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Impact sound insulation improvement of wooden floors on concrete slabs – A pilot study on solutions and test methods

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Summary

Improvement of impact sound insulation is one of the major challenges, when renovating housing. In Denmark, building regulations for impact sound in new-build were strengthened 5 dB in 2008, implying a main requirement $L'_{n,w} \leq 53$ dB between dwellings. The same value should also be a goal, when renovating housing. In Denmark, there are about 1 million dwellings in multi-storey housing. About half of the dwellings are built with timber floors, and the other half with wooden floors on concrete slabs, either in-situ cast or prefabricated hollow-core elements. In a project including mapping of sound insulation in the Danish housing stock and investigation of improvement possibilities, a pilot laboratory study of wooden floors on concrete was carried out. The laboratory study included impact sound improvement measurements of full-scale samples (10 m^2) fulfilling the conditions in EN ISO 10140. The measurements indicated up to about 8 dB improvement potential compared to floor constructions typical before the latest change of regulations, namely wooden floors on joists on PE wedges or similar. In addition, tests of small-scale samples (1 m^2) – unsuitable for type testing – were performed to provide a fast track ranking of different floor supports, giving also the opportunity to compare differences between small-scale floors with those from full-scale measurements. The paper presents results from the laboratory tests of different floor supports.

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1. Introduction

According to a social survey in 2010 in Denmark, about 35% of occupants in multi-storey housing are disturbed by neighbour noise, while for other housing types, it's less than 10%. Thus, there is a strong need to improve sound insulation in multi-storey housing. In Denmark, stricter regulatory sound insulation requirements for multi-storey housing, new-build, were implemented in 2008 and unchanged in regulations from 2010 [1]. Fulfilment of the new requirements should also be a goal, when renovating housing, and improving impact sound insulation is one of the major challenges. Table I shows the main requirements for impact sound between dwellings since the first requirements.

This paper focuses on impact sound improvement and describes a pilot laboratory study of wooden floors on concrete slabs.

Table I. Impact sound insulation requirements in the Danish Building Regulations.

Time period	Requirements ⁽³⁾ in building regulations	Impact sound insulation $L'_{n,w}$
Before 1956	no	$\sim 70 \text{ dB}$ ⁽¹⁾
1956 to 2007	yes	$\leq 58 \text{ dB}$ ⁽²⁾
From 2008	yes	$\leq 53 \text{ dB}$

(1) Estimated value representing houses with timber floor constructions typical until about 1950.
(2) Before 1982 various descriptors have been used, but limits correspond to the $L'_{n,w}$ -value used from 1982.
(3) More details about requirements, also for airborne sound insulation, are found in [2].

2. Housing stock in Denmark

In Denmark there are about 2.7 million dwellings in total, of these about 1 million in multi-storey housing – having far the highest percentage of people being disturbed by neighbour noise. In Figure 1 are found graphs for number of dwellings according to year of construction and dwelling types.

Buildings from different periods have different construction characteristics. In a Danish guideline [3], building types E1, E2 and E3 have been described, see also [2] with an overview of constructions and typical field sound insulation performance. This paper deals with solutions for impact sound improvement for floors for building types E2 and E3, see Figure 2 with main characteristics for constructions. The test plan and results are described in Sections 3 and 4.

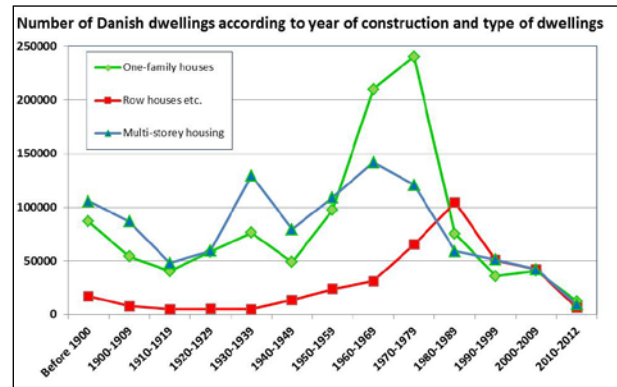


Figure 1. Number of Danish dwellings according to year of construction and type of dwellings – 10 year periods from 1900-2009. Source: Statistics Denmark [5].

The study is a part of a bigger project [4] including mapping of sound insulation in the Danish housing stock and investigation of improvement possibilities.

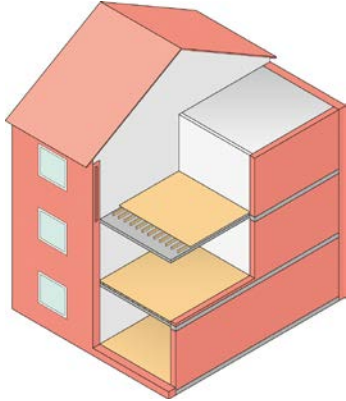
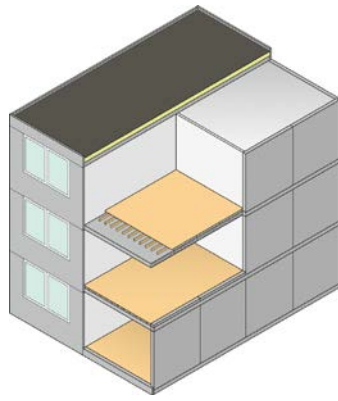
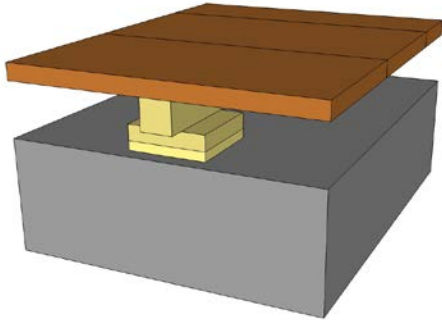
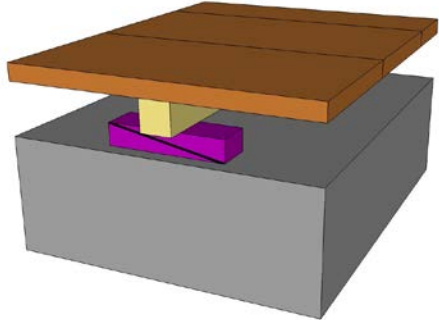
Main building types and construction characteristics for multi-storey housing in Denmark 1950ff	
<p>Building type E2 Brick-built buildings with in-situ concrete slabs Period: About 1950 to 1960 Number of dwellings in Denmark: Less than 100.000 dwellings.</p> 	<p>Building type E3 Concrete element buildings Period: From about 1960 Number of dwellings in Denmark: Approx. 400.000 dwellings.</p> 
<p>Typical floors are wooden floors on joists on supports of plywood and soft fibreboard.</p> 	<p>Typical floors are wooden floors on joists on supports of PE wedges.</p> 

Figure 2. Main building types and construction characteristics for multi-storey housing in Denmark, construction period from about 1930. Denotations E2 and E3 are from a Danish guideline [3].

3. Test plan and laboratory setup

As a part of the investigation of improvement possibilities of the impact sound insulation in existing housing with concrete slabs, a pilot laboratory study of wooden floors on concrete was carried out. The laboratory study included 13 floor constructions in total. This paper describes results for six wooden floors on joists on different supports, see descriptions of test specimens in Section 4, Table II. As reference test specimens were used two floors, A and B, being typical in Denmark since the 60's and 70's. Floor A is a wooden floor on joists on PE wedges and floor B similar, but with supports of plywood and soft fibreboard. The heights of the floors A and B are 90 mm and 94 mm, respectively.

Solutions for improved floors were searched for among floor constructions having about the same height as floors A and B, as it is essential to avoid changing of the height of the floor construction when renovating housing due to doors, door steps, room height.

Three of the tested improved constructions, floor C, D and G, had a similar design, but were supplemented with different rubber-based underlays between the wedges/supports and the concrete slab. These constructions had heights 92 – 96 mm, i.e. maximum 6 mm difference from heights of floors A and B. In addition, a wooden floor as floor G, but with mineral wool between the joists was tested (floor K).

All tested floors were made of 22 mm wooden parquet on 40 mm joists with c-c 600 mm on different supports with c-c 550 mm.

The test plan for the laboratory study included impact sound improvement measurements of full-scale samples (10 m^2) in compliance with the test standards in the EN ISO 10140 series [6], using the standardized tapping machine and a floor load 25 kg/m^2 approx. 24 hours prior to the test. As a supplement to the normal frequency range for building acoustics laboratory measurements 100 Hz to 5000 Hz, measurements in the one-third octaves 50 Hz to 80 Hz have been made. Although the measurements at the low frequencies are performed without using the additional guidelines in the standard and must be considered as survey measurements, the results provide a good indication of the shape of the curves in the resonance-dominated frequency area.

Ratings were carried out according to EN ISO 717-2 [7].

The tests were carried out in the test facilities at Technical University of Denmark in Kongens Lyngby. On the heavy weight reference floor (140 mm reinforced concrete slab) in the test facilities, different wooden floor constructions were built and tested. The test setup is shown in Figure 3.



Figure 3. Test setup for laboratory measurements of impact sound improvement. The photo shows the standardized tapping machine and the floor load 25 kg/m^2 .

In addition to the full-scale standardized measurements, small-scale measurements were performed using a 0.81 m^2 floor. The materials and distances between the joists were the same as for the full-scale floors, and the floor load almost the same, 25 kg/m^2 . The use of such a small test area is of course unsuitable for type testing, but was added to investigate whether a fast track ranking for this type of wooden floors would be possible using small samples more conveniently sized.

4. Laboratory test results

An overview of the results from the full-scale tests is given in Table II.

Figure 4 shows the improvement of the reduction of impact sound pressure level when floor A on normal PE wedges is compared to floor C and D, with two different rubber-based underlays between wedges and concrete slab. The improvement of the weighted single number value ΔL_w is 5-6 dB.

Figure 5 indicates the same improvement when changing the supports of soft fibreboard (floor B) to a rubber-based underlay (floor G). In combination with mineral wool between the joists (floor K) the improvement of the weighted single number value ΔL_w is 8 dB.

Table II. Laboratory test results ΔL_w for wooden floors on joists.

Floor No.	Floor description	Total floor height	Improvement of impact sound insulation ΔL_w
A	22 mm parquet boards on 40 mm joists on PE wedges - often used solution in existing buildings in DK	90 mm	17 dB
B	22 mm parquet boards on 40 mm joists on supports of plywood and soft fibreboard - often used solution in existing buildings in DK	94 mm	18 dB
C	22 mm parquet boards on 40 mm joists on PE wedges with a rubber-based underlay	96 mm	23 dB
D	22 mm parquet boards on 40 mm joists on PE wedges with a rubber-based underlay	92 mm	22 dB
G	22 mm parquet boards on 40 mm joists on supports of MDF board and a rubber-based underlay	96 mm	23 dB
K	As Floor G, supplemented with 45 mm mineral wool placed between the joists	96 mm	26 dB

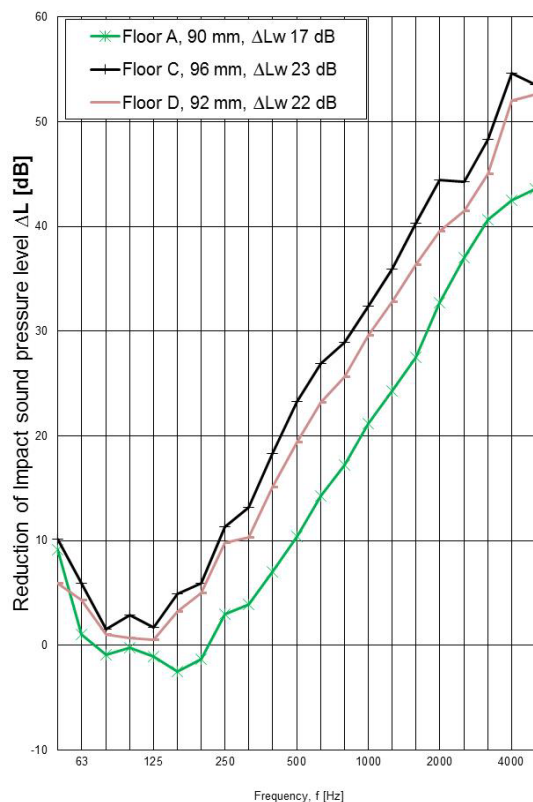


Figure 4. Reduction of impact sound pressure level per one-third octave for floor A, C and D. Laboratory measurements in accordance with EN ISO 10140.

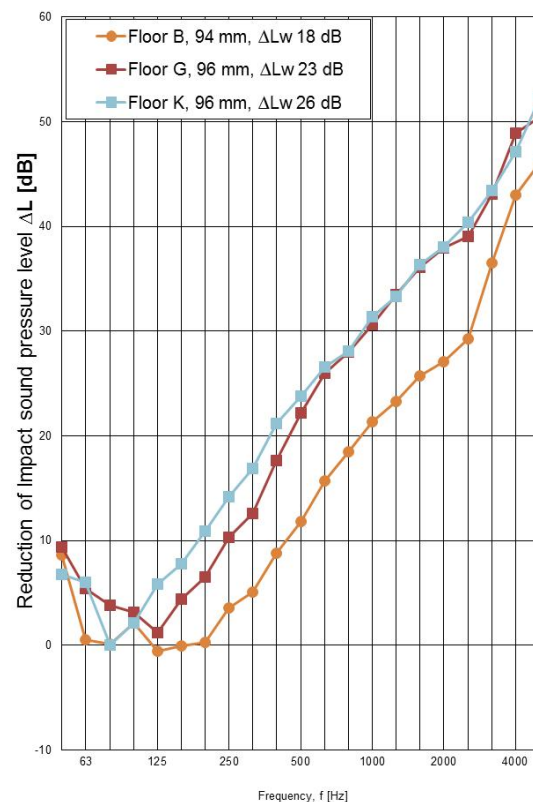


Figure 5. Reduction of impact sound pressure level per one-third octave for floor B, G and K. Laboratory measurements in accordance with EN ISO 10140.

The results show that for this type of floor constructions a rather simple measure – adding a softer underlay – due to shifting of the resonance dominated minimum values of the curve a few one-third octaves towards the lower frequencies –

can provide the necessary improvement of the impact sound insulation.

Further theoretical considerations concerning the reduction in the resonance area has not been a part of the project.

Figure 6 shows the reduction of impact sound pressure level for floor G using the full-scale floor and the small-scale floor test. Below 400 Hz there are differences up to 11 dB where the small-scale floor almost always exaggerates the improvement when compared to the full-scale floor. From 400 Hz there appears to be better agreement between the results of the two test floors.

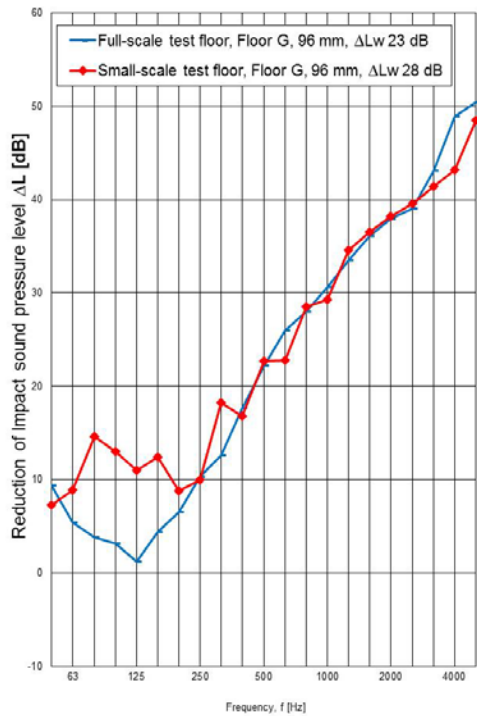


Figure 6. Comparison of the reduction of impact sound pressure level for floor G. Results from laboratory measurements of a full-scale test floor and a small-scale test floor.

Figure 7 shows the rating of the different floor construction types for the full-scale floors and the small-scale floors.

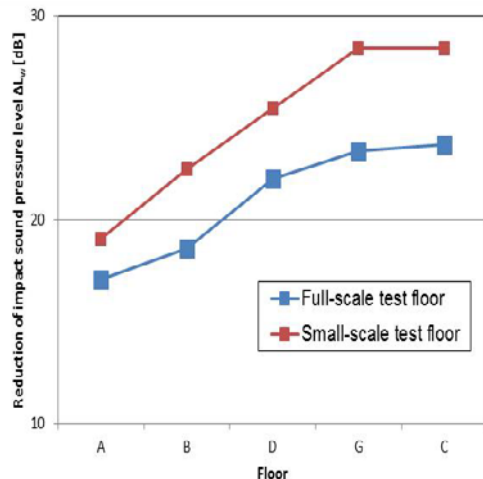


Figure 7. Ranking of floors according to ΔL_w value (with 1 dec.). Full-scale versus small-scale test floors.

It is clear that the rating of the small-scale floor is generally much higher, starting at +2 dB for the relatively hard PE wedge (floor A) and up to +5 dB for the softer supports of floor C and G. The results confirm the expected unsuitability of such small test floors for type testing. However, the ranking of the floor types is the same for the small-scale floors and the full-scale floors. This suggests that a small-scale floor may be used for comparative purposes, for example development of more efficient impact sound insulated wooden floors on joists.

5. Field measurement results

The improvement potential of one of the floor constructions was tested in a multi-storey housing. Measurements fulfilling EN ISO 140-7 [8] were performed in the same dwellings before and after renovation of the housing. The wooden floor on joists on PE wedges (similar to floor A) was replaced by a wooden floor on joists on PE wedges with a rubber-based underlay (similar to floor D). Figure 8 shows an example of the improvement of the measured impact sound level in the housing compared to the improvement obtained from the laboratory measurements of the reduction of impact sound pressure level of the two similar floor constructions.

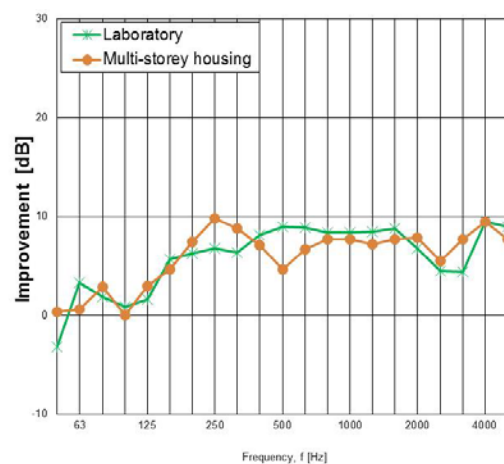


Figure 8. Comparison of the obtained improvement of the impact sound insulation using floor D instead of floor A as measured in the laboratory and as measured in a multi-storey housing - where the floors (similar types) were replaced as part of a renovation.

From results for floor D presented in Figure 8 it is seen that the measured results for improvement in the laboratory and in the building tested are very similar.

6. Discussion & Conclusions

During the latest decades, numerous refurbishment and renovation projects have taken place in Denmark, most of these focusing on upgrading technical installations, kitchen and bath rooms and not least at energy savings. Unfortunately, sound insulation improvement is almost never addressed, not even in cases where sound insulation is known to be a problem.

Consequently, there is a strong need for a more holistic approach, when renovating housing, implying sound insulation upgrade to be considered and planned simultaneously with other upgrades of housing, especially with thermal insulation upgrades.

Six wooden floors are described in this paper. Two of them are similar to the basic wooden floors on joists typically used in the Danish multi-storey housing with concrete slabs built before the latest 5 dB tightening of requirements in 2008. These floorings obtained a reduction of impact sound pressure level ΔL_w 17-18 dB in the laboratory measurements. The other four floors tested in the laboratory showed results for the reduction of impact sound pressure level ΔL_w 22-26 dB. All of those four wooden floors on joists had supports upgraded with a rubber-based underlay which gave about 5 dB improvements for ΔL_w . The best result was obtained with one of the upgraded floors with mineral wool in the cavity between the joists. For this floor a further improvement about 3 dB was obtained.

Consequently, fulfilment of the most recent regulations seems feasible, if in a renovation project, the floor typical before, is replaced by a floor with upgraded supports. A field test – where the wooden floors needed replacement and an improvement was specifically sought – showed good agreement with the laboratory result.

This pilot study has confirmed that simple changes of the typical floor constructions in Danish housing built after 1950 may be sufficient for fulfilment of today's strengthened requirements in the Danish building regulations.

The study with small-sized test samples showed – despite the fact that these are unsuitable for type testing – that they may be useful for ranking of different ideas for improved supports for wooden floors on joists.

The full-scale results reported in this paper are only extracts of the laboratory measurements made on a total of 13 different wooden floor constructions studied in the project.

Although further development and more field studies would be useful, most important is to apply the improved solutions in practice, when renovating housing, instead of choosing low-performance solutions of the past.

Acknowledgement

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