Sustainability and building acoustics

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Introduction

Like many other countries, Switzerland aims to achieve net zero emissions policy for new buildings at latest by 2050. Some regions and cities, like Zurich, even want to reach that goal in 2035. At the moment, there is a substantial innovation taking place for new ways to build, prefabricate and the use of natural materials, such as weed, straw, clay, rammed earth, sheep wool, cellulose and so on. Furthermore, a lot of thoughts go into the re-use and recycling of whole building parts, such as slabs and walls.

Challenges

New and so-called green buildings have to fulfil a broad variety of parameters that have to be optimised from an early design stage. The most important ones for our business are the following:

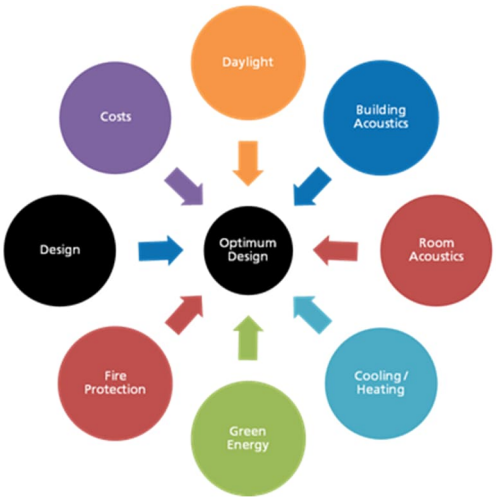

Figure 1: The optimal design is based on a range of factors

Building acoustics is just one of them, but the use of non-monolithic constructions bear new/well-known problems to solve.

Trends

The actual trends are the use of multilayered wooden or thin massive constructions in order to minimise the use of materials as much as possible. Also, the re-use and recycling of whole separation constructions is a big trend. The disadvantage for the concrete construction has been the insertion of pipes and electrical wiring that leads to a bad recycling situation. Therefore, another trend is to separate the primary and secondary structures.

Labels and building acoustics requirements

At the moment, the following green building labels are most prominent in Switzerland: SNBS, Minergie-Eco, SGNI (Swiss DGNB), DGNB and sometimes LEED as well as BREEAM. Among the plethora of different criterias we use the two following ones for the lifecycle analysis:

- Non Renewable Energy (NRE): kWh / m2
- Greenhouse Gas Emissions (GHG): kg CO2 / m2

And the requirements for building acoustics is in the European average and namely:

Building acoustics in residential
Standard requirements: $D_{nTw} + C \geq 52$ dB
and $L'_{nTw} + C_{I,100\text{-}2'500} \leq 53$ dB
Increased requirements: $D_{nTw} + C \geq 56$ dB
and $L'_{nTw} + C_{I,100\text{-}2'500} \leq 49$ dB

Building acoustics in schools / offices
Standard requirements: $D_{nTw} + C \geq 45$ dB
and $L'_{nTw} + C_{I,100\text{-}2'500} \leq 60$ dB
Increased requirements: $D_{nTw} + C \geq 50$ dB
and $L'_{nTw} + C_{I,100\text{-}2'500} \leq 55$ dB

Usually, the limits for offices and schools are not too difficult to reach, but the increased residential limits are sometimes tricky for lightweight constructions.

Overview slabs

Over the last few years, we have had the opportunity to test a few “new” constructions in our lab facility in Dornbirn. In order to compare them with other constructions we extended the overview with some already known slabs and walls. Some of them were measured only in-situ, but that gives us a good idea of how they perform in real life and not just in the lab.

Table 1: overview of known floor slabs

Construction	Details
Massive Construction 16 cm	Tiles / 6 cm floating floor / 2 cm impact insulation / 2 cm insulation / 16 cm concrete slab / plaster
Massive Construction 20 cm	Parquet / 8 cm floating floor / 2 cm impact insulation / 2 cm insulation / 20 cm concrete slab / plaster
Massive Construction 24 cm	Parquet / 6 cm floating floor / 2 cm impact insulation / 2 cm insulation / 24 cm concrete slab / plaster
TCC 6 cm floating floor (project)	6 cm floating floor / 2 cm impact insulation / 6 cm filling (sand) / 10 cm concrete / 14 cm massive wood
TCC 6 cm floating floor (lab)	6 cm floating floor / 2 cm glass wool / 2 cm insulation / 10 cm concrete / 14 cm massive wood
TCC 8 cm floating floor (lab)	8 cm floating floor / 2 cm EPS-T / 2 cm insulation / 10 cm concrete / 14 cm massive wood
CLT 7 cm floating floor	Parquet / 7 cm floating floor / 3 cm impact insulation / 6 cm filling / 1.5 cm Fermacell / 18 cm CLT
MiTek Posi-Joist	14 mm parquet / 3 mm underlay / 55 mm floating floor / 12 mm plywood / 249 mm PosJoist filled with mineral wool / 25 mm gyproc / 2 x 12.5 mm Fermacell

One extensive study has been carried out for wooden slabs with rammed earth between the beams. We have measured a variety of different layers.

Table 2: Overview of only the rammed earth slabs

Construction	Details
Rammed earth slab Raw	40 mm CLT / 120-150 mm rammed earth between beams with 2 x 120 mm x 260 mm height
Construction 01	18 mm clay tiles / 30 mm dry screed board heating / 60 mm filling
Construction 02	21 mm parquet / 44 mm sand filling / 35 mm Heraklith BM / 40 mm impact board
Construction 03	21 mm parquet / 45 mm dry screed Lithotherm / 18 mm wooden insulation / 22 mm Iosver PS81 / 60 mm filling
Construction 04	18 mm clay tiles / 30 mm dry screed board heating / 30 mm Isover PS81 / 60 mm filling
Construction 05.1	4 mm linoleum / 60 mm floating floor / 30 mm Isover PS81 / 60 mm filling
Construction 05.2	60 mm floating floor / 30 mm Isover PS81 / 60 mm filling
Construction 05.3	4 mm linoleum / 95 mm floating floor / 30 mm Isover PS81 / 60 mm filling
Construction 06.1	21 mm parquet / 60 mm floating floor / 30 mm Isover PS81 / 60 mm filling
Construction 06.3	21 mm parquet / 95 mm floating floor / 30 mm Isover PS81 / 60 mm filling

Overview walls

For the walls we compare the following constructions:

Table 3: Overview of the walls and their construction

Construction	Details
Massive Concrete	1 cm plaster / 25 cm, 30 cm concrete / 1 cm plaster
Rammed Earth	25 cm, 35 cm, 45 cm rammed earth
Double CLT	2 x 15 mm Fermacell / 100 mm CLT 5C / 60 mm mineral wool / 100 mm CLT 5C / 2 x 15 mm Fermacell
Knauf Drywall double studs	2 x 15 mm Diamant / 5 cm steel stud / 2 mm felt / 5 cm steel stud / 2 x 15 mm Diamant
Straw separation wall	12.5 mm + 15 mm gypsum fibre boards / 12 cm wooden stud filled with straw / 15 mm gypsum fibre boards / 12 cm wooden stud filled with straw / 12.5 mm + 15 mm gypsum fibre boards
External wall bricks with 20 cm EPS	1 cm plaster / 20 cm EPS glued / 1 cm plaster
External wall bricks with 22 cm mineral wool	1 cm plaster / 22 cm Flumroc Compact Pro glued / 1 cm plaster
Wood chips external wall	Wooden cladding / 3 cm ventilation / 6 cm wood fibreboard / 24 cm wooden studs with wood chips / 15 mm plywood / 5 cm wooden fibreboard / 18 mm ply-wood
Straw external wall 1	26 mm wooden cladding / 44 mm ventila-tion / 4 cm wood fibreboard / 180 mm wooden stud with Iso Straw 105 kg/m3 / 15mm plywood / 30 mm installation frame / 20 mm plywood
Straw external wall 2	26 mm wooden cladding / 44 mm ventila-tion / 4 cm wood fibreboard / 180 mm wooden stud with Iso Straw 105 kg/m3 / 15mm plywood / 60 mm installation frame decoupled / 2 x 12.5 mm gypsum boards
Weed Chalk	2 x 15 cm weed chalk brick with plaster on both sides

Lab measurement results

The following results show the detailed sound reduction curves R as well as impact insulation values L_n for the "new" constructions.

Rammed earth slabs

In order to more easily understand the construction, the following section cut shows construction number 01.

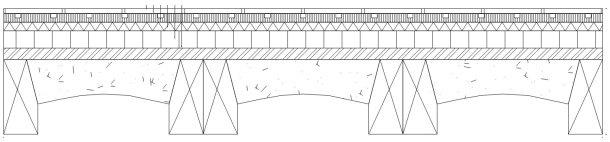

Figure 2: General section cut of the rammed earth slab.

We have not added all variations in the charts as construction 05 and 06 have more variations that don't add more information. For the sound reduction indices only three constructions were measured, apart from the raw slab.

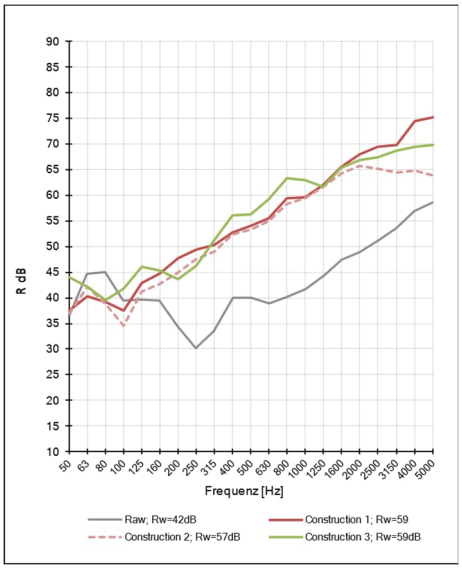

Figure 3: Sound reduction indices of four slabs

The impact noise measurements show a few known facts. Constructions 01-04 are with dry screeds, which results in higher impact sound values as expected. The thick screeds (orange) result in very low impact sound values, even down to 50 Hz.

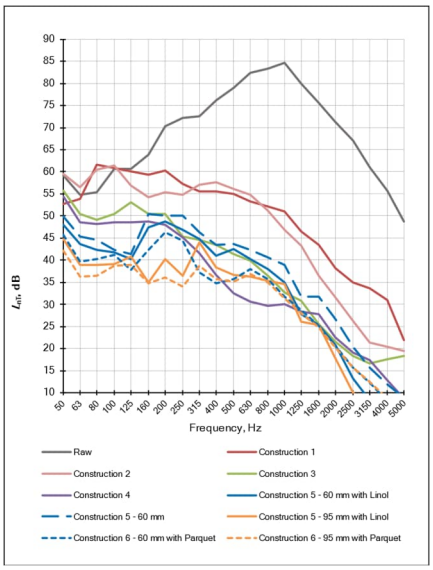

Figure 4: Impact noise results of the listed slabs.

The single values are as follows:

Construction rammed earth slabs	Impact noise
Construction 01	$L_{n,w}$ = 53 (0) dB
Construction 02	$L_{n,w}$ = 42 (1) dB
Construction 03	$L_{n,w}$ = 42 (1) dB
Construction 04	$L_{n,w}$ = 40 (0) dB
Construction 05.01	$L_{n,w}$ = 42 (1) dB
Construction 05.02	$L_{n,w}$ = 42 (0) dB
Construction 05.04	$L_{n,w}$ = 37 (-1) dB
Construction 06.01	$L_{n,w}$ = 36 (0) dB
Construction 06.02	$L_{n,w}$ = 41 (1) dB

Rammed earth walls

The rammed earth slabs show a very similar behaviour to a 30 cm concrete wall, apart from the higher frequencies above 2'000 Hz.

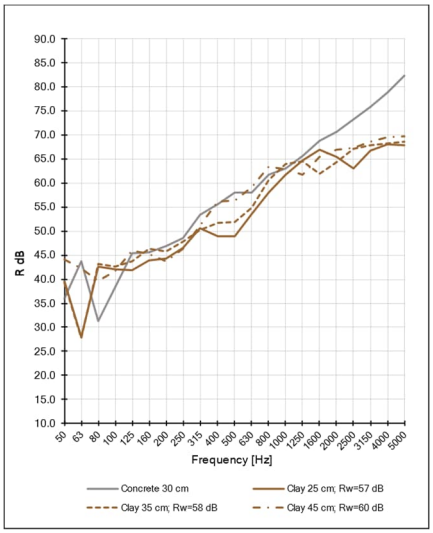

Figure 5: Sound indices of the rammed earth walls.

Wooden frame with wood chips or straw

The wooden frames with wood chips or straw inside have very similar single values R_w than their counterparts filled with mineral wool. In the chart they're compared to a common brick wall with mineral wool insulation, as the latter is a standard external wall construction in Switzerland.

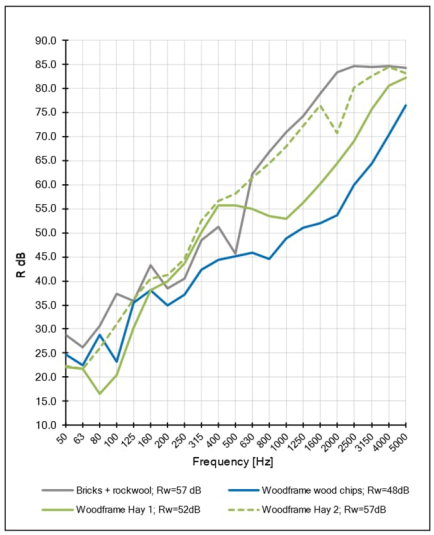

Figure 6: General section cut of the rammed earth slab.

MiTek slab

The light construction of the MiTek slab measured in Switzerland by Acouwood AB shows the following curves:

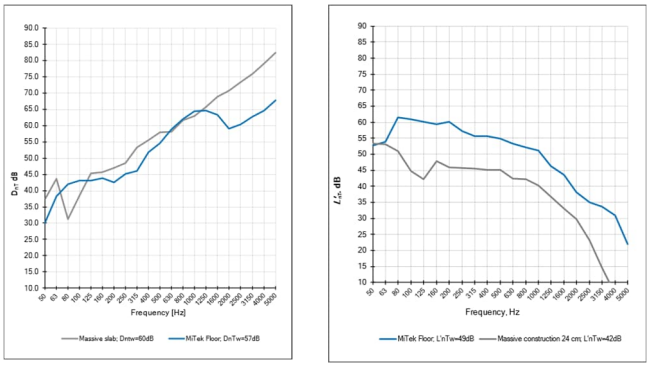

Figure 7: General section cut of the rammed earth slab.

Both values fulfil the increased limits of residential buildings. In the charts we compare it to a standard concrete construction in order to have an idea where we stand.

Comparison of building acoustics and green energy parameters

And now we can focus on the big comparison of the constructions sorted after the GHG value.

Table 4: Overview of slab constructions

Construction	Thickness	GHG kg CO2/m2	NRE kWh/m2	Airborne noise	Impact noise
Rammed earth raw slab	30.0 cm	32	76	R_w = 42 (0;-3) dB	$L_{n,w}$ = 80 (-5) dB
Rammed earth slab Construction 02	44.0 cm	37	139	R_w = 57 (-1;-6) dB	$L_{n,w}$ = 53 (0) dB
Rammed earth slab Construction 06.2	45.0 cm	54	166	n.a.	$L_{n,w}$ = 41 (1) dB
Rammed earth slab Construction 05.2	45.0 cm	55	166	n.a.	$L_{n,w}$ = 42 (0) dB
Rammed earth slab Construction 06.1	47.1 cm	56	172	n.a.	$L_{n,w}$ = 36 (0) dB
TCC in-situ	38.0 cm	63	201	n.a.	L'_{nTw} = 53 dB
TCC 8 cm floating floor	36.0 cm	72	227	R_w = 60 (-2;-6) dB	$L_{n,w}$ = 49 dB
TCC 6 cm floating floor	34.0 cm	79	211	R_w = 59 (-2;-6) dB	$L_{n,w}$ = 53 dB
Massive construction 16 cm	28.0 cm	81	271	n.a.	L'_{nTw} = 48 (-3) dB
CLT 7 cm floating floor	37.0 cm	101	378	R_w = 63 (-4;-10) dB	$L_{n,w}$ = 45 (-1) dB
Massive construction 20 cm	35.5 cm	110	317	D_{nTw} = 65 dB	L'_{nTw} = 33 (-1) dB
Rammed earth slab Construction 05.4	48.5 cm	112	330	n.a.	$L_{n,w}$ = 37 (-1) dB
Rammed earth slab Construction 05.1	45.4 cm	118	387	n.a.	$L_{n,w}$ = 40 (0) dB
Massive construction 24 cm	35.5 cm	119	342	D_{nTw} = 60 dB	L'_{nTw} = 42 dB

Massive construction 16 cm	35.5 cm	119	342	D_{nTw} = 56 dB	L'_{nTw} = 49 dB
Rammed earth slab Construction 01	43.8 cm	135	540	R_w = 59 (-2;-6) dB	$L_{n,w}$ = 53 (0) dB
Rammed earth slab Construction 04	43.8 cm	135	540	n.a.	$L_{n,w}$ = 40 (0) dB
MiTek	38.0 cm	209	654	D_{nTw} = 57 (-1;x) dB	L'_{nTw} = 49 (0;x) dB

And in a second table the walls:

Table 5: Overview of wall constructions

Construction	Thickness	GHG kg CO2/m2	NRE kWh/m2	Airborne noise
Rammed earth	25.0 cm	10	42	R_w = 57 (-2;-5) dB
Rammed earth	35.0 cm	13	56	R_w = 58 (-1;-4) dB
Rammed earth	45.0 cm	17	71	R_w = 60 (-2;-6) dB
Hay external wall construction 1	35.0 cm	27	113	R_w = 52 (-5;-12) dB
Drywall Knauf double studs and Diamant	25.0 cm	34	133	D_{nTw} = 58 (-1;-4) dB
Weed Chalk	38.0 cm	52	259	R_w = 53 (-2;-6) dB
Wood chips external wall 1	43.3 cm	60	264	R_w = 48 (-2;-7) dB
Wood chips external wall 2	43.3 cm	60	264	R_w = 47 (-1;-6) dB
Straw Separation wall	30.5 cm	63	271	R_w = 73 (-5;-13) dB
Massive construction bricks with 22 cm rockwool	41.0 cm	71	235	R_w = 57 (-3;-7) dB
Straw external wall construction 2	39.0 cm	74	277	R_w = 57 (-2;-9) dB
Massive construction bricks with 20 cm EPS	39.0 cm	81	270	R_w = 44 (-2;-6) dB
Massive (Concrete)	27.0 cm	87	228	D_{nTw} = 58 dB (-1;-4) dB
CLT separation wall double	32.0 cm	92	404	R_w = 69 (-2;-6) dB
Massive (Concrete)	32.0 cm	104	269	D_{nTw} = 61 dB (-1;-4) dB

Interpretation

We can conclude that the rammed earth constructions generally have low GHG values and offer decent and even very good airborne and impact noise values. It comes at the cost of height, when compared to a standard concrete slab. “Normal” wooden constructions lay in the middle of the field, when looking at the green building values, but just fulfil the standard values of impact noise limits.

For the walls the picture is similar. The rammed earth is on the podest when it comes to green house gases and they offer decent sound reduction indices. Concrete is at the end of the comparison and the wooden frame constructions somewhere in the middle. Generally, the calculations of the GHG and NRE values highly depend on the wood used as well as on used data. In Switzerland there is furthermore always a positive LCA value for wood, even though wood stores CO2 during its life.

Conclusions

We can conclude the following findings (that largely have been known already):

- A lot of data is available, yet not concentrated or evaluated
- Green building values are still vague and differ a lot (depending on basis or database)
- Alternative materials (straw, clay, weed, cellulose, etc.) have similar performance as mineral wool and massive constructions
- Wooden / leightweight constructions are not per se better concerning green energy parameters or acoustical parameters
- Thick floating floors (> 8cm) are still unbeatable in terms of green energy to acoustical ratio
- More research and development is needed in order to offer cheaper constructions with wood and natural materials in order to optimise the use of materials and the building acoustics performance.

Thanks

I would like to thank Michael Hämmerle from Kuster + Partner Dornbirn for the help with the constructions and lists and to Acouwood AB in Malmö for the results of the MiTek slabs.

Literature

[1] EcoBau, database of GHG and NRE values
URL: https://www.ecobau.ch

[2] Dataholz
URL: https://www.dataholz.eu

[3] Lignumdata, database of GHG and NRE values
URL: https://www.lignumdata.ch