Performances of low frequency impact sound in wooden buildings

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ABSTRACT

Since 1999 Sweden has required an extended frequency range for sound insulation in residential buildings, using 50 Hz as the lower limit. This regulation update has driven the design and development of multi storey residential building systems with wooden structures in a positive direction. Already in the mid 1980´ies there existed scientific proof that it the perceived impact sound will improve if the frequency range was extended below the lower standard limit 100 Hz at that time. Lately, researchers have indicated that the perceived impact sound can be even further improved if the frequency range is extended below current lower standardized limit of 50 Hz. Assume that the frequency range for impact sound requirement will be further extended to include frequencies from 25 Hz, what would that mean for modern wooden apartment buildings? Acouwood and Kuster & Partner AG are collecting data from 20 Hz, no matter if the standard measurement procedure cannot be applied below 50 Hz. It gives a good overview of potential annoyance risk but also of acoustic performances of modern sustainable multifamily buildings and how they can be improved. This paper summarizes measurement results of impact sound from 20 Hz in several wooden buildings.

1. INTRODUCTION

Impact sound insulation is a bigger challenge than airborne sound insulation concerning design and perception of the inhabitant in wooden buildings, specifically for ”normal sized” dwellings. We believe that even if minimum requirements are fulfilled in Sweden or Switzerland, complaints appear from time to time, and it is clearly the impact sound that creates most amount of annoyance. Of course, complaints cannot be completely avoided since there are deviations between individuals and in addition different behaviour amongst adjacent neighbours. Airborne sound insulation is a clearly less pronounced problem compared to impact sound regarding perceived sound insulation even if “only” minimum requirements are fulfilled for airborne sound. Hence, daily work in projects confirms the fact that minimum legal requirements in Sweden and / or Switzerland for airborne sound is a decent level, verified by research in connection to the revision of the Finnish legal requirements [1]. Following the same research results the impact sound level requirements might need a raise

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though, which also corresponds to our own experience. Therefore, in wood projects it is recommended to use a raised requirement compared to current minimum level (at least sound class B according to SS 25267 [2]) for impact sound insulation. Then applying only minimum requirements for airborne sound insulation creates a good balance for buildings with wood structures, also contributing to economically strong solutions. However, recent Swedish research [3] confirms that a further extension of the frequency range down to 25 Hz might improve perceived impact sound insulation even more.

Therefore, pre-assume that the frequency range will be further extended for impact sound in the future, how will that affect the current wood constructions?

Firstly, let´s assume the current legal requirement in Sweden:

- $L'_{\mathrm{nT,w,50}} = L'_{\mathrm{nT,w}}+C_{\mathrm{I,50\text{-}2500}} \leq 56$ dB (minimum legal requirement)
- $L'_{\mathrm{nT,w,50}} = L'_{\mathrm{nT,w}}+C_{\mathrm{I,50\text{-}2500}} \leq 52$ dB (sound class B)

The research results from [3] have been discussed within the Swedish Standard committee on building acoustics (SIS/TK 197) and the proposal is to maintain current level of requirement but extend the frequency range down to 25 Hz as voluntary option for impact sound. The aim is of course to create basis to reduce the number of tenants annoyed in multifamily houses with light weight structures. It is well known that such a requirement is not falling within the standardized frequency range as of today (therefore voluntary option), which of course implies that such a change is only hypothetical in terms of mandatory requirement currently, however still very important for the industry to better understand what is needed to design high quality future wood houses for even better optimization in terms of annoyance. The future requirements could then be approximately:

- $L'_{\mathrm{nT,w,25}} = L'_{\mathrm{nT,w}}+C_{\mathrm{I,}\mathbf{25}\text{-}2500} \leq 56$ dB

That can be translated into sound class B according to the Swedish standard SS 25267, in terms of perceived sound insultation or instead according to minimum requirements in Finland. If keeping the existing level of perceived sound according to minimum requirements in Sweden, then the requirement would become approximately:

- $L'_{\mathrm{nT,w,25}} = L'_{\mathrm{nT,w}}+C_{\mathrm{I,}\mathbf{25}\text{-}2500} \leq 60$ dB

What results can be expected from modern timber structure solutions if extending the frequency range to 25 Hz for impact sound?

2. RESULTS FROM MEASUREMENTS

When measuring impact sound insulation, the authors and the team in each company always collect data from 20 Hz. Right or wrong in terms of standardized measurements, at least we gather information no matter if some data are out of the normal standardized range. For the third octaves 20 Hz, 25 Hz, 31,5 Hz and 40 Hz we do not standardize to the reverberation time to 0,5 s, we just measure the level difference. It has been shown that no matter how many absorbers you put in a room the level below 50 Hz remains unchanged [4]. By doing measurements down to 20 Hz we learn more about potential problems in measurement technique but also challenges for the building sector if extending the frequency range even below 50 Hz in the future. Hence, we have gathered a considerable amount of data in an extended frequency range over the years and we start to understand potential challenges for the wood industry and from that we can slowly conclude what must be done to improve the floor structures to perform better regarding perceived sound. As a basis for the results in this paper three typical Swedish structural floor constructions are shown, in figures 1 to 3 below.

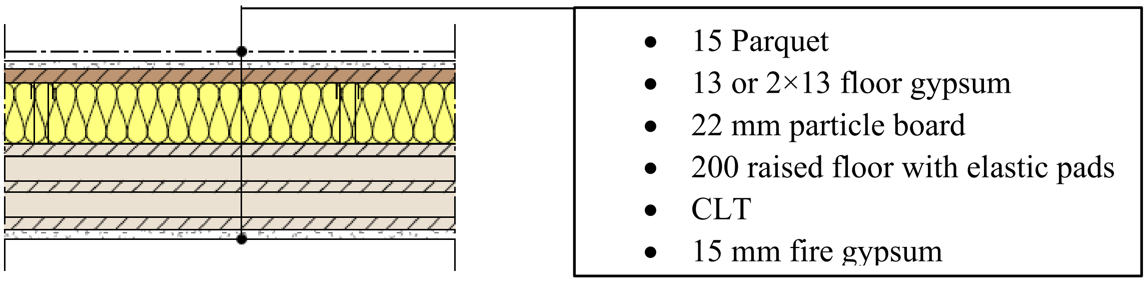

Figure 1: Floor structure 1 – CLT with raised floor on resilient pads.

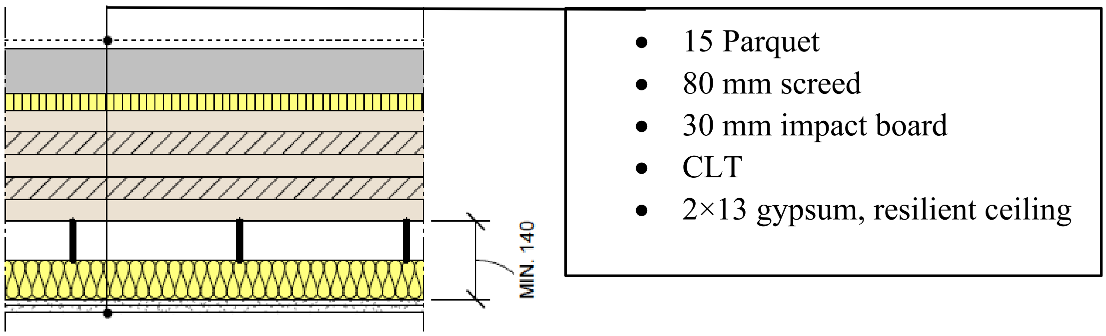

Figure 2: Floor structure 2 – CLT with screed on impact board and resilient ceiling.

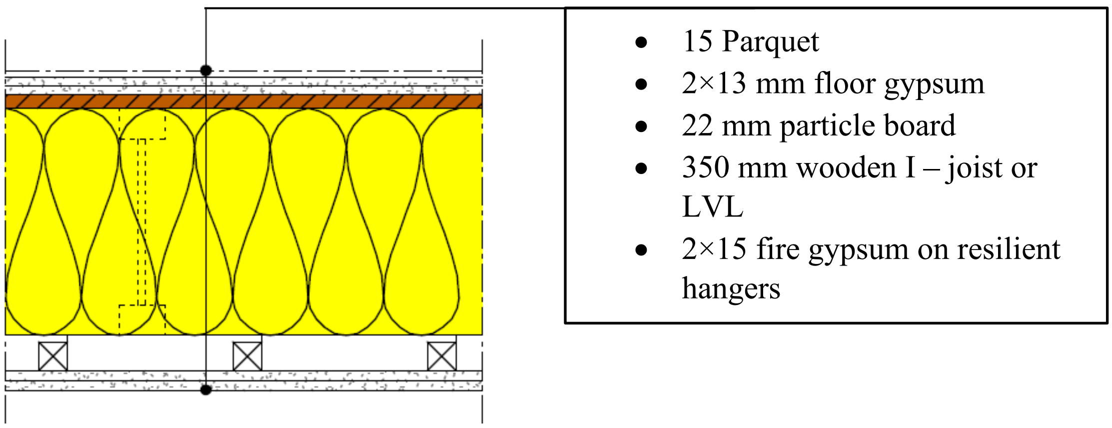

Figure 3: Floor structure 3 – Lightweight I-joist or LVL beam system.

In table 1 the min- and max-values are shown from several different buildings.

Table 1: The table shows possible limit values and measured min and max values with different evaluations; 1. Impact sound in an extended frequency range $L'_{nT,w}+C_{I,25\text{-}2500}$ (dB) and 2. Extended ISO evaluation, $L'_{nT,w}+C_{I,50\text{-}2500}$ (dB).

Floor structure no	Limit value expecting no change in perceived impact sound	Limit value expecting better correlation to perceived impact sound	Measured values	Measured values according to current evaluation
	$L'_{nT,w}+C_{I,25\text{-}2500}$ (dB)			$L'_{nT,w}+C_{I,50\text{-}2500}$ (dB)
1	≤ ca 60 dB	≤ ca 56 dB	56-60	48-56
2			56-60	45-52
3			48-60	45-56

3. ANALYSIS

Lightweight I – joist systems vary more than the CLT structures, probably due to larger spread in floor buildup details, beam type, beam height and similar, but also due to a larger variation in junction design compared to the CLT structures. It is clearly shown though, that it is possible to design lightweight floor structures comprising I – joist systems fulfilling very high requirements even if the frequency range would be extended to 20 or 25 Hz. Displayed measurement results comprise different beam types (LVL and I-joists) and different beam heights but also some variations in the layers on top of the floor structures. Hence figure 3 shows only a basic principle, there are naturally some variations in the overall design of the included buildings.

It is, of course, difficult to use the most far-reaching conclusions as such, but some important observations can still be made. Important to note is that in no case the values exceeded what can be expected to correspond to Swedish minimum requirements in a further extended frequency range. If designing the floor structure to fulfil requirements from 50 Hz it is likely that a potential new minimum requirement starting at 25 Hz (less than 60 dB) also will be fulfilled. For floor structure no 2, there are obviously a slightly larger margin to current minimum requirement, however if extending to 25 Hz also this floor fall in the same "class" as floor structure 1 and 3. This indicates that floor type in figure 2 may not be completely equivalent to class B in terms of perceived sound, despite fulfilling current sound class B requirements in Sweden.

- Overall, the requirement levels as discussed in the Swedish standard organization SIS TK 197 are quite applicable also for wood buildings as designed today in Sweden. It will be possible also to design lightweight wood buildings with even higher requirements. I joist systems can be optimized further to perform very high sound insulation even in an extended frequency range below 50 Hz. However, it is connected to raised costs which implies that it must be connected to what people are ready to pay.
- CLT systems show less spread between different solutions probably due to the CLT structure itself. With different complementary treatments we assume that it would be possible also to optimize floor structures to fulfil sound class B also in a potential future extension of the frequency range.

4. DISCUSSION

Modern wood floor structures appear to be competitive regarding both impact sound and airborne sound. There are no obvious obstacles to extend the frequency range further regarding impact sound (more than perhaps measurement technique and standard development in an extended range), future floor constructions will still fulfil minimum requirements as proposed in this paper. We have the knowledge today to design floor configurations fulfilling both minimum requirements and sound class B – this can be used for further refining of the floor structures.

Next step should be to study if the requirement levels in dwellings aimed for elderly and students typically, really are needed. For dwellings aimed for elderly people there are already some less strict requirements in Sweden but are they correct? This is a topic necessary to return to in all articles and papers since there are no real scientific proof that the requirements should remain the same independently of which type of residential unit the requirements are set. That is, do we really need similar requirements for small dwellings for students and elderly as for dwellings aimed for families? The floor surfaces are smaller in those dwellings, and they are aimed for one single grown up person reducing risk for annoying impact sound considerably. Additionally, students need to consider costs to a higher extent implying that it is our duty to put the correct requirements adapted to the risk for annoyance and to maximize rentable surface (Wall thickness is a cost). Each wall in a student dwelling is a partition which means if too thick it requires a lot of floor area reducing rentable surface, rising the cost. In the same manner a thinner floor structure can end up in cheaper buildings since the façade surface is shrinking and maybe resulting in an extra storey. The requirements should be correct in terms of perception from project start based on which type of residential unit they are applied to. It is important not only for timber structures but for buildings in general.

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