Changed sound properties due to minor construction changes in a lightweight building

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This paper relates to building acoustic measurement inside a two-storey office house. The construction, which is known as lightweight, is prefabricated in volumes at a factory and is then transported to the building yard for assembling. It is build up of a wooden frame with particle boards and plaster boards attached.
The building consists of a number of nominally, or almost nominally, identical rooms with assumed sound properties. In the projection stage, the construction was slightly modified in some of the rooms in order to see in what way the sound properties would be affected. In total eight impact sound pressure level measurements and eight sound reduction index measurements were performed and analysed for the different set-ups.

1 Introduction

Wooden buildings constitute an essential part of the building trade in Scandinavia. Several techniques exist; 1) Lightweight timber frame manufactured on-site, 2) Industrial manufactured lightweight timber frame and 3) Solid wood system. The second technique, industrial manufacturing, has shown an increased interest during the last years since and concept seems to be very attractive to the manufacture.

Complete house modules can be produced indoors at a factory with a more optimized production technique compared to on-site building. Industrial prefabrication in turn leads to benefits in terms of minimized risk of moisture problem during building, better working environment for the workmen, excellent accuracy to size and shorten production time at the building yard. However, the technique shares the classical drawbacks with other forms of lightweight buildings like poor sound and vibration properties at low frequencies.

Luleå University of Technology is running a research and development project which aims to improve the sound properties for module based systems. As a part of the project, on-site sound measurements were performed to a two-storey module based office building in order to study the effect of a numbers of minor construction changes.

2 Test object and experimental setup

The tested building consists of volume elements, prefabricated at a factory, transported to the building yard and there assembled to form the entire building. The building is supported by a wooden frame complemented with mineral wool and various boards of fibre, particle and gypsum. Between modules in the vertical direction, a 4mm bitumen strap serves as vibration insulation. The surface layer of the floor is 2.5mm linoleum carpet. The construction is shown in Fig. 1.

In the tests, totally 16 similar rooms were involved yielding 8 sound measurements between two rooms in vertical direction. Impact sound pressure level and airborne sound reduction were measured in accordance with ISO 140-7 and 140-4 respectively.

Two of the measurements refer to the standard case, i.e. no modifications. The remaining six measurements deals with various construction modifications, like removing or replacing the boards between the volumes, adding an extra layer of glued gypsum board to the floor and to interchange the type of glue.

The construction modifications are summarised in Table 1.

3 Results

The results in Table 2 refer to the normalized impact sound pressure level together with the spectrum adaptation term from 50 to 2500 Hz, i.e. $L'_{n,w} + C_{I,50\text{-}2500}$ and to the sound reduction index with the corresponding low frequency adaptation term, i.e. $R'_{w} + C_{50\text{-}3150}$.

3.1 Standard (A,B)

The results from the two standard cases give an indication of the variation between nominally identical volumes. The differences between the measurements were 2 dB for impact sound and 1 dB for sound reduction.

3.2 Excluding boards (C,D)

Excluding the ceiling board in combination with either floor board strips or totally excluding floor board improved the impact sound with approximately 2 and 5 dB respectively. The corresponding sound reduction index measurements show contradictory results with decreased insulation with 2 dB using board strips but increased insulation with 2 dB with the floor board omitted.

3.3 Extra floor gypsum board (E)

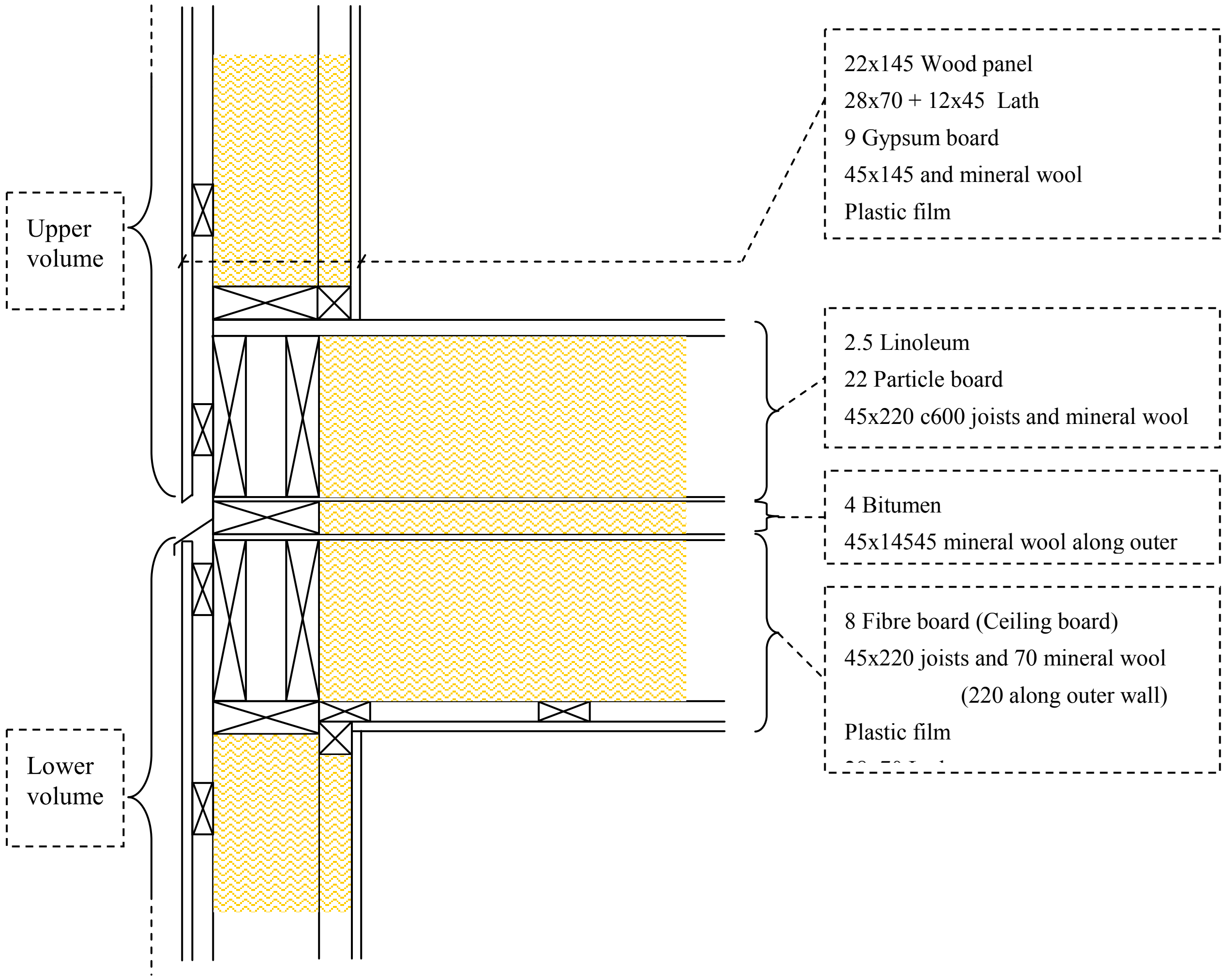
When adding an extra layer of gypsum board, the sound reduction index was almost unaffected while the impact sound level increased 1 dB.

3.4 Extra ceiling gypsum board

The effect of adding an extra layer of gypsum board to the ceiling was remarkable, 6 dB improvement for impact sound and 4 dB for sound reduction.

3.5 Elastic glue compared to traditionally glue for floor gypsum boards

The impact sound pressure level was found to be 4 dB higher when the elastic glue was used compared to the case with traditional glue (which becomes hard after drying).



.Fig.1 Construction.

Test no.		Room no.	Specification
A	Sending room	226	Standard
	Receiving room	133	Standard
B	Sending room	233	Standard
	Receiving room	134	Standard
C	Sending room	234	300mm strips of floor board replaces the standard board
	Receiving room	131	Ceiling board excluded
D	Sending room	225	Floor board replaced by thin wind proofed cloth
	Receiving room	132	Ceiling board excluded
E	Sending room	224	Floor gypsum added
	Receiving room	129	Ceiling board excluded
F	Sending room	230	Standard
	Receiving room	130	Ceiling board excluded 2x13 gypsum board in ceiling
G	Sending room	204a	Floor gypsum added with elastic glue
	Receiving room	112	Standard
H	Sending room	204b	Floor gypsum added with standard glue
	Receiving room	118	Standard

Table 1 Test configuration.

Test	$L'_{n,w}$	$C_{I,50\text{-}2500}$	$L'_{n,w}$ $+C_{I,50\text{-}2500}$	R'_w	$C_{50\text{-}3150}$	R'_w $+C_{50\text{-}3150}$
A (Standard)	58	1	**59**	58	-4	**54**
B (Standard)	59	2	**61**	58	-3	**55**
C (Floor board strip, no ceiling board)	57	1	**58**	57	-4	**53**
D (No floor board, no ceiling board)	55	0	**55**	61	-4	**57**
E (Floor gypsum, no ceiling board)	62	-1	**61**	57	-3	**54**
F (Ceiling: no board, extra gypsum)	52	2	**54**	62	-3	**59**
G (Floor gypsum elastic glue)	60	-1	**59**	-	-	-
H (Floor gypsum, standard glue)	54	1	**55**	-	-	-

Table 2 Results.

4 Discussion and conclusions

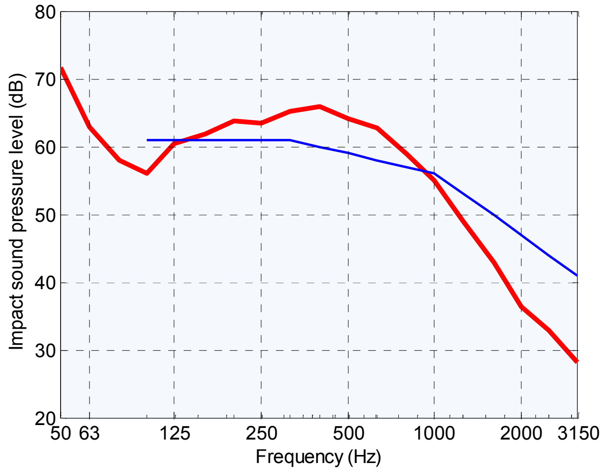
4.1 Variations and measurement error

It is always risky to draw certain conclusions from the type of measurements presented in this paper. The different test setups are measured for *one* setup only. It is then very hard to reveal whether possible deviations is caused by the actual constructional modification or caused by natural variation among nominally identical building modules, a variation that sometimes can get significantly high. Besides that, the measurement itself contains a certain degree of uncertainty, in this case about +/- 1 dB. For every interpretation of a comparison between two sound measurements from different test setups it is necessary to be aware of the parameters that might affect the result;

1) Natural variation between nominally identical building volumes
2) Uncertainty of the measurement
3) Real changes in the construction.

4.2 General tendencies

It is noticed that in the area from about 200 to 800 Hz, the sound insulation is poor in relation to the standardized reference curve, see Figure 2. For the standard cases (A,B) it is also noticed that the impact sound level is specially high at about 50 Hz. The same tendency is seen for some other test setups (G,F).



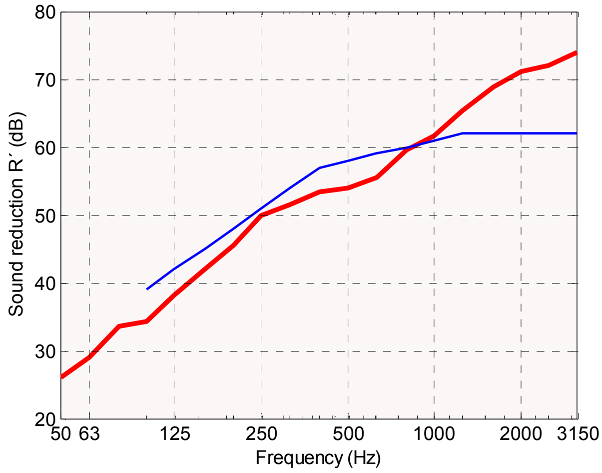


Fig. 2. Impact sound pressure level (upper) and airborne sound reduction (lower) for room 134 (Standard (B)).

4.3 Test cases

The results from the tested setups are in some cases in accordance from what should be expected while the opposite is true for others which indeed is perplexing.

When both floor and ceiling boards are excluded (D) the impact sound improves 5 dB and the airborne sound insulation with 2 dB compared to standard. The result is expected since a dividing layer normally worsens the sound properties. With the same argument, the similar setup C with board strips, should have shown improvement although that was not the case. According to known acoustic theory, which partly is confirmed by the measurements, it is recommended not to use horizontally fully covered board in the middle of a floor construction.

Improvement as a result of using floor gypsum board (E) was expected in advance but the measurement indicates no difference compared to the standard setup. On the other hand, the improvement when using an extra layer of ceiling gypsum board is more than expected.

To use elastic glue instead of traditional glue is again a constructional modification where the expectations and measurement results do not coincide since the impact sound level *increased* 4 dB when the elastic glue was applied although previous measurements within the same project has proved lower sound impact level for such a case.

Significant conclusions from the measurements of the different setups are hard to draw due to the variation between nominally identical room and building volumes which were far higher than expected. For more reliable results when the effects of minor constructional modifications are to be evaluated, tests in laboratory - under higher control - are therefore preferable.