Klara Byggsystem

DOCUMENTDATA

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TITLE: **MOISTURE RESISTANCE AND GENERAL DESIGN PRINCIPLE**

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UTGÅVA

P : PRELIMINARY

D : INITIAL REVIEW PROCESS OK, APPROVED AS START DOCUMENT

C : FINAL DOCUMENT

X : AS-BUILT DOCUMENTATION

ÖVRIGA NOTERINGAR

Innehållsförteckning

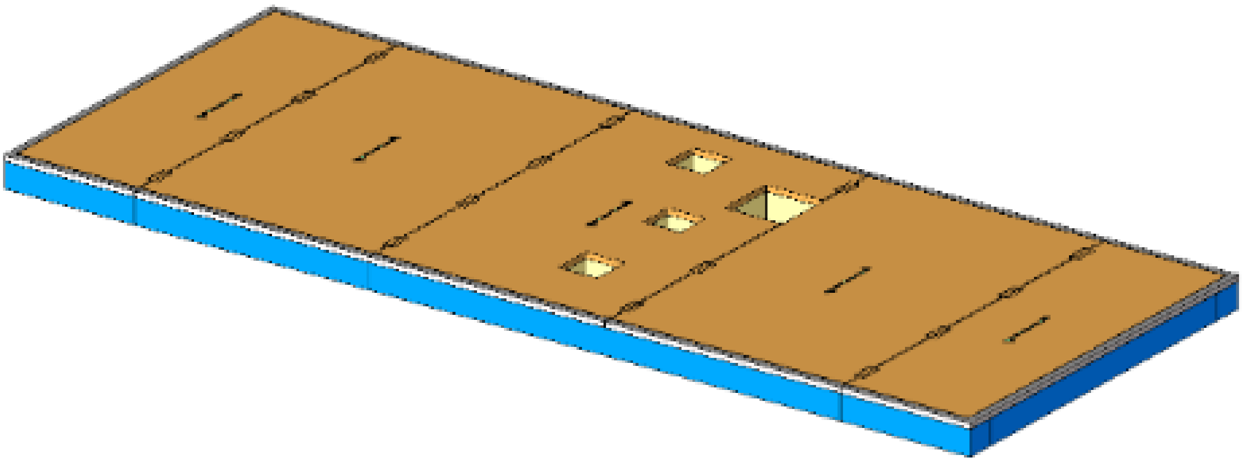
1 Introduction

This report presents the technical analysis and principles underlying the Klaragrunden foundation system, which utilizes cross-laminated timber (CLT) as a structural element. The system is suitable for use in the construction of residential homes and row houses. The report discusses the technical characteristics and performance criteria of the Klaragrunden system, as well as the specific requirements stipulated in the European and Swedish building codes (BBR).

The main design premises that are to be fullfilled

- Distribute load from the above structure the foundation
- Protect the building from ground-based emission such as radon and odour/smell
- Protect the building from ground-based moisture
- Lifespan of 50, 100 years or more

For strength calculations se Klara report 1002-CALC-TECH-01-01.



Figur 1 Klaragrunden

2 Technical properties

2.1 Geometri

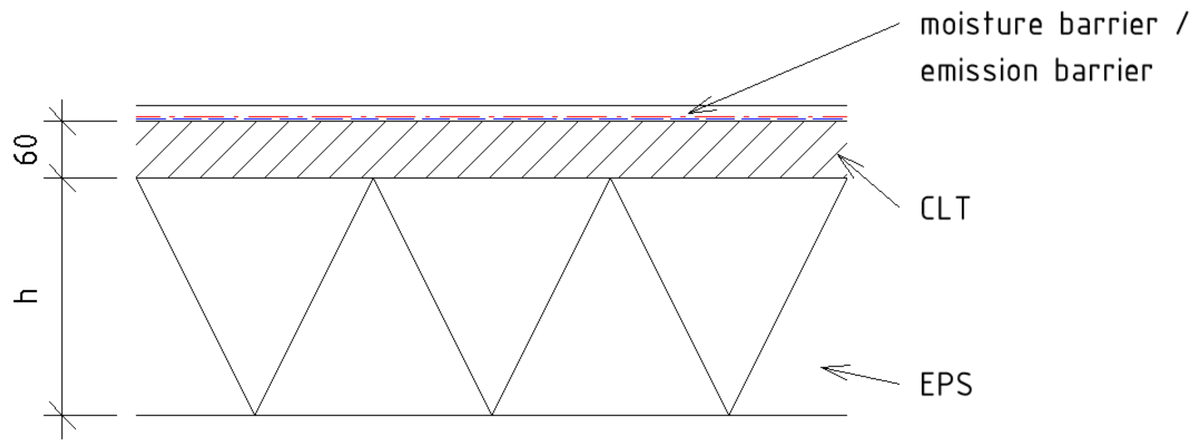
The system is based on prefabricated modules that have the maximum unit size of 3,2mx12m. Typical size is 2,4m x 8m.

2.2 Construction parts

2.2.1 General principle

The general design is based on a load distribution topping layer of CLT, that is resting on a bed of EPS.

Emission barrier:	Composite film (aluminium foil, 12 µm) – applied on site
Protection layer:	Siga Wetguard
Topping layer:	CLT 60
Insulation:	EPS C80 Climate

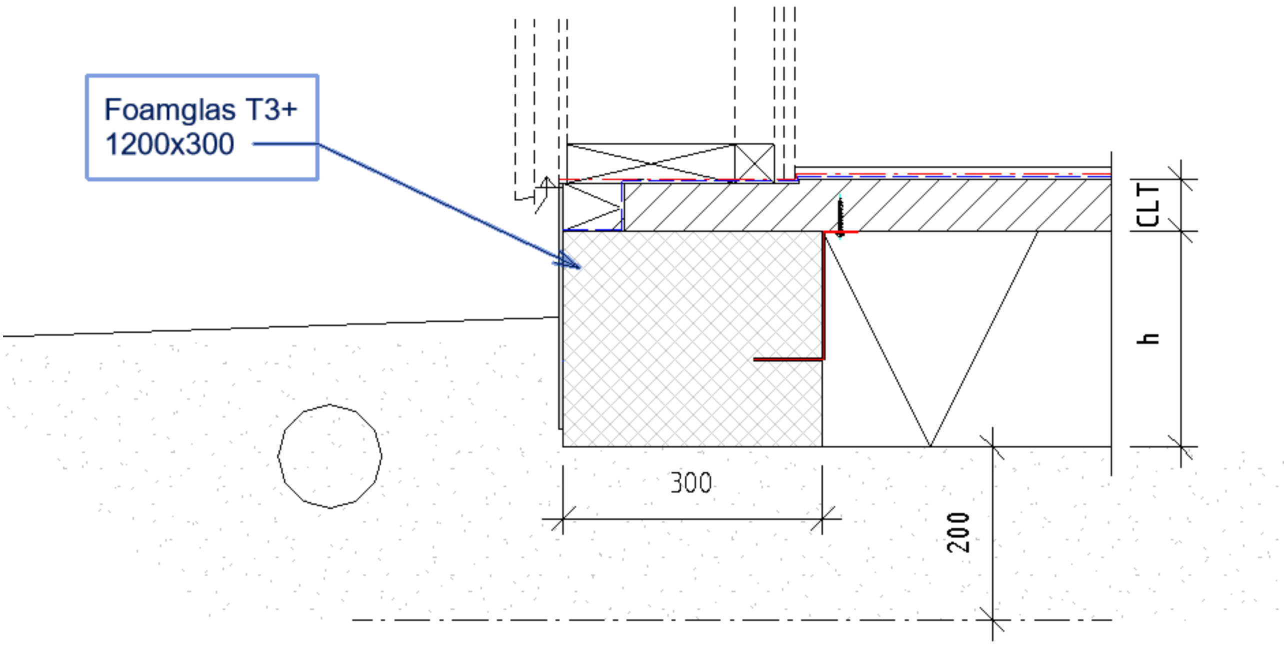


Figur 2 Example

2.2.2 Slab edge element

The load distributing edge element is based on high strength insulation material.

Emission barrier:	Composite film (aluminium foil, 12 μm)
Protection layer:	Siga Wetguard
Topping layer:	CLT 60
Insulation:	Cellular glass
	EPS S400
	XPS300/500/700



Figur 3 Klaragrunden

2.3 Joints and connections

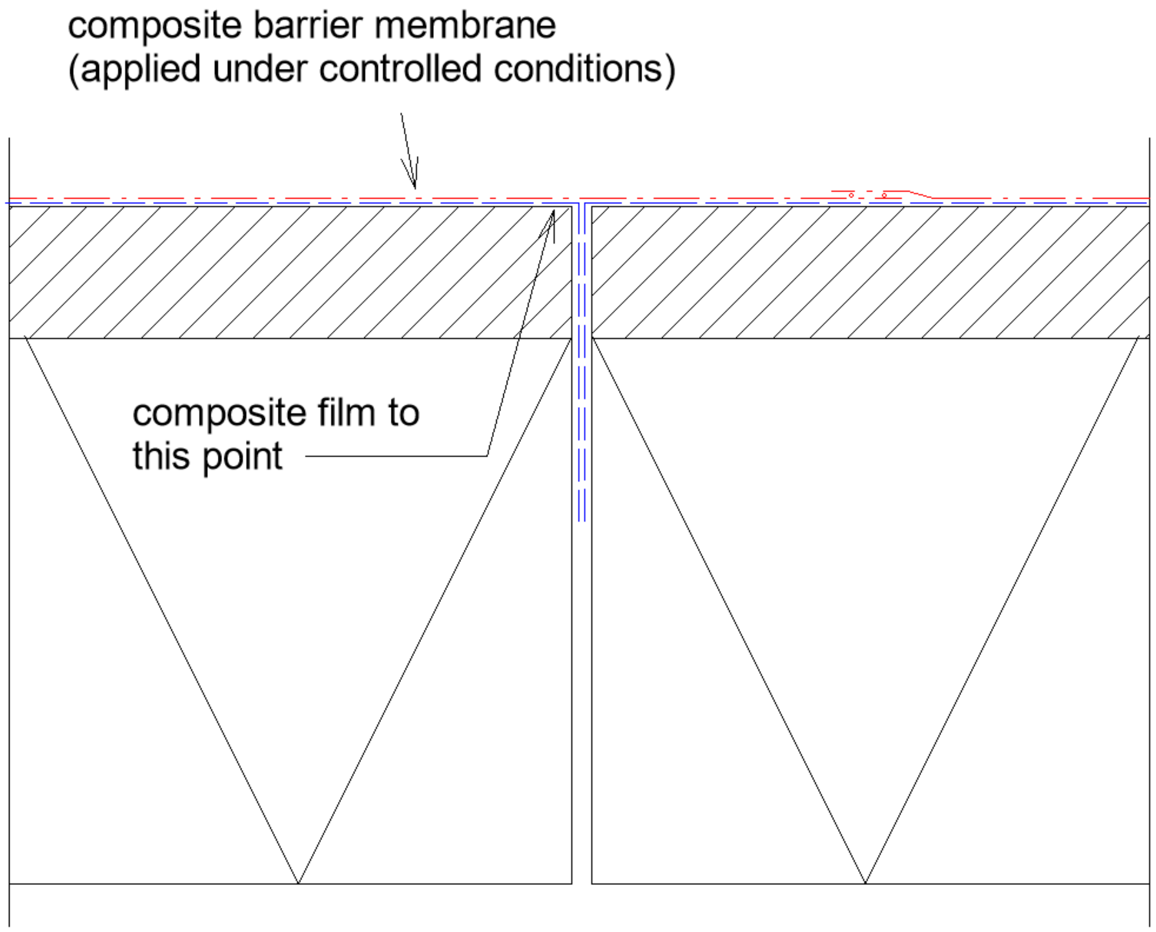
2.3.1 Slab-to-slab connection

The modular plates are mechanically fastened using a controlled procedure in which the plates are brought together using a moment tool. The connection between the plates is secured using steel fasteners. The applied pre-tension, in conjunction with the use of high-strength steel connection plates, ensures that the initial clearance between the elements is minimized.

Figur 4 Rothoblaas Geko Panel Puller

The joint is sealed by joint compound. The expected shrinkage for the modules according to season variation in humidity is expected to be 1,0 mm/m. Hence, a module of 2,4 m need to have a joint flexibility of 2,4 mm (See appendix 1, APPENDIX-CALC-002).

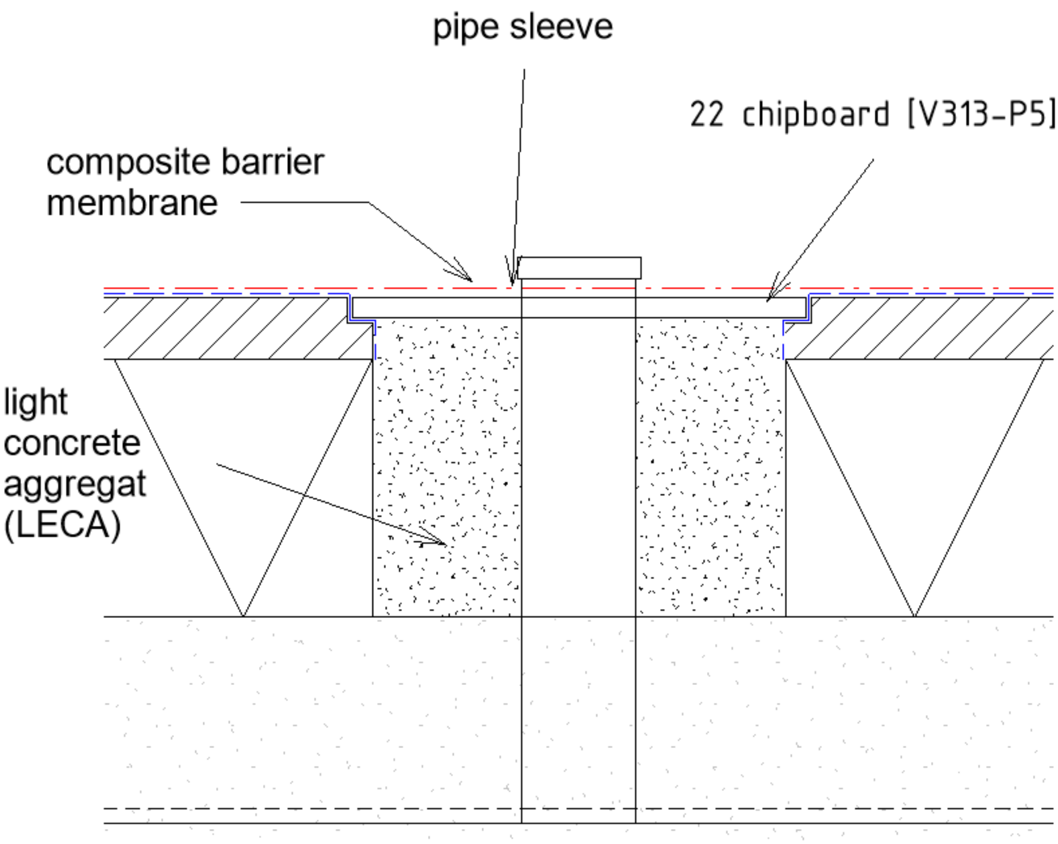
An emission barrier is applied on top of the foundation slab just prior to applying the finial finishing floor. The joints of the emission barrier is able to cope with the shrinkage of the modules.



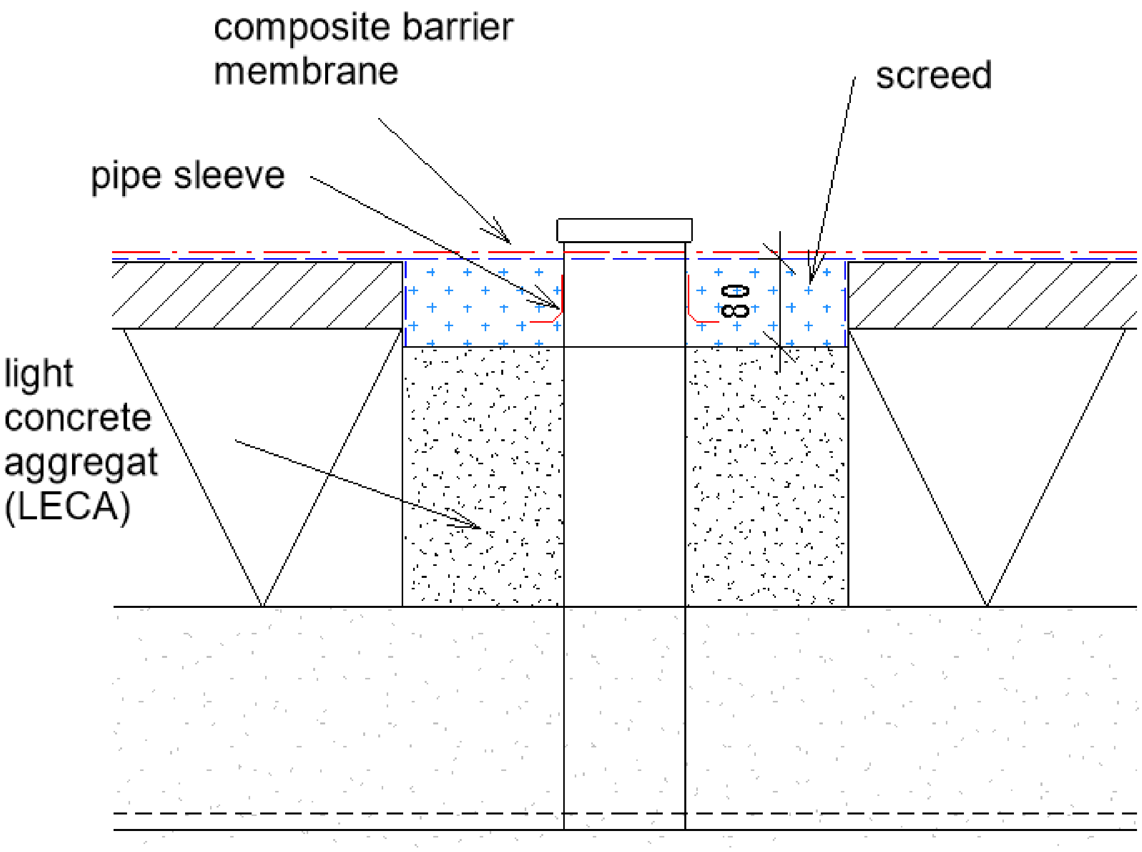
The composite barrier membrane can be replaced when flooring is replaced if necessary, or as a preventive measure. The aluminium based barrier does have a life expectancy of 100+years.

2.3.2 Internal shaft for piping

Klaragrunden includes provisions for the incorporation of auxiliary systems, such as drainage pipes and electrical conduits, through the use of shafts. There are two suggested methods for closing up shafts, first option is to use chipboard to mend the opening. The second option is the use screed to fill up the top of the shaft. Either way, air tightness is ensured by the composite barrier.



Figur 5 Klaragrunden shaft chipboard



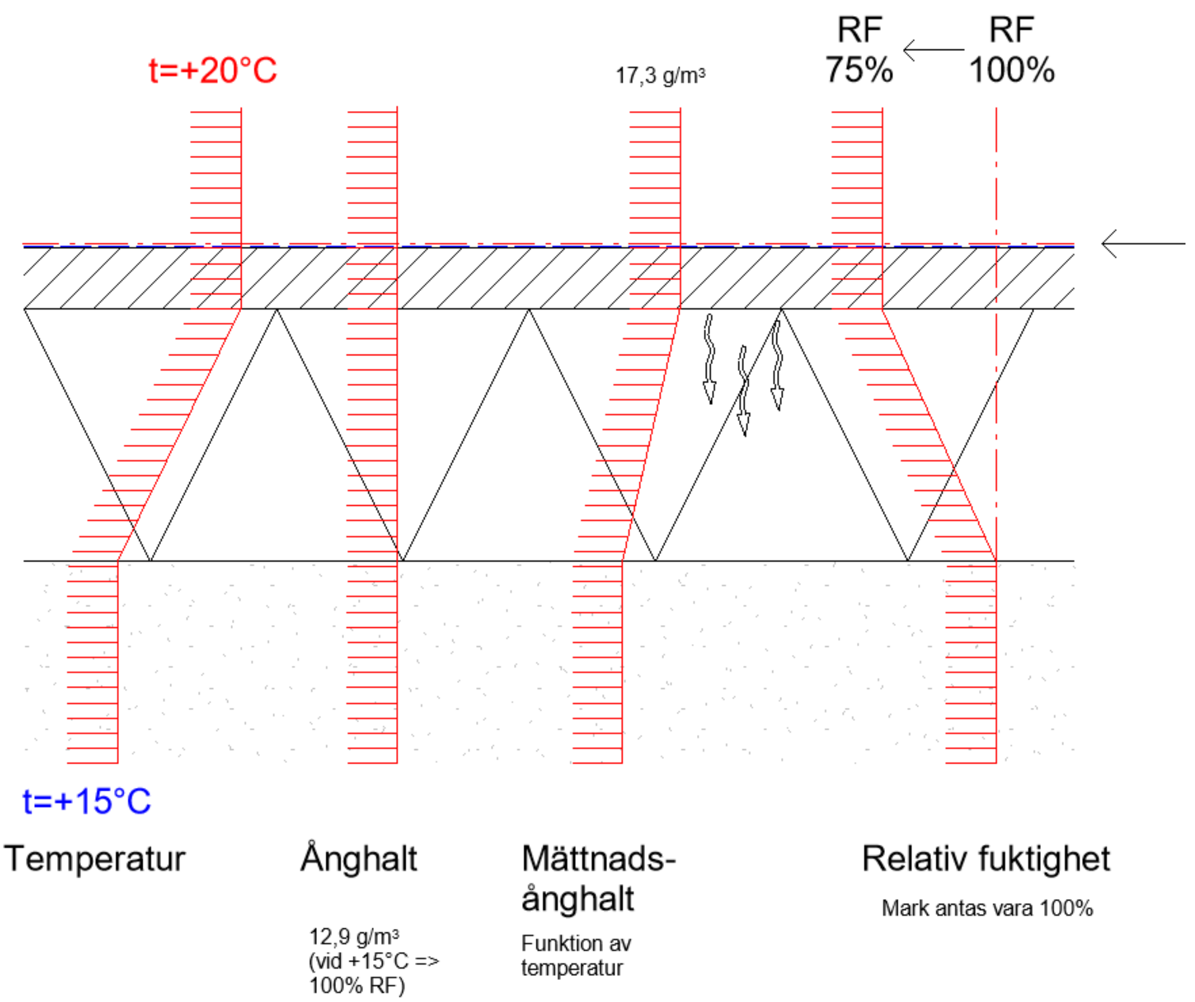
Figur 6 Klaragrunden shaft screed

3 Principles for ground moisture mitigation

The critical moisture level for wood materials is 75% (BBR §6:52). If the moisture level exceeds 75% there will be an increased risk for mould and degenerative effects.

3.1 Temperature difference as barrier

The figure below shows the principle by which insulation beneath CLT-slab serves as a moisture barrier against ground moisture. The moisture content is constant in both the CLT slab and the ground. The temperature difference across the insulation causes the saturation moisture content to be higher in the CLT slab than in the ground, resulting in a lower relative humidity in the concrete slab compared to the ground.



Figur 7 Klaragrunden

The saturation moisture level for different temperatures are shown in the table below. The table also shows what temperature delta is required for achieving a corresponding 75% relative humidity. Within normal temperatures, a delta of 5 degrees is sufficient.

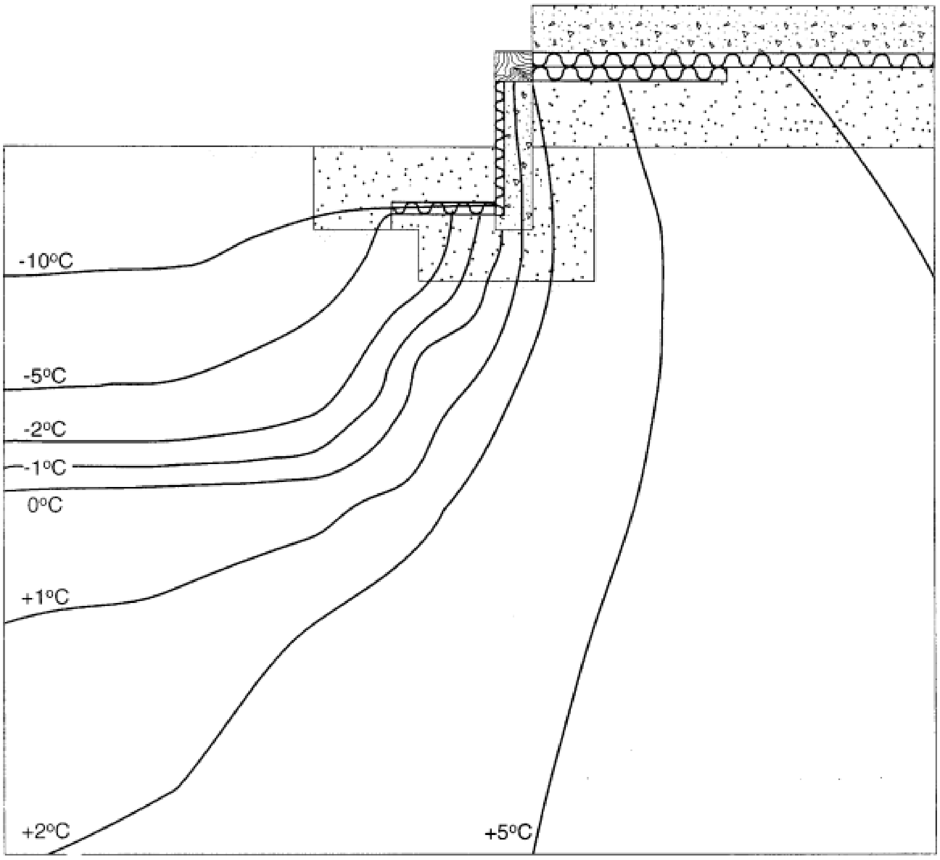
T [C]	G [g/m3]	G*75%	T(g*75%))	delta T
-10	2,14	1,61	-13,4	3,4
-8	2,53	1,90	-11,4	3,4
-6	2,99	2,24	-9,7	3,7
-4	3,52	2,64	-7,7	3,7
-2	4,14	3,11	-5,5	3,5
0	4,85	3,64	-3,6	3,6
2	5,56	4,17	-1,9	3,9
4	6,37	4,77	-0,2	4,2
6	7,27	5,45	1,7	4,3
8	8,28	6,21	3,6	4,4
10	9,41	7,06	5,6	4,4
12	10,67	8,00	7,5	4,5
14	12,07	9,06	9,4	4,6
16	13,64	10,23	11,3	4,7
18	15,37	11,53	13,2	4,8
20	17,29	12,97	15,2	4,8
22	19,41	14,56	17,1	4,9
24	21,75	16,32	19,0	5,0

Figur 8 Klaragrunden

To conclude, as long as the CLT slab is 5 degrees warmer than the ground, the relative humidity will never supersede 75% and there will be no risk for negative effects due to high moisture level.

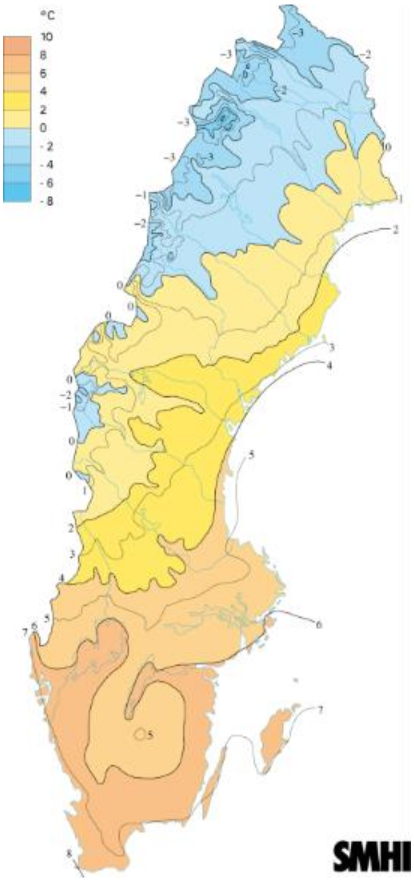
3.2 Temperature difference as a barrier

For an insulated foundation placed directly on the ground, a heat cushion is formed under the building. This means that the ground is heated under the house. The foundation of the house is then so large that the ground under the building is not cooled down by the outdoor climate, which can mean that the insulation is not sufficient to maintain a temperature difference between the ground and the CLT slab. As shown above, temperature delta of 5 degrees is required.



Figur 9 Isotherms in the ground near a foundation (ISO 13793:2001)

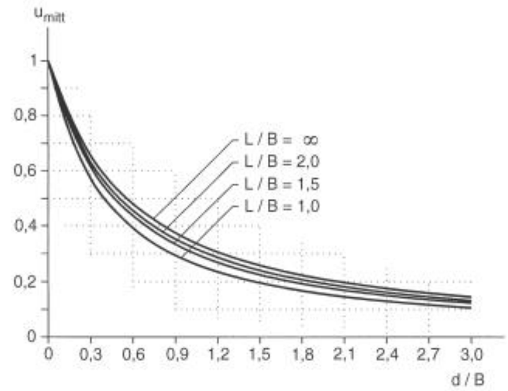
A method for calculating the heat cushion is presented in Fukthandboken (chapter 4.1.2.2.1). Since the design temperature inside a building normally is 20-22 degrees, it's easy to realize that the ultimate design case would be a high outdoor temperature. According to Fukthandboken (P126) the ground temperature under the building will be constant, given that building is not very narrow. It is also stated the ground temperature can be set to the air temperature year mean for that location (P124). Below is an example calculated for a 12x8 Klaragrund placed in a yearly mean temperature of +8 degrees, insulated with 200 EPS C100 Climate. A year mean indoor temperature of 20 degrees is assumed.

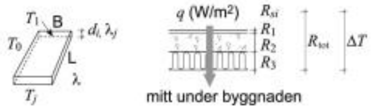


Figur 10 Mean temperature for Sweden

Beräkningsmetod enl. Fuktahandboken
Erik Goverde 2023-01-04

L		12 m	
B		8 m	
		1,5 m	
Rtot	-	m²K	
d		9,68 m	
lambda,j		1,5 W(mK)	figur 8.2.3
di		0,2 m	tjocklek EPS
lambda,i		0,031 W/(mK)	(C80 Climate)
d/B		1,21	för att läsa diagrai
umitt		0,27	ur diagram
Ti		20 C	Innetemp
To		8 C	Medeltemp ute
Tj		**11,2 C**	Temp mark
umitt		0,27	
deltaT		8,76 C	
mättnadsånghalt			
v (20)		17,29 g/m3	
v (Tj)		10,15 g/m3	
RF ukplatta		59%	Ska vara <75%
			OK!



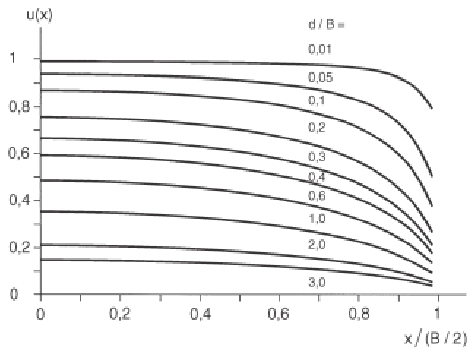


L = byggnadens längd, m
B = byggnadens bredd, m
R_{tot} = totalt värmemotstånd mellan inneluften och isoleringens undersida, (m² · °C)/W
d = ekvivalent jordtjocklek, dvs. det totala värmemotståndets tjocklek uttryckt i meter jord, m
λ_j = jordens värmeledningsförmåga, W/(m · K)
d_i = tjocklek på underliggande isolering, m
λ_i = värmeledningsförmåga för den underliggande isoleringen, W/(m · K)
T_i = årsmedeltemperatur inomhus, °C
T_o = årsmedeltemperatur utomhus, °C
T_j = temperatur på isoleringens undersida mitt under byggnaden, °C
u_{mitt} = relativ temperatur mitt under byggnaden
ΔT = temperaturskillnad mellan inneluft och värmeisoleringens undersida, °C

$$d = R_{tot} \cdot \lambda_j \approx \frac{d_i \cdot \lambda_j}{\lambda_i}$$

$$u_{mitt} = \frac{T_j - T_o}{T_i - T_o}$$

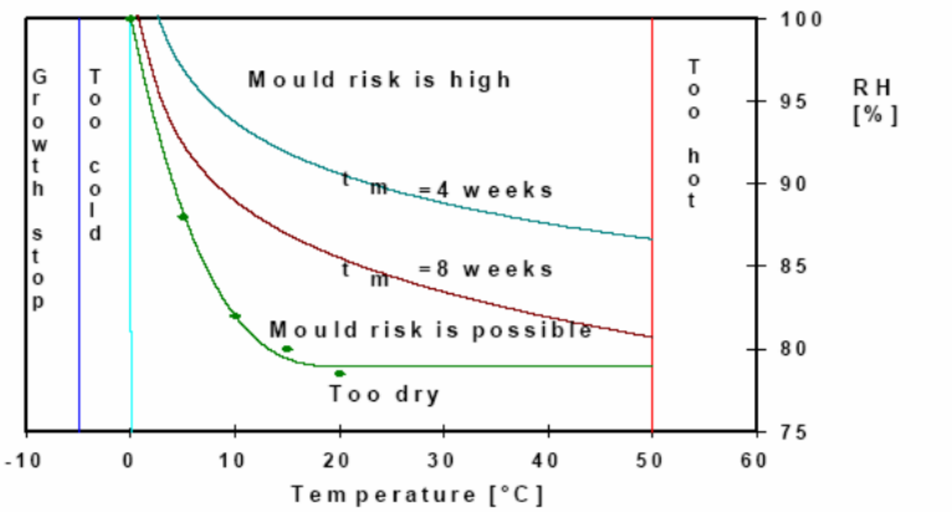
$$\Delta T = T_i - T_j = (1 - u_{mitt}) \cdot (T_i - T_o)$$



Figur 4.1.23. Temperaturfördelning under isoleringen från byggnadens centrum till kanten. Lång byggnad. För L/B = ∞ och x = 0 erhålls den övre kurvan i figur 4.1.22.

As shown in the calculation above, even the southmost placement in Sweden the insulation alone is a sufficient barrier to avoid critical moisture levels. With the current design, a mean year temperature of 14 degrees seems to be the threshold. For reference, Year mean of Berlin is 10,1 degrees, Paris has 11,7 degrees and Milan 13,0 (climate-data.org, 2022).

The limit of a relative humidity of 75% is a considered a safe level. A higher relative moisture level could be accepted depending on other factors such as temperature and duration.

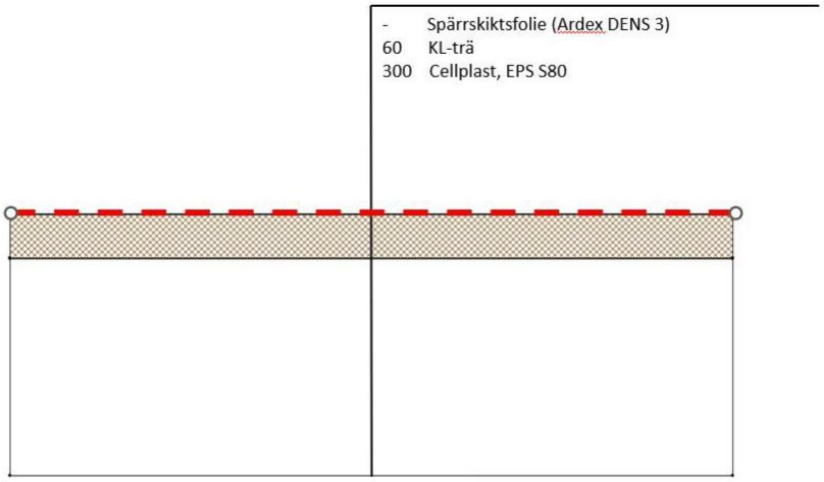


Figur 11 En överblick över kritiska temperaturer och fuktighetsgränser för mikrobiell tillväxt (Virtanen, 2004)

3.3 WUFI 2D Simulations

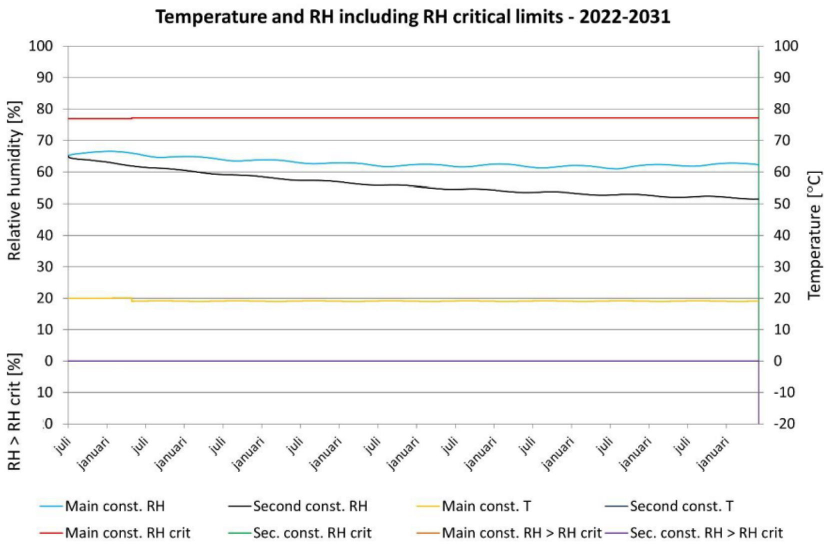
A number of simulations has been performed, to verify the hand calculations. The model location is Lund (8,4 year mean). Indoor temperature is set to 20 degrees. Calculations are performed according to ISO 13788. CLT moisture ratio of 12% (correspond to a relative humidity of 65%)

3.3.1 General model



Figur 2 - Utförande 2

Model 1



Figur 12 WUFI 2D input and output

The analysis shows that CLT slab will seek an year mean equlibirum equliant relative humidity level of 50%, which is well below the threshold level of 75%. The blue line in the chart is the case with a underlaying emission barrier.

3.3.2 Model with screed topping

In the case with tiled floor it is common to apply a topping layer of screed to ensure a perfect level, especially when using large tiles. Since the composite emission barrier is 100% watertight and does not transfer moisture or any gas applying screed does not expect to affect the humidity level of the CLT board.

4 Flooding and damage during operation

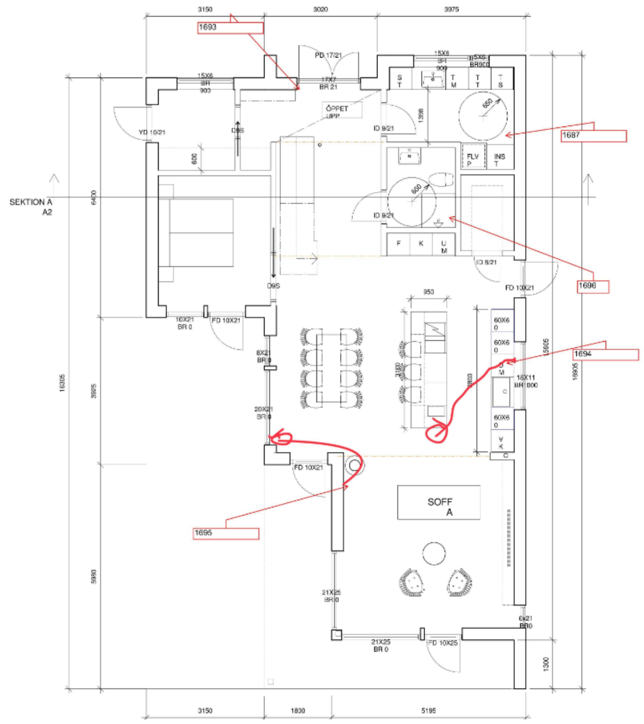
In case of damage due to water (malfunctioning dishwasher etc) the emission and moisture barrier will provide a protective function. The water will accumulate on top of the barrier and increase the chance that the damage will be discovered in an early stage.

In the case that the emission barrier, and the moisture protection barrier, does malfunction or become damaged (during for example flooding) the CLT sheet may be exposed to water. The emission barrier can in such a case be removed, and the CLT sheet can dry out both towards the foundation and towards inside the building.

5 In field measurements

Two projects are currently under continues monitoring. In general all sensors show values within expected values.

5.1 Project House Rundberg



Figur 13 Plan

Description: House Rundberg, a private villa located in Allarp.
Erection date: 2023-03-01
First sensor date: 2023-04-01jh

Comment: Sensor woody1693 is placed in direct contact with screed and seems to be influenced by the moisture level in the screed. Assembly instructions are updated to avoid direct contact between wood/screed.

5.2 Project Wallberga

Figur 14 *Plan*

Description: Rowhouse, 24 apartments located in Vallberga.
Erection date: 2021-08-01
First sensor date: 2023-03-17

Comment: Se appendix


Klara