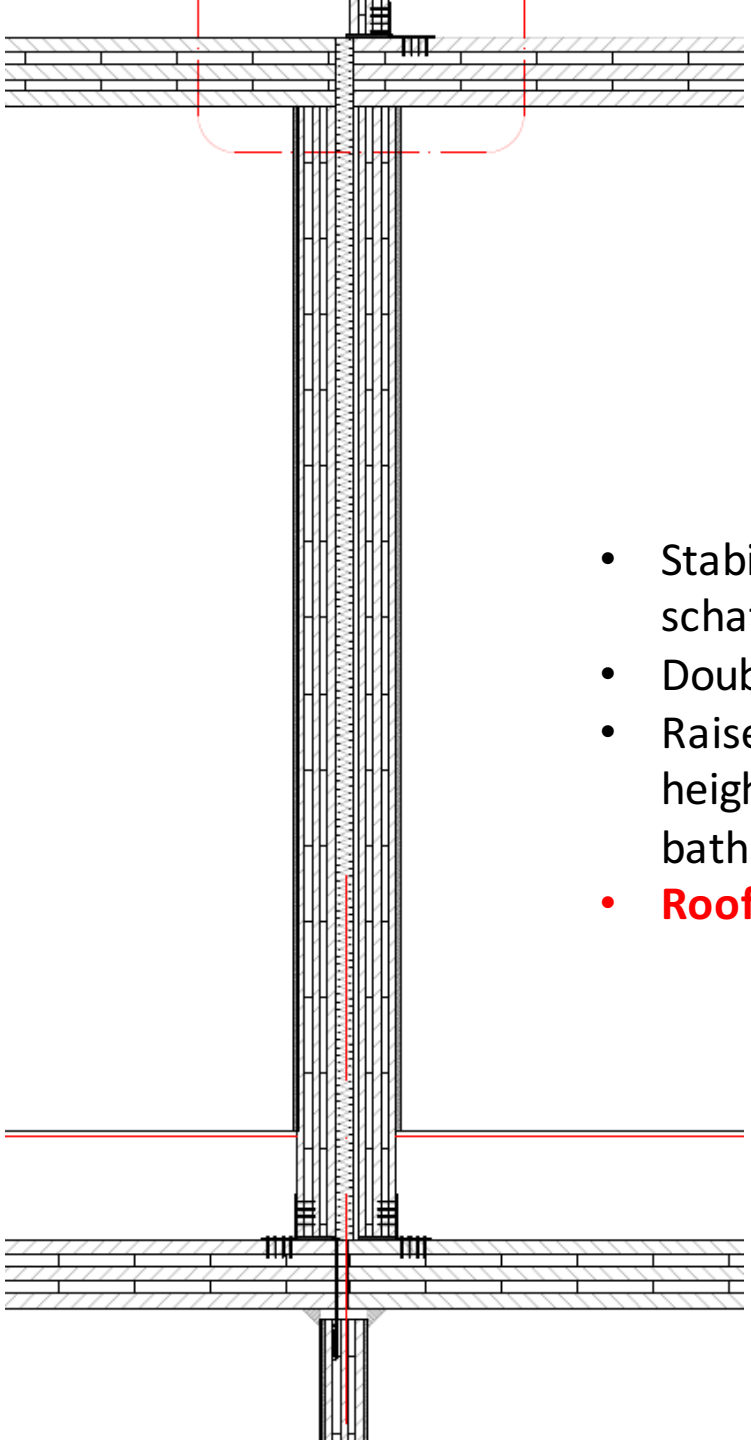
- Vertical and horisontal airborne
  - $R'_w + C_{50\text{-}3150}$ between 59 and 63 dB
- Vertical impact sound
  - $L'_{n.w} + C_{I,50\text{-}2500}$ between 53 and 58 dB
- Surprisingly low amount of flanking sound and floor assembly is not optimum
  - Better to optimise the floor structure and accept lower airborne sound insulation (my opinion)
  - BUT – still a very good example!

Karlskrona


BUSS HPL
UTBREDNING CYKELGARAGE
LEKYTA
GEMENSAM UTEPLATS
GEMENSAM UTEPLATS

Karlskrona





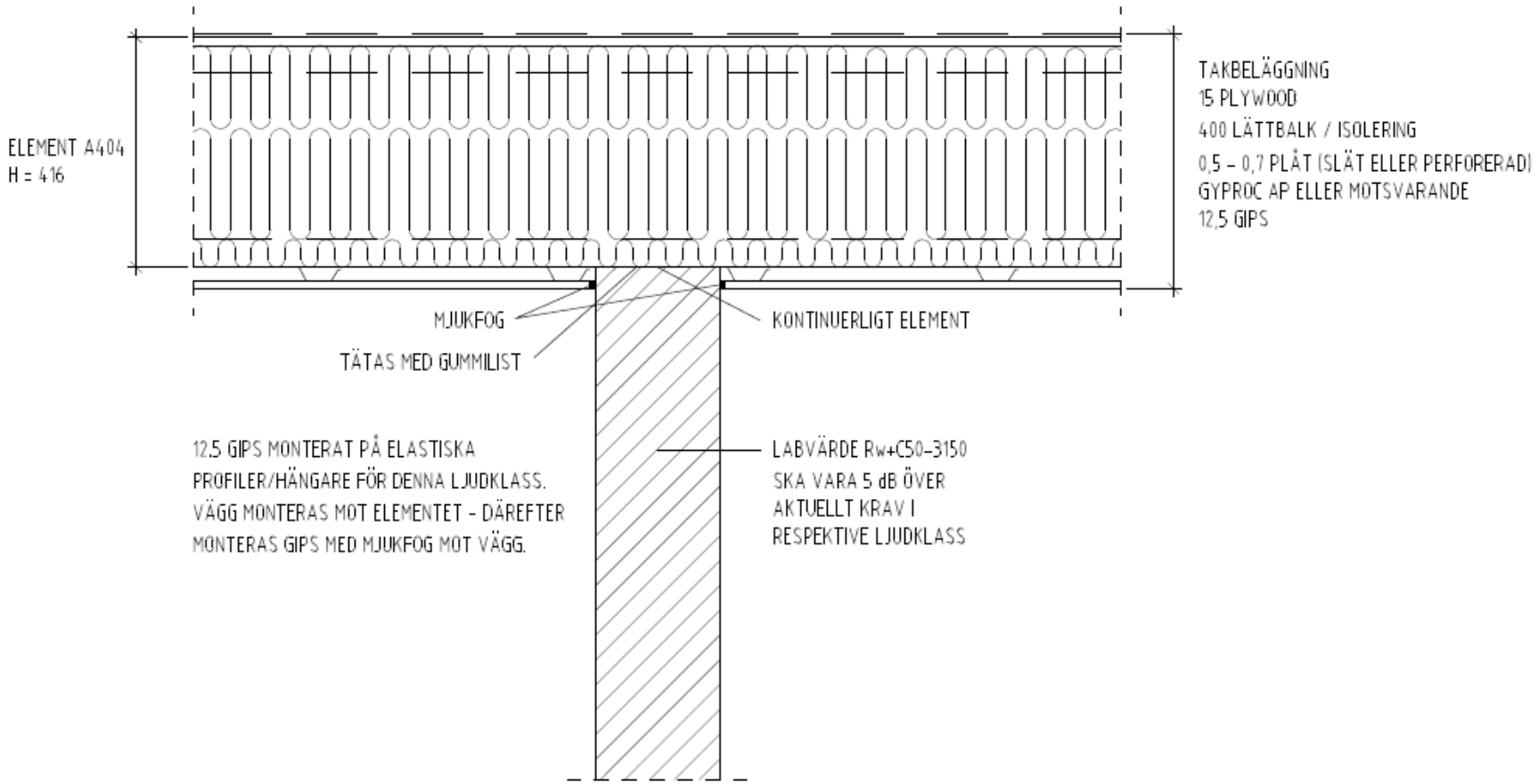
- Stabilising concrete schaft
- Double CLT walls
- Raised floors adapted to height of prefabricated bathrooms
- **Roof is facade……..**

Roof Element – flanking transmission

Roof Element – flanking transmission

TYPLÖSNING BBR

LÄGENHETSSKILJANDE KONSTRUKTION BOSTÄDER DnT,w,50 >= 52 dB



Takelement – resultat (Lättelement)

Prov	Standardelement består av kont. element med kortling över stöd. Tilläggsåtgärder, se nedan	Resultat		Bilaga
		$D_{n,f,w}$	$C_{50\text{-}3150}$ [1)]	
A405_slät	utan kortling, 1 lag gips (GN) dikt an	60	-5	05
A405_slät	2 lag gips (GN) på 25 AP	72	-13	02
A405_slät[2)]	2 lag gips (GN) på 25 AP	72	-12	03
A405_slät	Element delat + 1 lag gips (GN) dikt an	74	-9	08

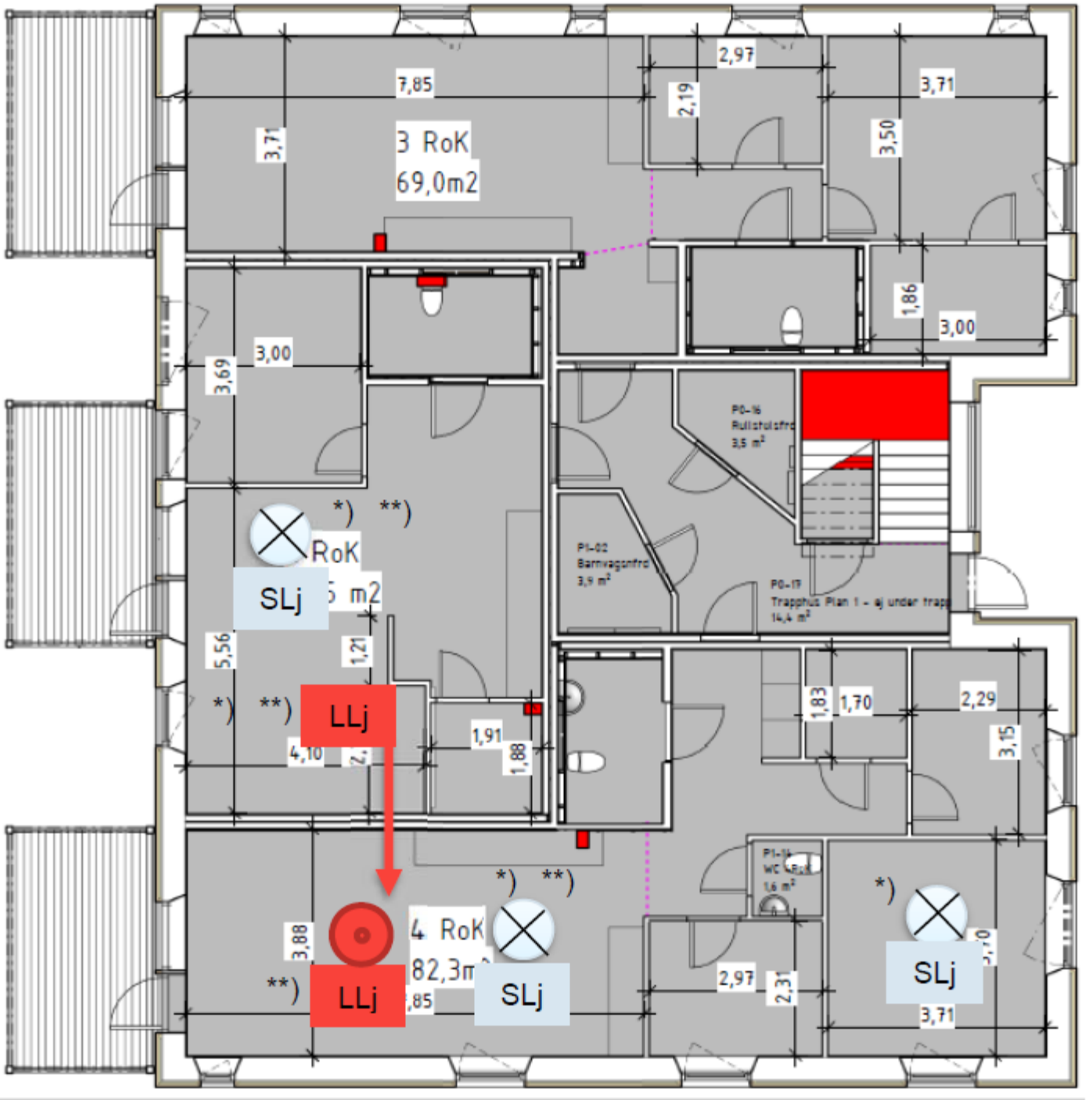
Takelement – resultat (Lättelement)

- **BBR** – 1 lager gips på akustikprofiler mot kontinuerligt element (både perforerat och operforerat)
- **Klass B** – 2 lager gips på Akustikprofiler mot kontinuerligt element alternativt delat element utan åtgärd (både perforerat och operforerat)
- **Klass A** – Element delat + 1 lager gips dikt an (både perforerat och operforerat)
- **48 dB** – 1 lager gips dikt an (både perforerat och operforerat)
- **44 dB** – ingen åtgärd, eventuellt att man förutsätter ett vanligt mineralullsundertak, beroende på rumsstorlekar (både perforerat och operforerat)

Lusthusbacken

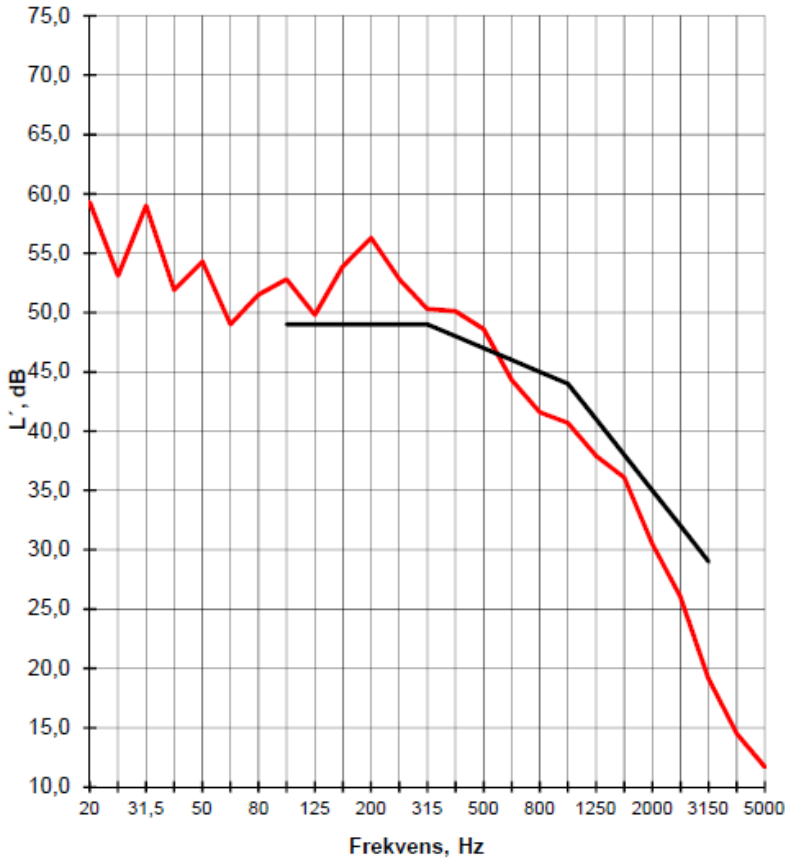
4 small houses in Piteå, ecological buildings nominated to the ”building of the year”

Masonites building system, ”further developed”

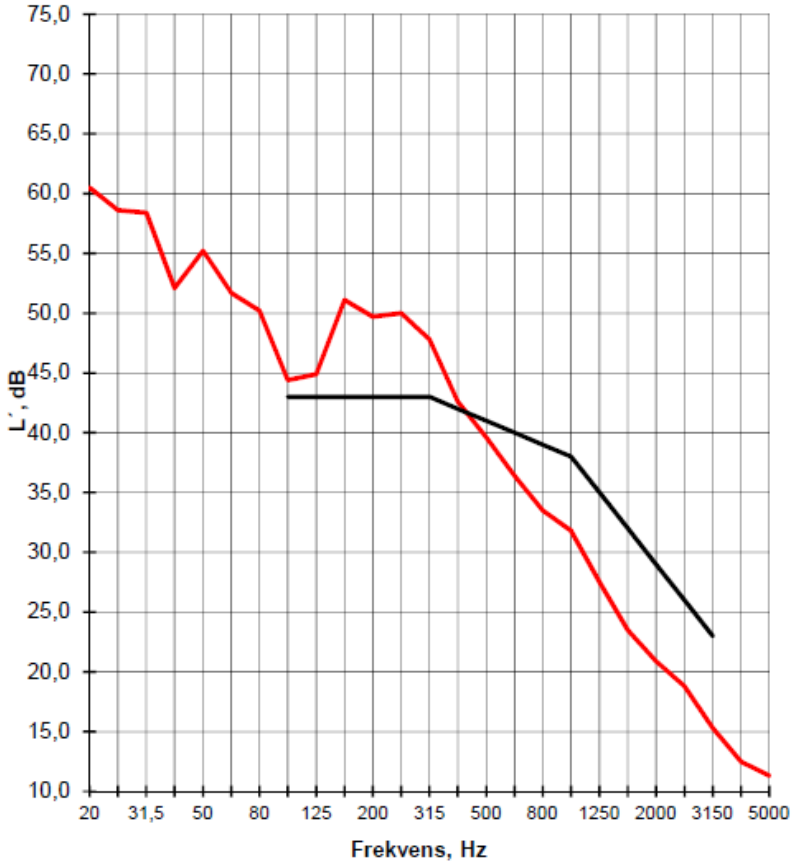


Floor assembly – Sound class A for impact sound (also fulfills minimum level even with $C_{I,AkuLite,20\text{-}2500}$ included)

SS-EN ISO 717-2		
$L'_{n,w}$	47	dB
$L'_{n,w+Ci,50\text{-}2500}$	48	dB
$L'_{n,w+Ci,AkuLite,\ 20\text{-}2500}$	55	dB



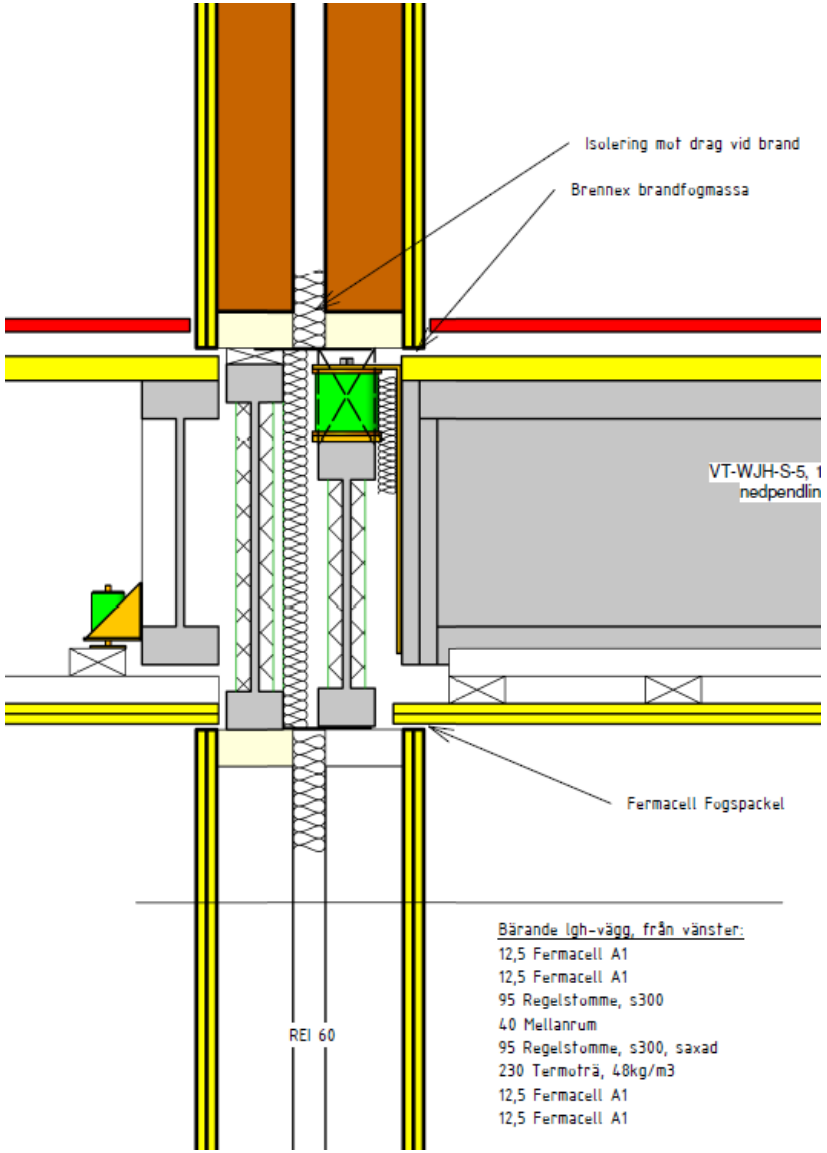
SS-EN ISO 717-2		
$L'_{n,w}$	41	dB
$L'_{n,w+Ci,50\text{-}2500}$	45	dB
$L'_{n,w+Ci,AkuLite,\ 20\text{-}2500}$	56	dB



Airborne

$D_{nT,w,50}$ = 59 dB

Partition wall



Airborne (hor):

$D_{nT,w,50}$ = 51 dB

Only 1 layer of Fermacell (though it looks like 2)

Airborne (vert):

$D_{nT,w,50}$ = 59 dB

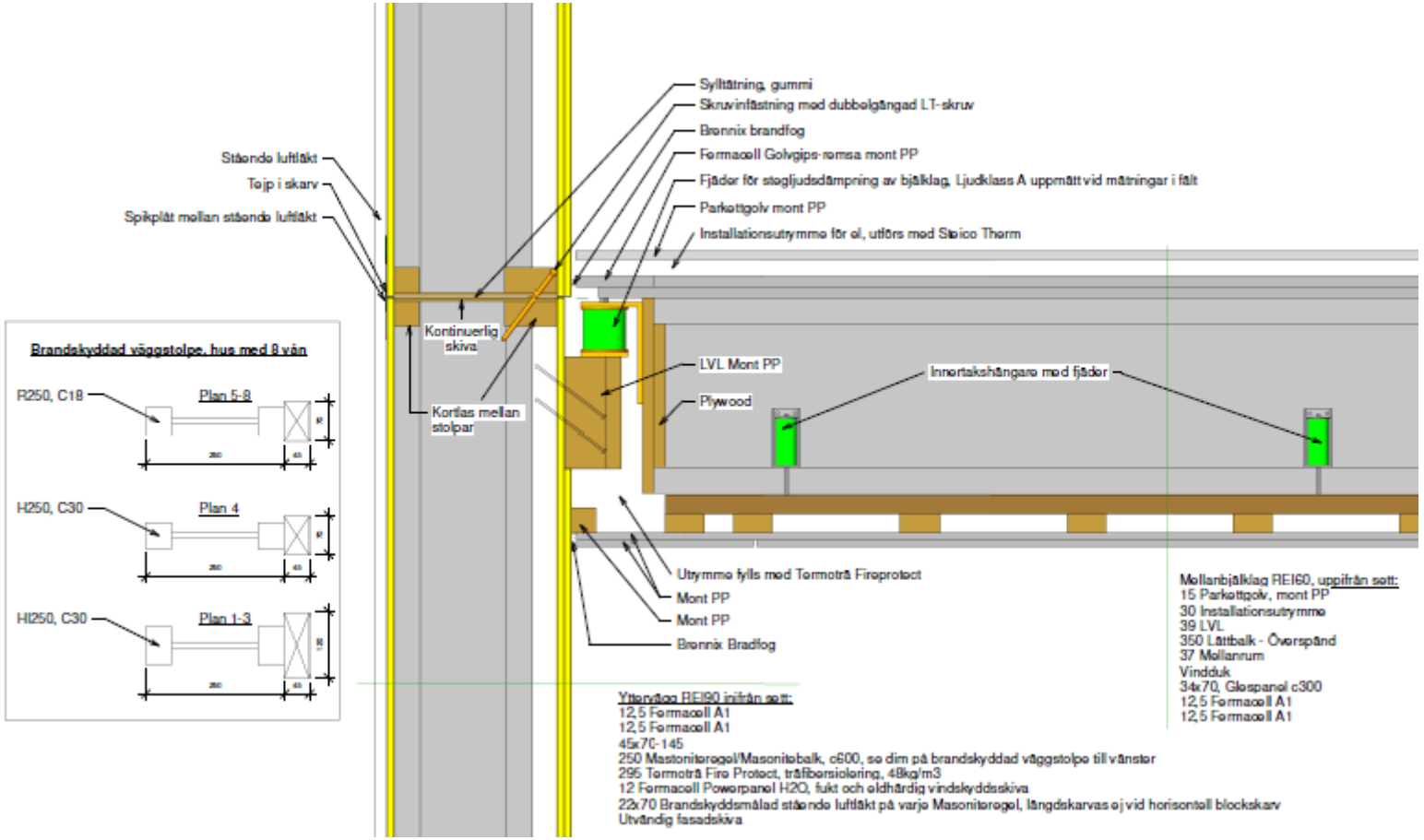
Skellefteå

57 new ”bostadsrätter” in the center of Skellefteå, each five storeys

Masonites building system

A lot of work to manage facade due to traffic noise since a new raod is planned connected to a new bridge. Screended balconies and careful floor plan was the solution

Masonite system – new junction

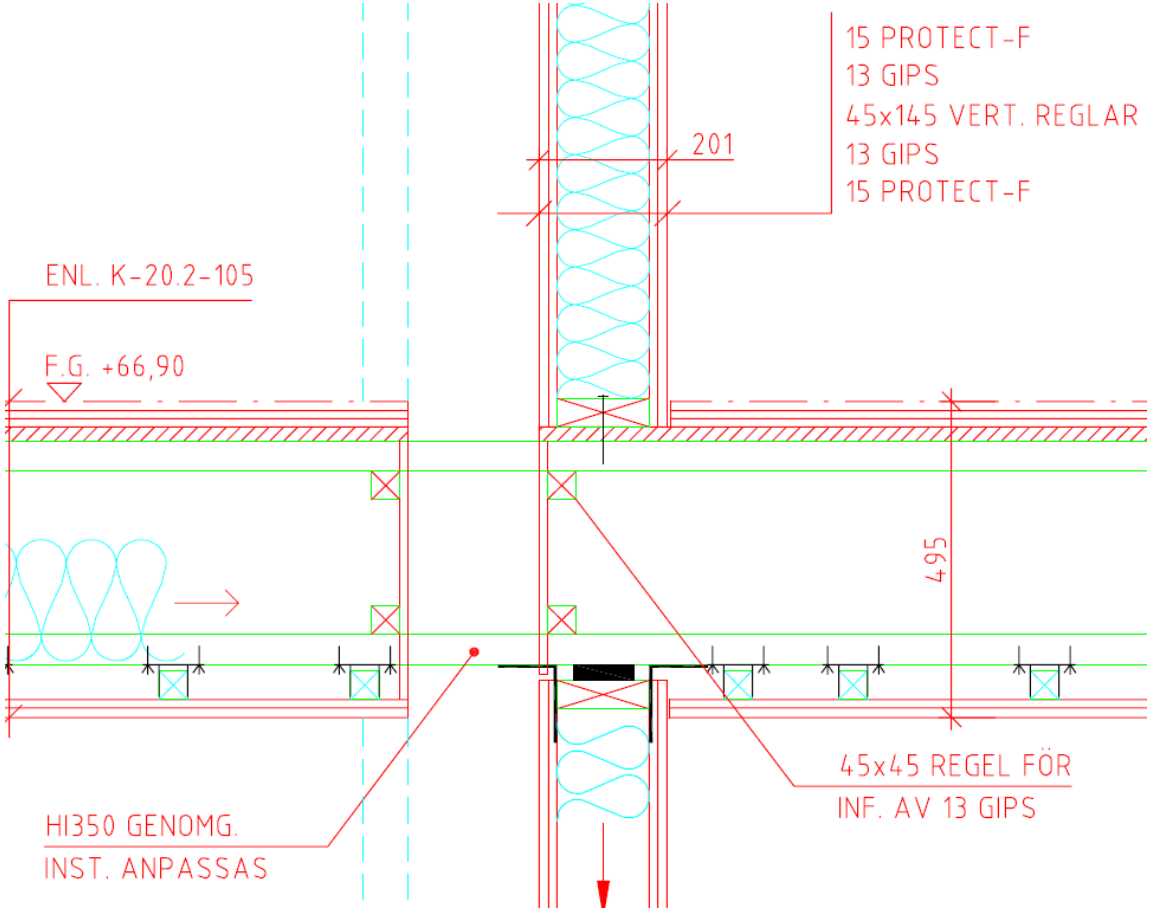


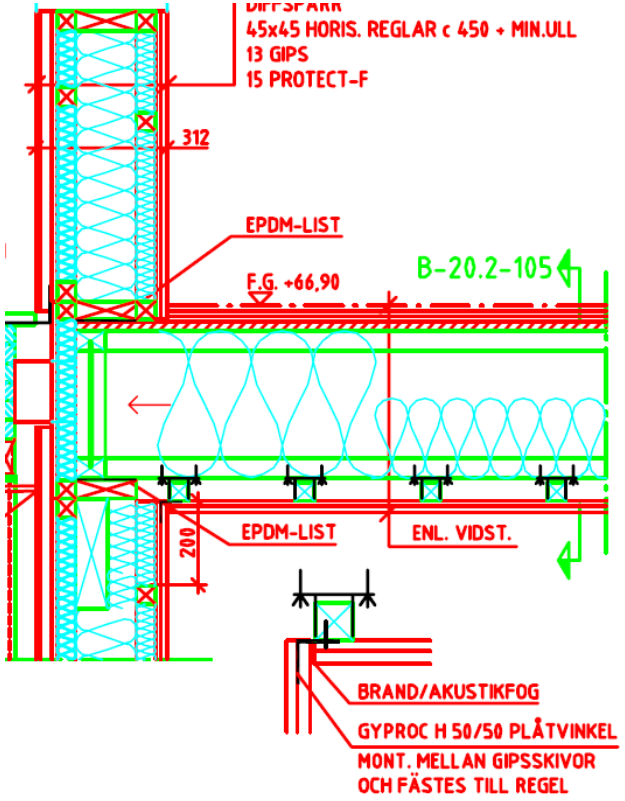
Airborne sound vertically might become critical – Probalby BBR (almost..) but not class B.

Higher houses require loadbearing connection

Masonite system – using an existing parking as foundation

Masonite system – using an existing parking as foundation

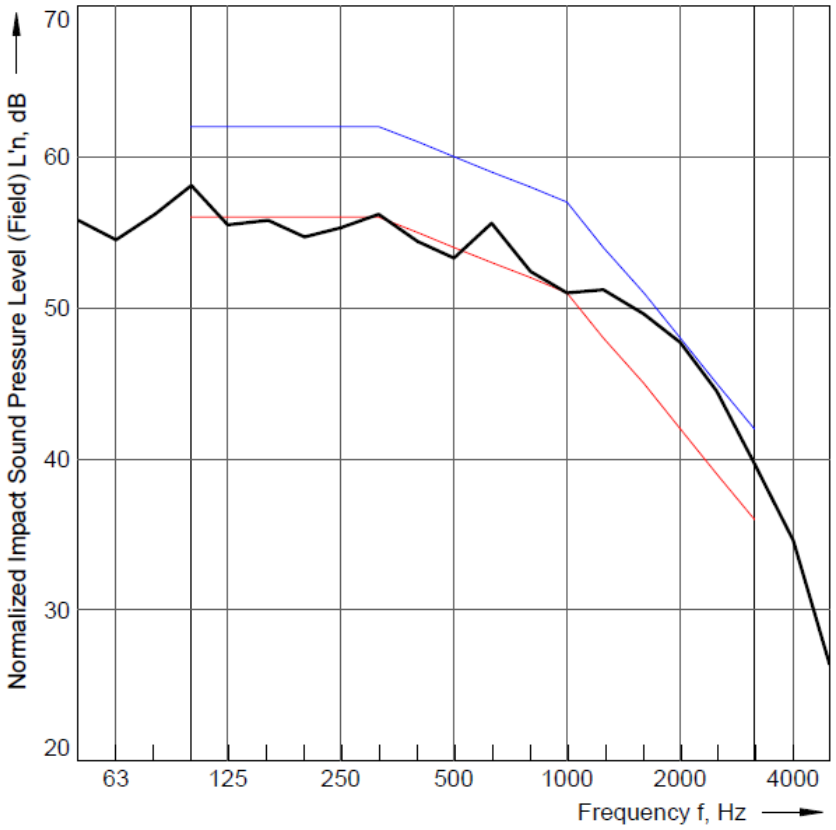


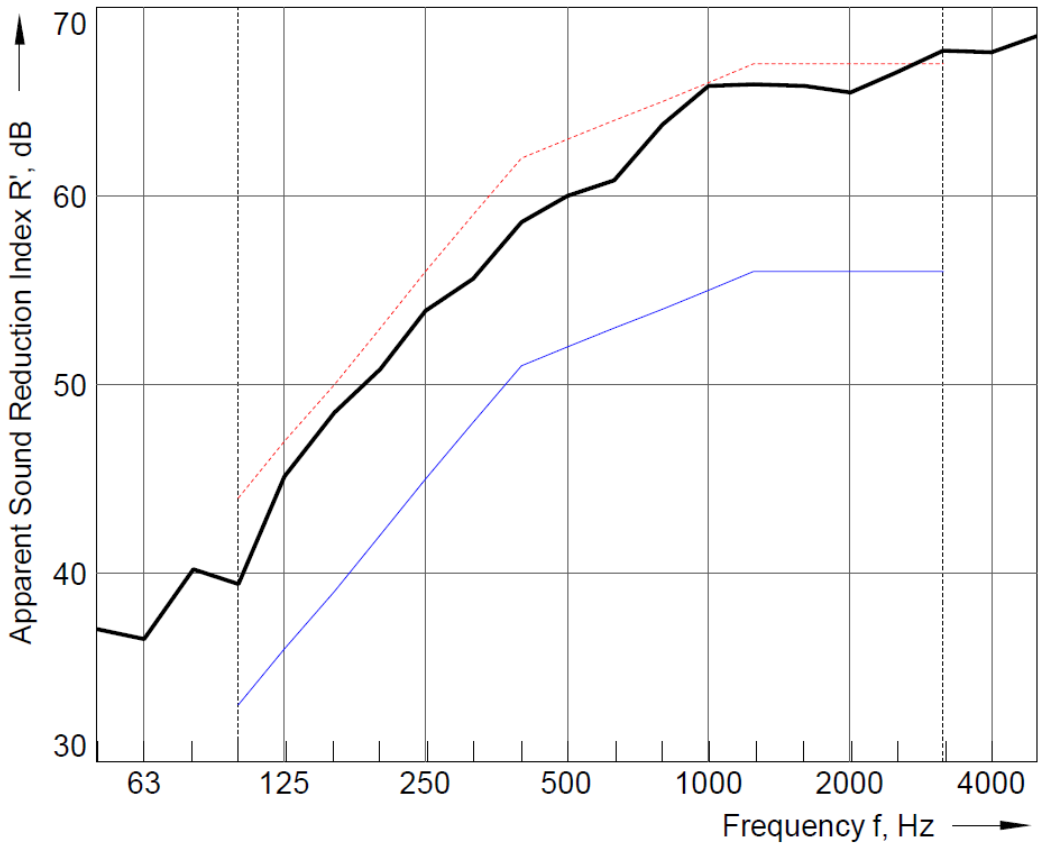


Masonite system – using an existing parking as foundation

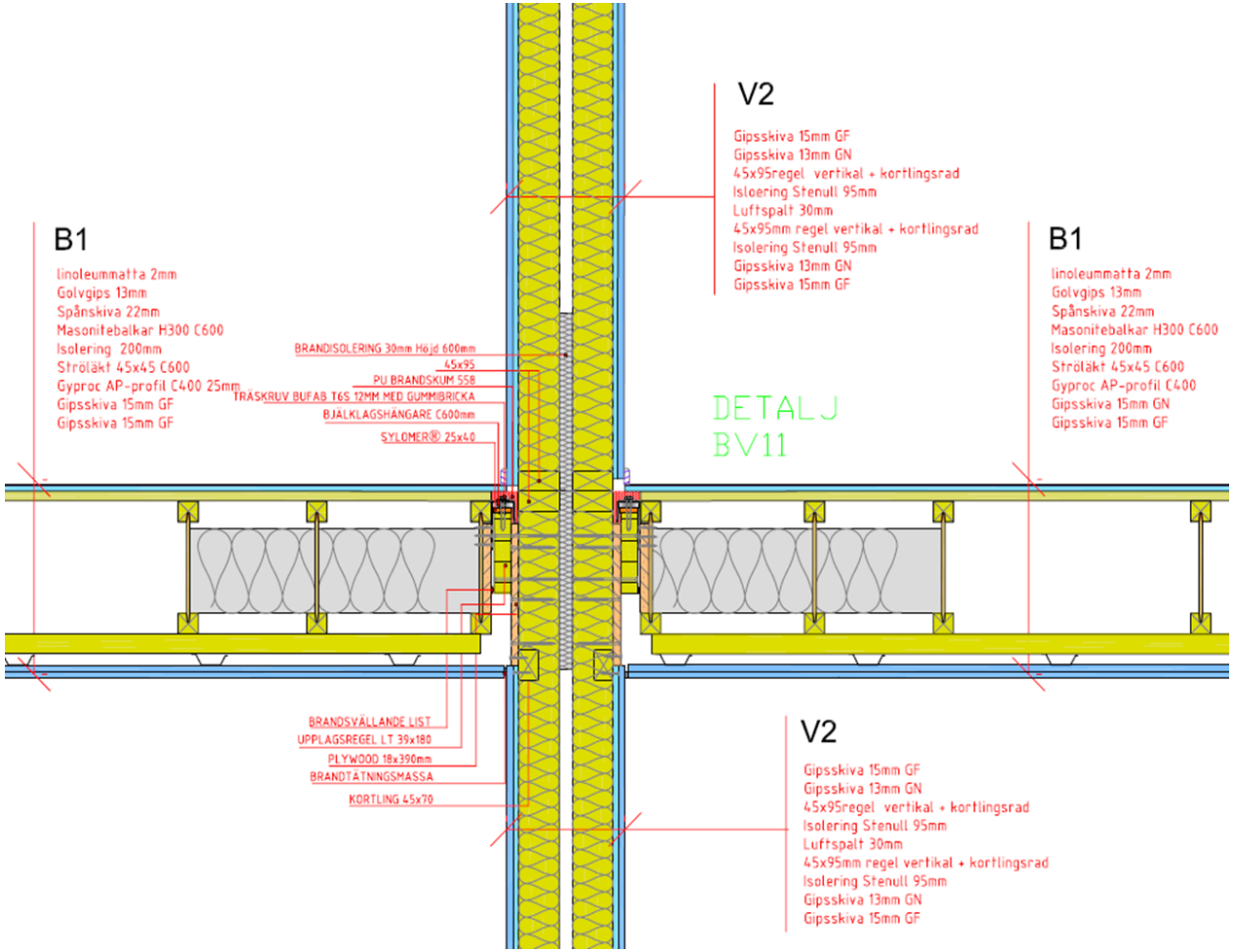
Steg $L'_{n,w}+C_{I,50\text{-}2500}$ = 51 dB ($L'_{n,w}$= 54 dB)

Luft $R'_{w}+C_{50\text{-}3150}$ = 60 dB

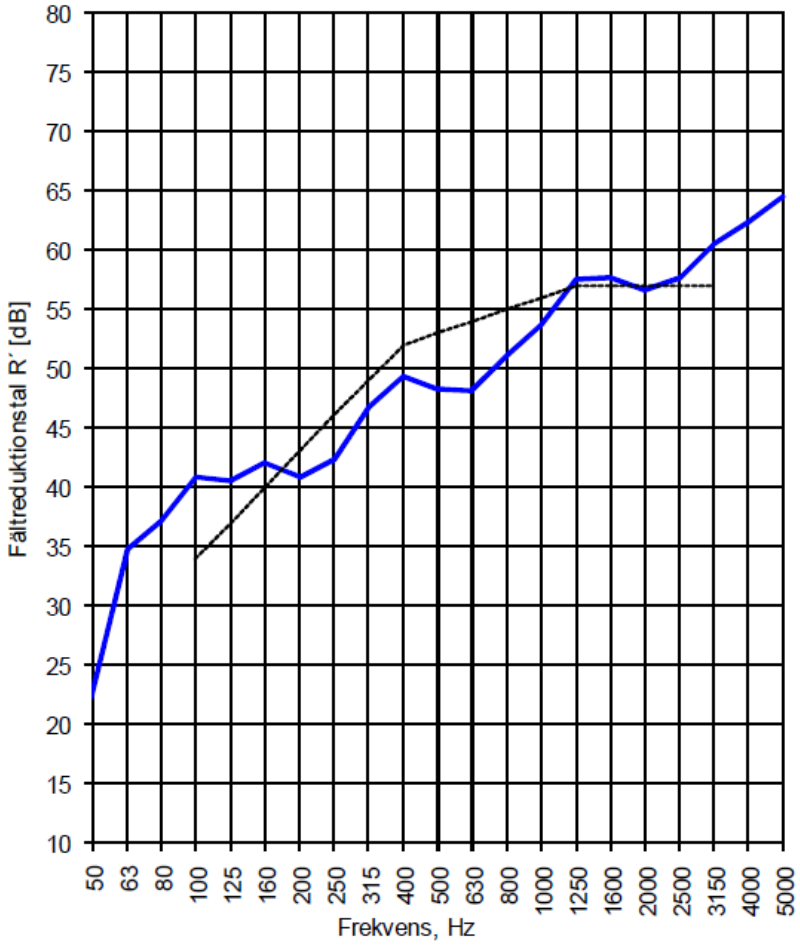




Masonite system – Kv Kullen (residential flats for elderly)



$R'_w+C_{50\text{-}3150}$ = 51 dB (vert)



Volume elements

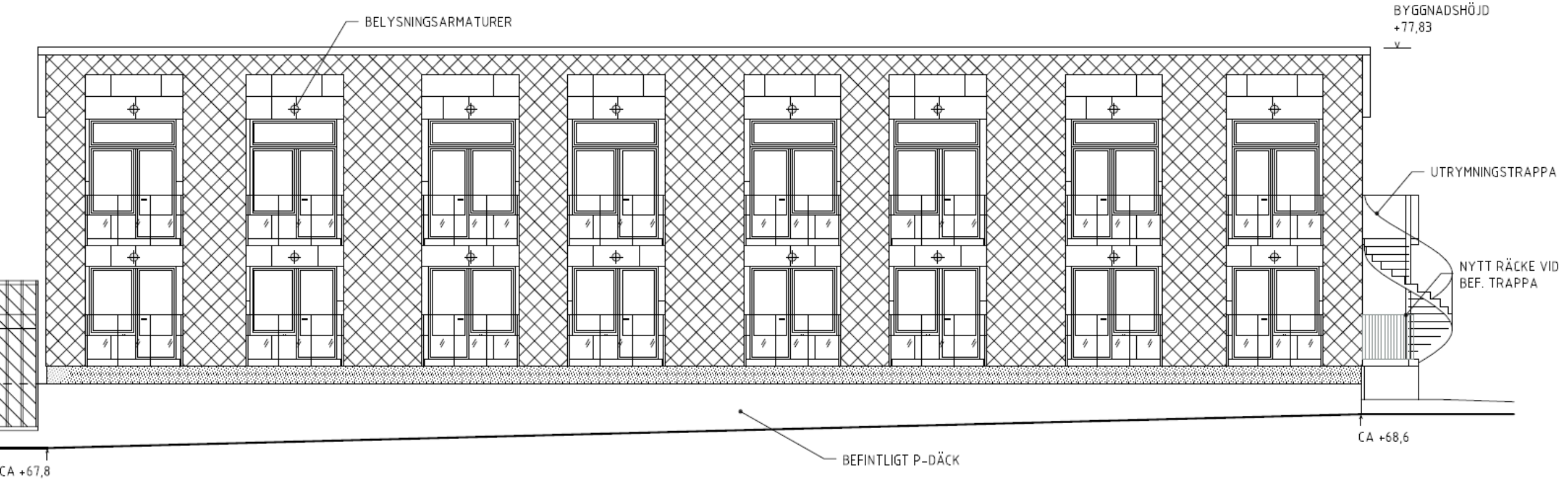
- Build on existing buildings / Foundations, student dwellings and small dwellings

- Fast, efficient and predictable (also acoustically – sometimes….)

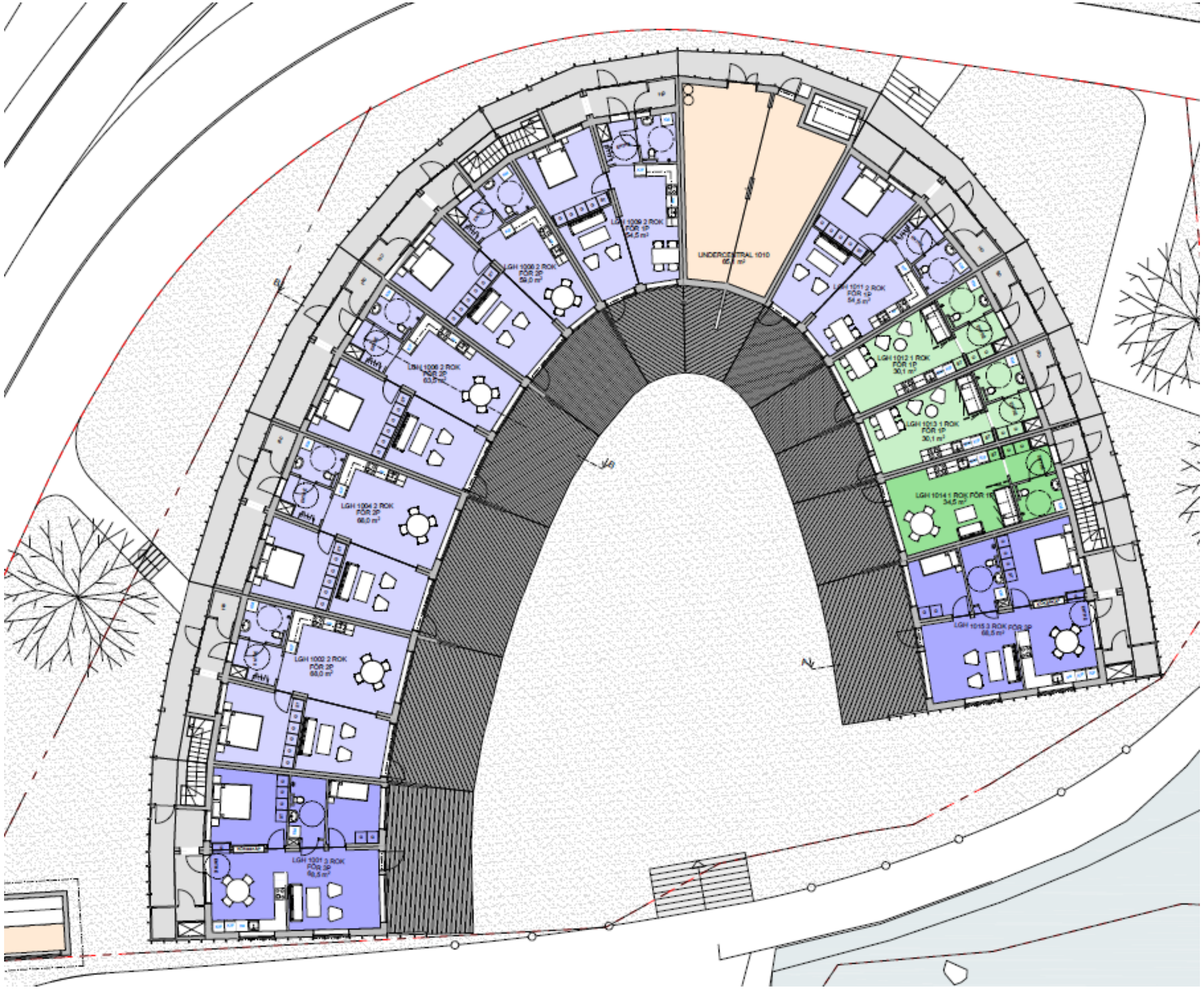
- Can be done with many different expressions

Orminge

Young people residential units Alingsås

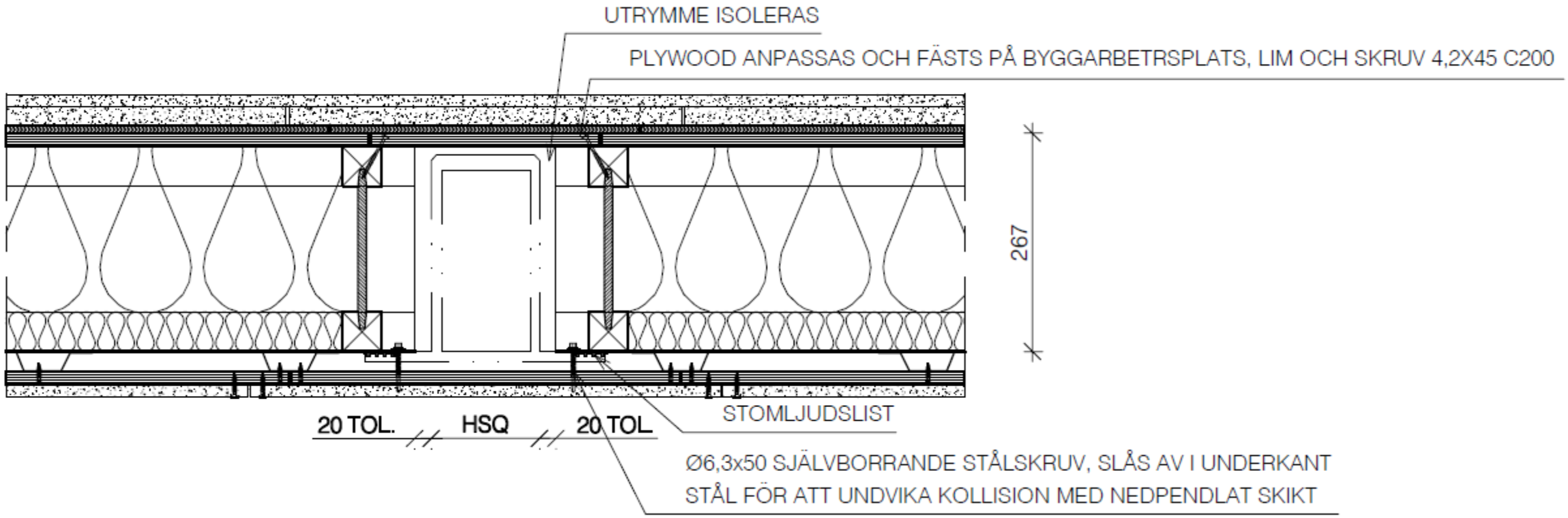


Karlskrona

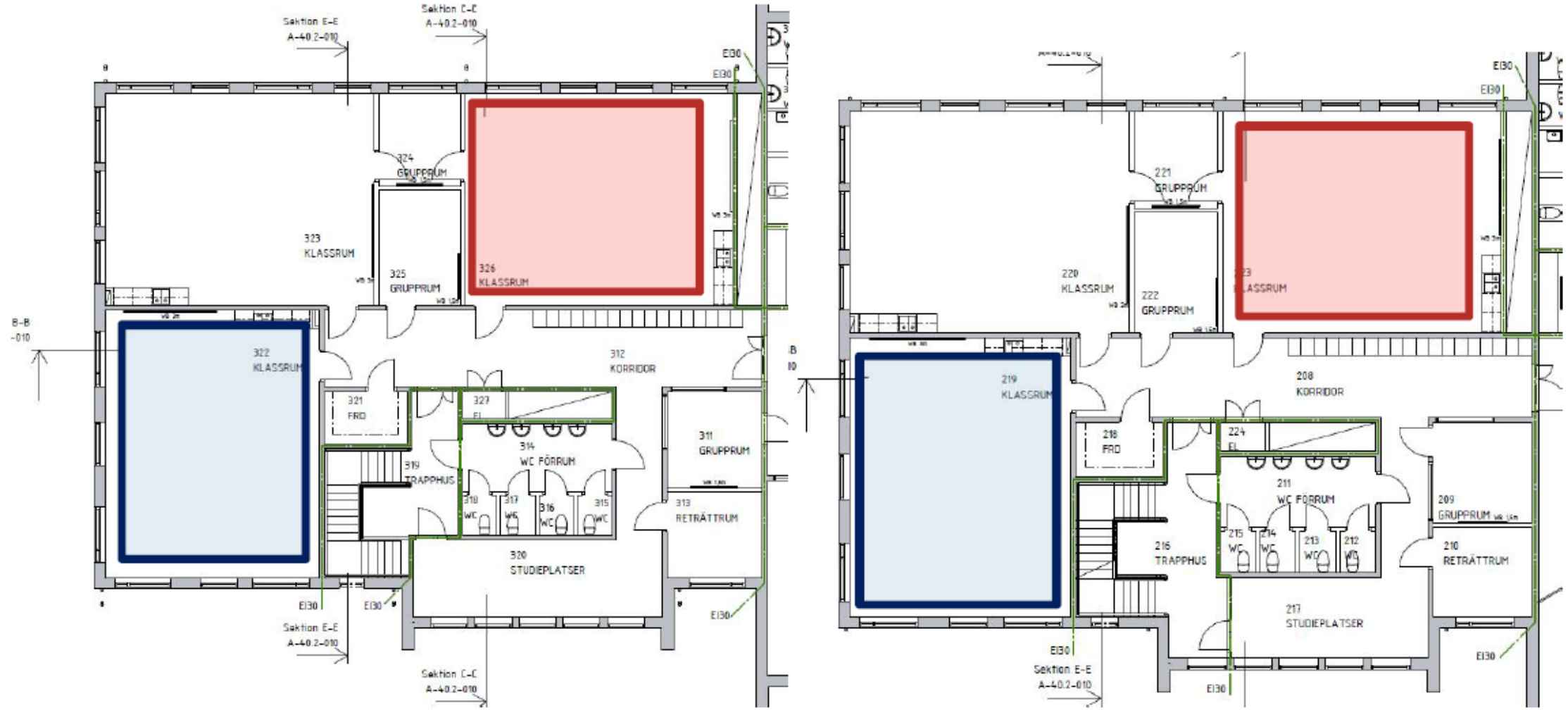


UNDERCENTRAL 1010
LGH 1004 2 ROK FÖR 2P
LGH 1012 1 ROK FÖR 1P 30,1 m²
LGH 1013 1 ROK FÖR 1P 30,1 m²

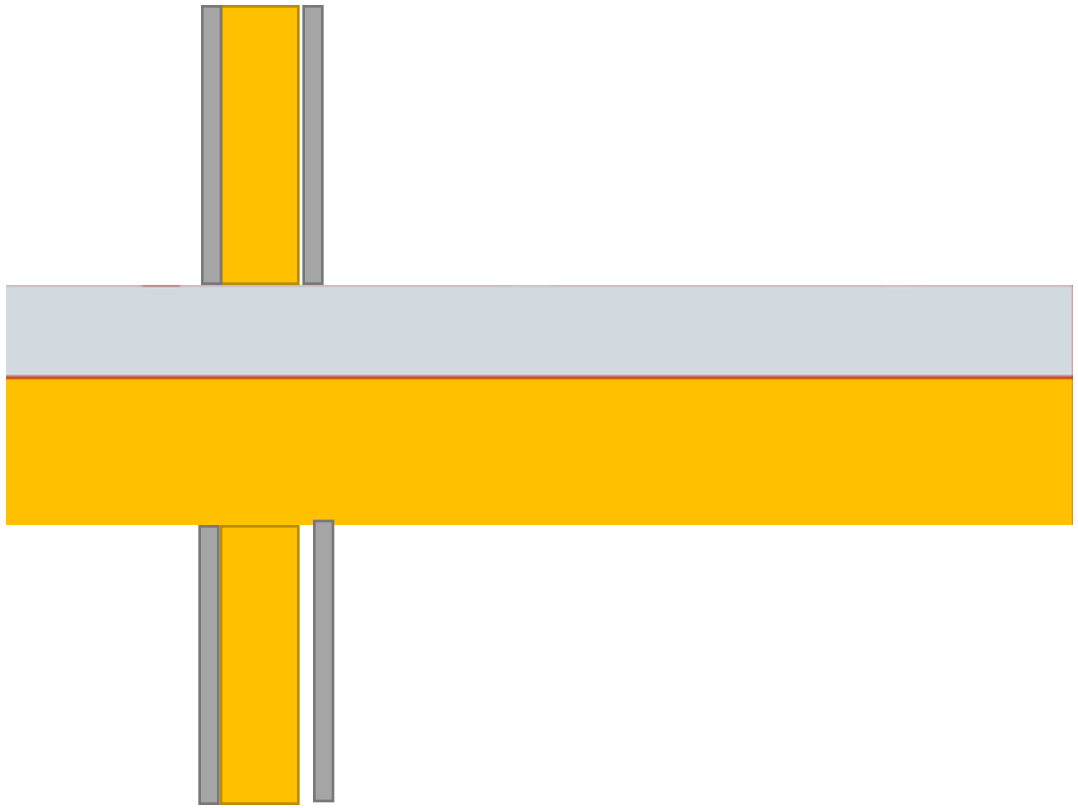
Schools / offices floor structure

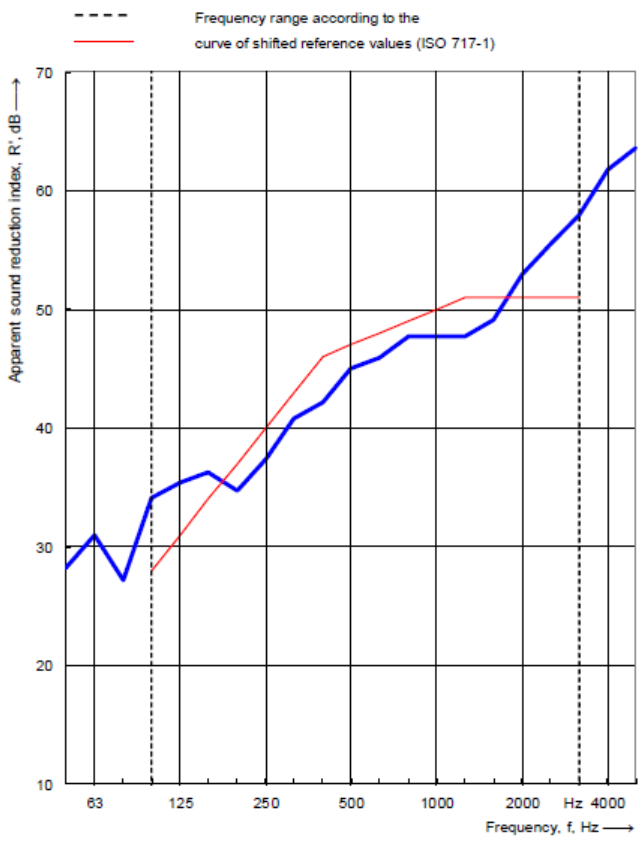


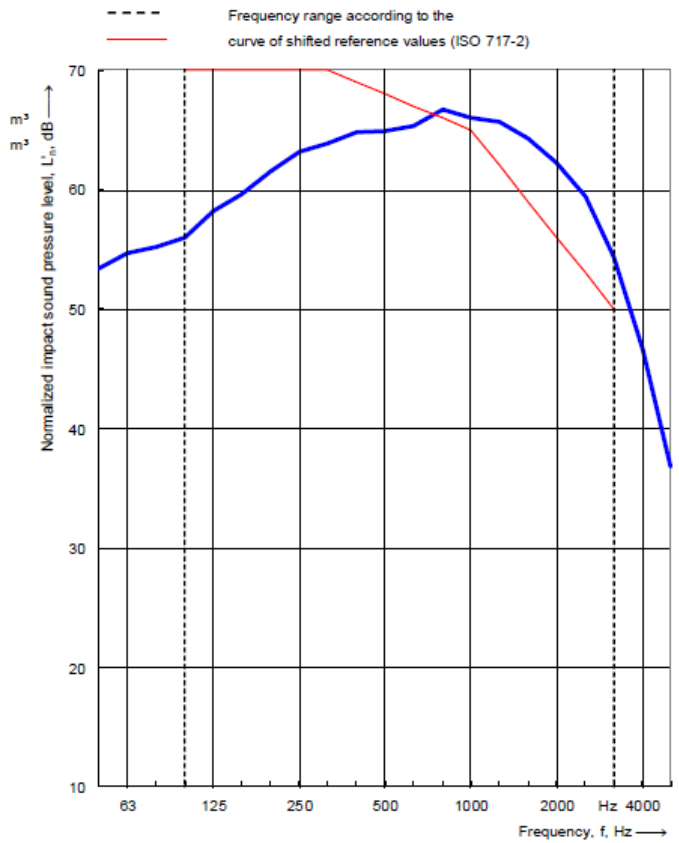
Falun school building



Falun school building







Measured without ceiling; 160 CLT+90 concrete+Linoleum
Flanking load bearing stud walls 45*120+gypsum

R'_w = 47 dB ($C_{50\text{-}3150}$= -1)

$L'_{nT,w}$ = 68 dB ($C_{I,50\text{-}2500}$= -7)

Office (often CLT and raised floor)

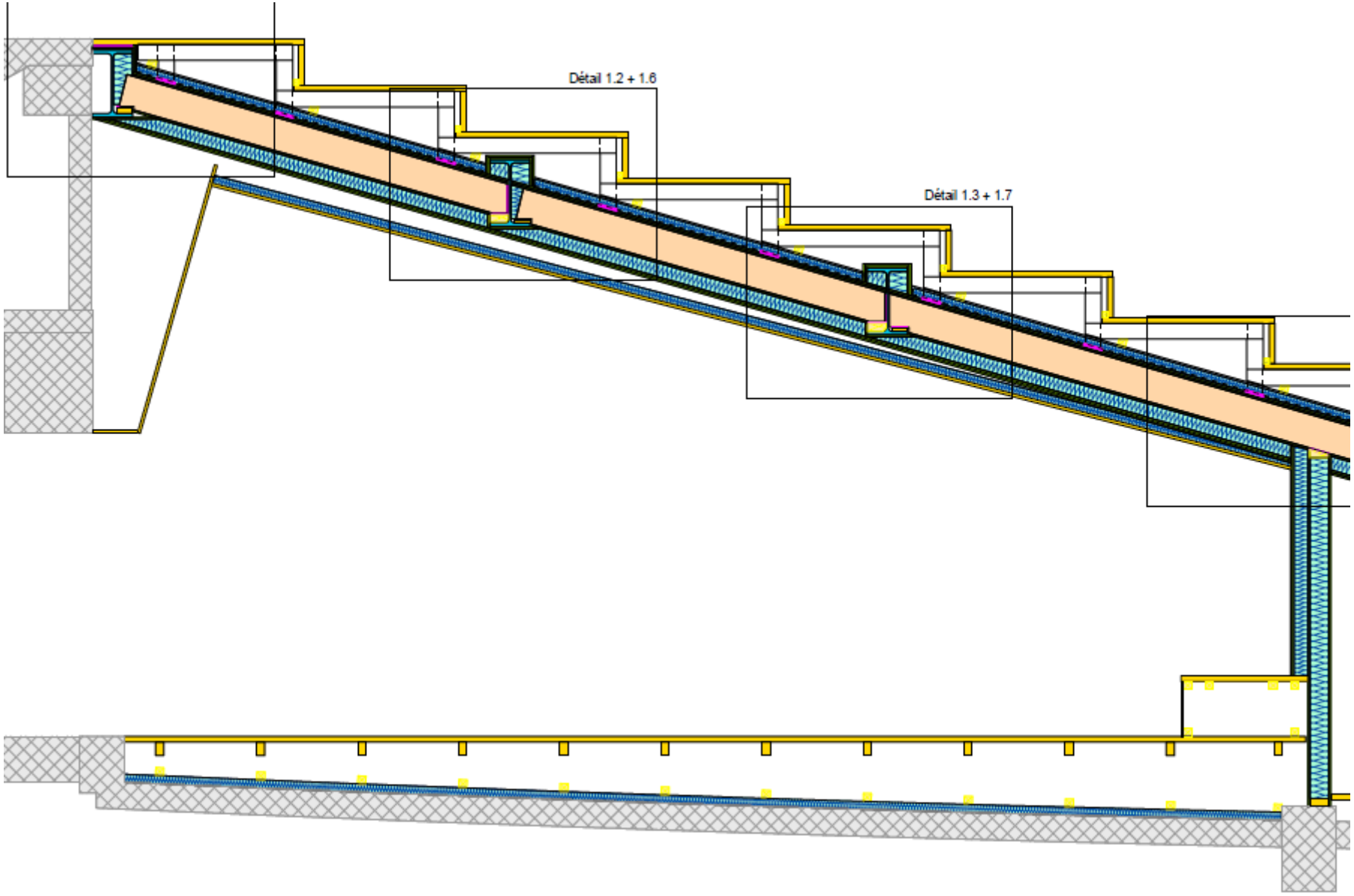
Cinema - Switzerland

Cooperation with Lund University:

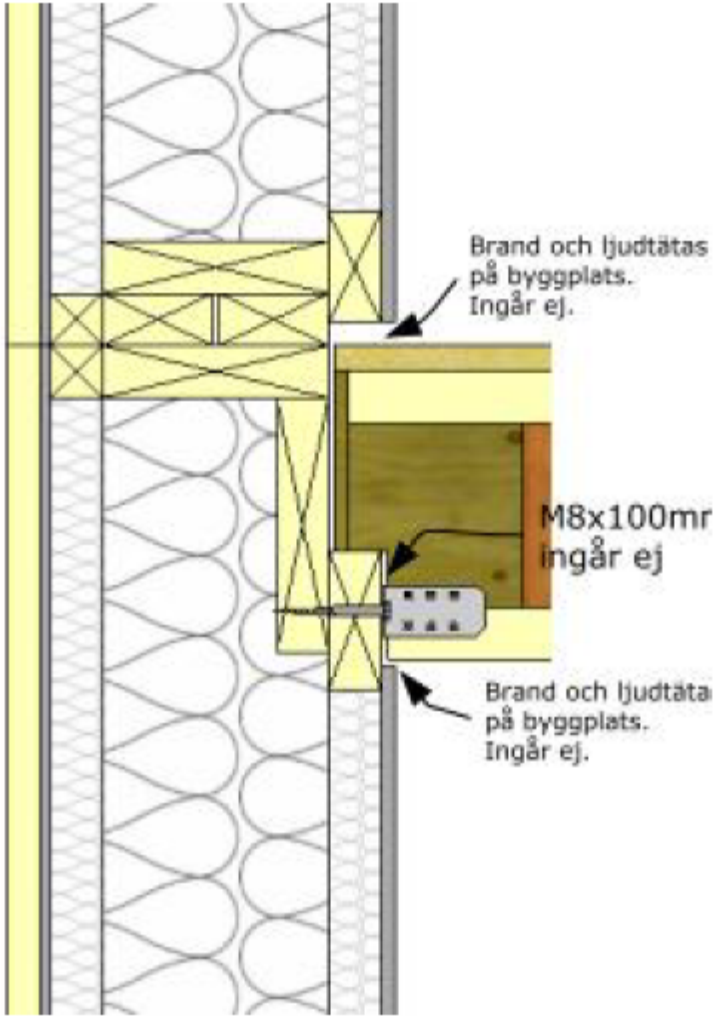
New Cinema hall; 2 halls become 3.

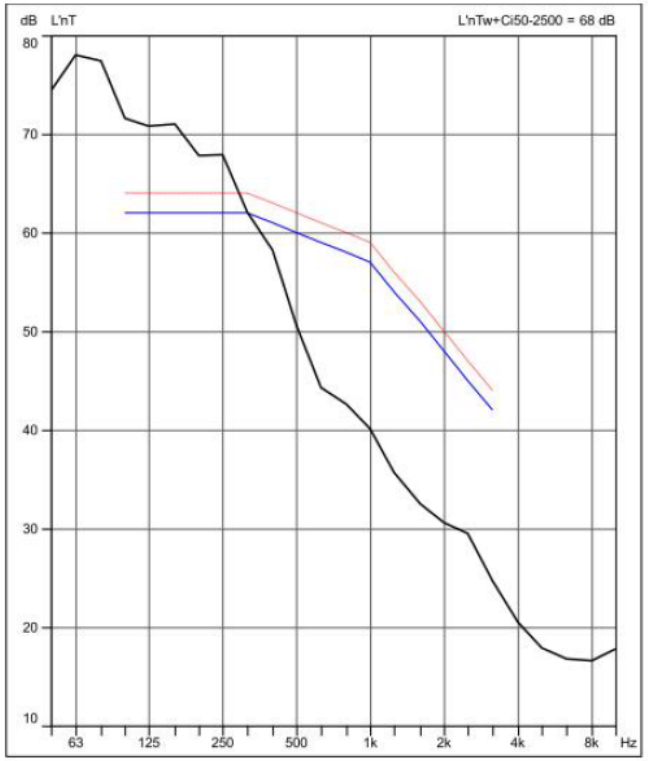
Wood became the natural choice due to weight and working ability (on site)

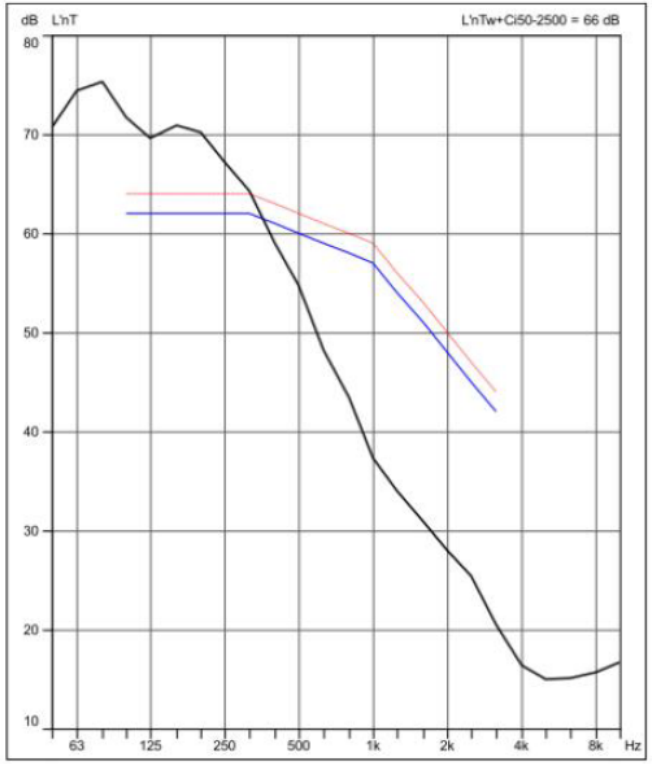
Princip nytt bjälklag



It might go wrong……

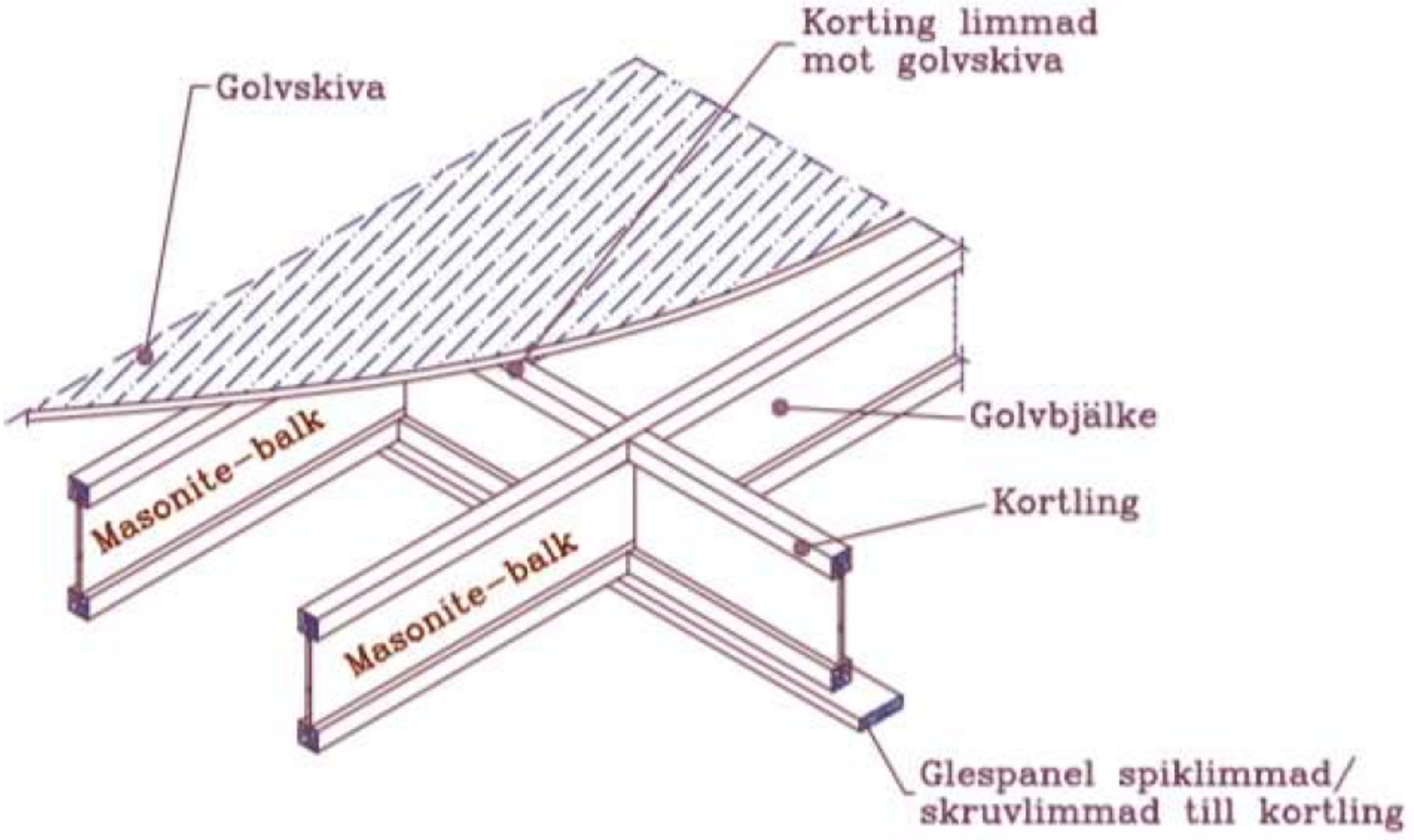






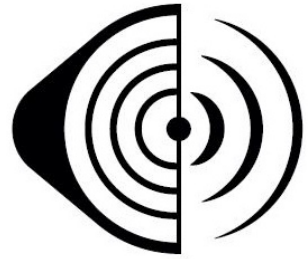
22mm golvspånskiva
250mm Masonitbjälkar
95mm Stegljudsisolering

It might go wrong…… How solve it?

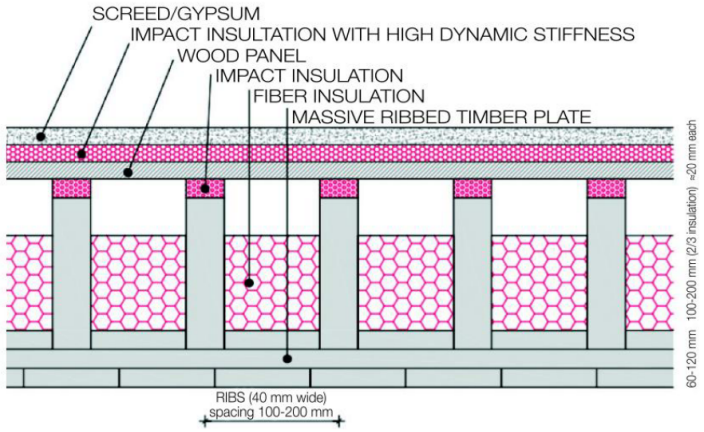


Calculation and control

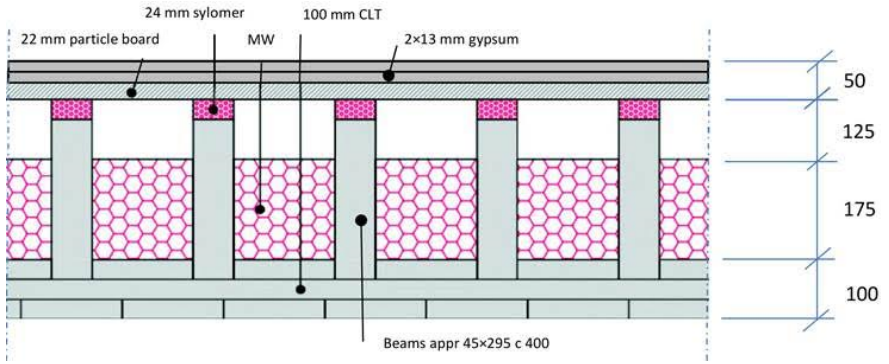
- Use available tools (will come back to that very soon)
- Coordinate with Constr. Design and Fire!
  - This is important. We need to find common solutions optimized for the actual project.
- Make control at an early stage and many building site visits
  - Listen, ”feel” and measure (and perform interviews with habitants if available)

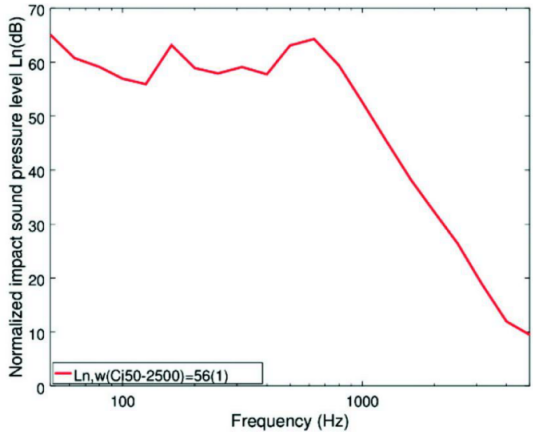


Caklculation and control – Silent Timber Build ”SEAWOOD” www.silent-timber-build.com

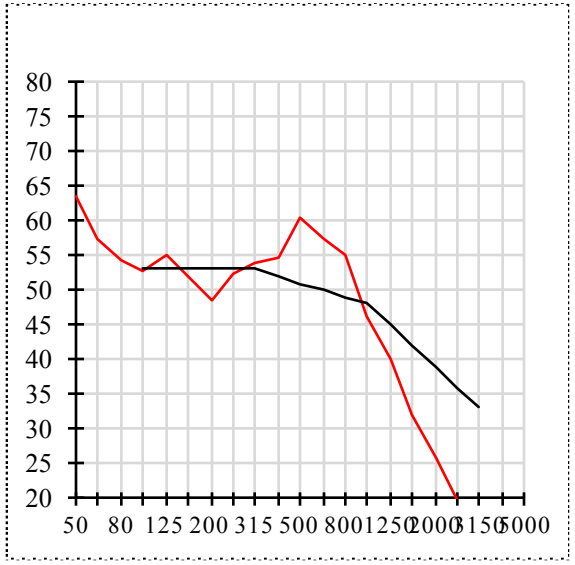


➔





$L_{nw} + C_{I,50\text{-}2500}$ = 57 dB



$L_{nw} + C_{I,50\text{-}2500}$ = 53 dB

Helpful tools - calculations?

- www.lignum.ch
- www.silent-timber-build.com / SEAWOOD
- EN ISO 12354 (2017) / BASTIAN

Helpful tool - calculations?

- Calculatis StoraEnso ”first release 2018”
  - Only CLT in the first version and only floor assemblies and wall assemblies, Junctions to be started in 2019
- SBUF (AkuLite) – ”Undvik fel och fällor”
  - http://vpp.sbuf.se/Public/Documents/ProjectDocuments/653d2470-3183-4c5f-8a11-d7b11fe15c52/FinalReport/SBUF%2012445%20Slutrapport%20Undvik%20akustiska%20fel%20och%20fällor.pdf (includes different facade solutions)

Helpful tools - calculations?

- CLT handbook Swedish wood (some errors regarding acoustic numbers so be careful of what can be expected)

- TRADA CLT design and performance.
  - https://bookshop.trada.co.uk/bookshop/view/9402F749-0129-42AF-8C18-F420E60C04CC

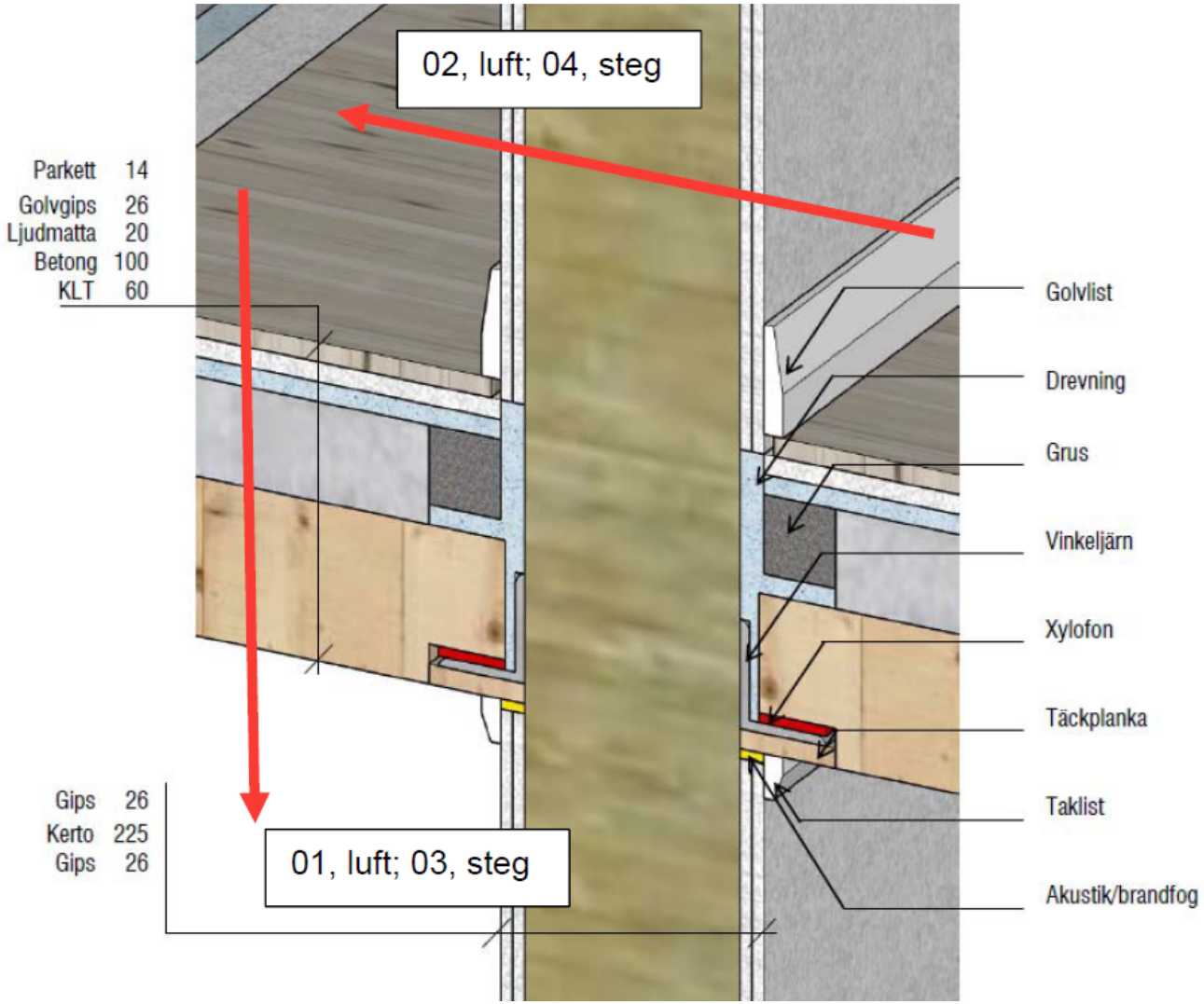
- StoraEnso CLT Guidelines
  - http://www.clt.info/wp-content/uploads/2015/10/Ljudegenskaper-för-KL-trä-från-Stora-Enso-SE.pdf

- Masonite Beams online handbook
  - http://handbok.masonitebeams.se/

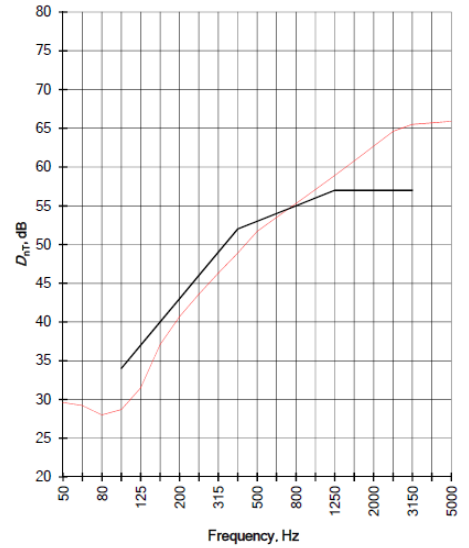
Future?

- Acousticians make drawings – solutions; that is what we need
- Devlop more accurate standards for wood
- Buildings will be higher ➔ new challenges
- Calculate the full building i 3D

Future?



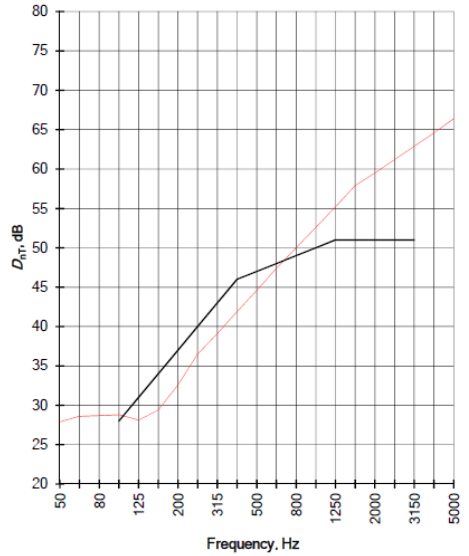
f (Hz)	R (dB)
50	29,6
63	29,2
80	28
100	28,7
125	31,5
160	37,1
200	40,7
250	43,6
315	46,3
400	48,9
500	51,7
630	53,5
800	55,3
1000	57,1
1250	58,9
1600	60,8
2000	62,7
2500	64,6
3150	65,5
4000	65,7
5000	65,9



SS-EN ISO 717/1

$D_{nT,w}$ =	53 dB		C	=	0 dB
max dev.	5,5 dB		$C_{50\text{-}3150}$	=	-3 dB

f (Hz)	R (dB)
50	27,9
63	28,6
80	28,7
100	28,8
125	28,1
160	29,4
200	32,6
250	36,5
315	39,1
400	41,9
500	44,6
630	47,4
800	50
1000	52,6
1250	55,2
1600	57,9
2000	59,5
2500	61,2
3150	62,9
4000	64,6
5000	66,4



SS-EN ISO 717/1

$D_{nT,w}$ =	47 dB		C	=	0 dB
max dev.	4,6 dB		$C_{50\text{-}3150}$	=	-2 dB

Acoustic reports……

Summary

- Wood is a fantastic material and creates huge opportunities
- Consider – design the floor assembly with ”some margin”
- Stability in high rise buildings → might give flanking transmission. How much can we accept?
- The workplace is much more quiet and more attractive
- It is possible to build with wood!

Thanks for listening!

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