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Consequences of revised sound insulation requirements between dwellings in Norway

Anders Løvstad and Per Kåre Limmesand
Brekke & Strand Akustikk, Hovfaret 17B, 0275 Oslo, Norway, anl@brekkestrand.no

The Norwegian standard NS 8175 which gives requirements for sound insulation in various buildings types, amongst them dwellings, was revised in 2019. One major change in the revision was to include frequencies down to 50 Hz in the sound insulation requirements for dwellings. This paper briefly discusses the revised requirements in comparison with the corresponding requirements in the other Nordic countries. Then practical consequences in how constructions separating dwellings vertically and horisontally must be built to meet the new requirements are investigated. Specific challenging situations are highlighted and exemplified with measurement results. Possible measures are discussed. This is done for slabs and walls made of concrete, cross-laminated timber and light-weight wooden constructions.

1 Introduction

Good acoustic living environments comprise sufficient sound insulation and noise mitigation towards both adjacent dwellings, outdoor traffic and other internal or external noise sources, which are important measures in order to reduce possible health issues as well as to ensure the well-being of residents.

In Norway acoustic conditions and sound classification of buildings is given in the national standard NS 8175 [1], which is directly referred to in the national regulations on technical requirements for construction works (TEK17 [2]), where sound class C is stated as the preaccepted performance level (minimum requirement). NS 8175 was revised in 2019 [3], where a major change in the revision was to include frequencies down to 50 Hz in the requirements for both airborne and impact sound insulation. It may be argued that addressing this issue was the main reason for revising the standard. In the 2012 edition, the spectrum adaptation terms were recommended in the standard, but not included in the mandatory requirements. Despite that Standards Norway have withdrawn the 2012 edition, the Norwegian Building Authority will not update the reference in TEK17 to the 2019 edition until an ongoing economical evaluation of the consequences of the revised requirements is concluded, which may be expected in 2021.

As a basis for the revision of the sound requirements between dwellings in NS 8175, an extensive socio-acoustic survey was carried out to evaluate the required sound requirements [4], assessing which parameters should be used and the requirements themselves. A main finding in the survey was that for impact sound insulation no correlation was found between reported subjective annoyance and objectively measured values unless the spectrum adaptation term $C_{I,50\text{-}2500}$ was included. For airborne sound insulation, slightly better correlation was found when the spectrum adaptation term $C_{50\text{-}5000}$ was included. Standardised descriptors gave slightly better correlation than the normalised descriptors, but the difference was not significant.

In a review article Verdaxis et al. [5] examined studies which combined acoustic data and subjective responses. They found that most studies suggest that measurements should include extended frequencies down to 50 Hz (or even down to 20 Hz) for impact sound insulation. For airborne sound insulation, the picture is not quite as clear, and the conclusions in published research vary. However, as pointed out by Rindel in [6], it is the most critical situation that should form the basis for the sound requirements, thus including the spectrum adaptation term $C_{50\text{-}5000}$.

Firstly, this paper gives a brief overview and discussion of the current requirements in the Nordic countries, and in Norway specifically. Secondly, consequences and needed measured and adjustments in order to fulfil the new requirements when building with various heavy and light-weight slabs and walls are discussed.

2 Sound insulation requirements

Sound insulation requirements between dwellings in Norway have remained unchanged since 1997, when the first edition of NS 8175 was published. The minimum requirements to fulfil the national regulations for airborne and impact sound insulation have been $R'_w \geq 55$ dB and $L'_{n,w} \leq 53$ dB, respectively. Revised requirements in class C in the 2019 edition of NS 8175 [3] are $R'_w + C_{50\text{-}5000} \geq 54$ dB and $L'_{n,w} + C_{I,50\text{-}2500} \leq 54$ dB. These requirements are listed in Table 1, and compared with current minimum requirements in the other Nordic countries.

It should be noted that e.g. in Sweden the higher class B given in the Swedish standard SS 25267 [7] is often used, where the requirements are 4 dB stricter (i.e. $D_{nT,w} + C_{50\text{-}3150} \geq 56$ dB and $L'_{nT,w} + C_{I50\text{-}2500} \leq 52$ dB). Up until now, class B has seldom been used in Norway, presumably due to the seemingly huge leap in cost and building complexity as the requirement was 3 and 5 dB stricter for airborne and impact sound insulation, respectively, and included frequencies down to 50 Hz. In the revised NS 8175 $R'_w + C_{50\text{-}5000}$ complies for classes A to C, with 4 dB between the classes, encouraging building projects to use class B.

Airborne and impact sound insulation requirements have been and are subject of extensive research and debate, also in the Nordic countries. Despite partly being founded on the same research and empirical experience, different parameters and frequency ranges are used in the Nordic countries, as Table 1 shows. Up until the recent revision of NS 8175, Denmark, Iceland and Norway had the same requirements, not including frequencies below 100 Hz neither for airborne nor impact sound insulation. Finland and Sweden use standardised parameters, while Denmark, Iceland and Norway use normalised ones. With the recent Norwegian revision, Norway and Sweden take frequencies down to 50 Hz into account both for airborne and impact sound insulation, although using different spectrum adaptation terms for airborne sound insulation.

Table 1: Current minimum sound insulation requirements between dwellings in the Nordic countries.

Descriptor Airborne / impact sound	Denmark DS 490 2018 [8]	Finland 796 2018 [9]	Iceland IST 45 2016 [10]	Norway NS 8175 2012 [1]	Norway NS 8175 2019 [3]	Sweden BBR28 2019 [11]
R'_w / $L'_{n,w}$	55 / 53		55 / 53	55 / 53		
$R'_w + C_{50\text{-}5000}$ / $L'_{n,w} + C_{I50\text{-}2500}$					54 / 54	
$D_{nT,w}$ / $L'_{nT,w} + C_{I50\text{-}2500}$		55 / 53				
$D_{nT,w} + C_{50\text{-}3150}$ / $L'_{nT,w} + C_{I50\text{-}2500}$						52 / 56

When comparing the current requirements to the corresponding ones from the middle of the 1990s, as summarised by Rasmussen and Rindel [12] and in the work report 1996-04 E [13] from the acoustics group of the then existing Nordic Committee on Building Regulations (NKB), it is evident that a diverging development has happened since then. All Nordic countries then used R'_w and $L'_{n,w}$. Requirements where given separately for townhouses and multi-storey building, but i.e. the requirement for airborne sound insulation between townhouses and impact sound insultation between multi-storey buildings where the same, $R'_w \geq 55$ dB and $L'_{n,w} \leq 58$ dB, respectively.

3 Consequences of revised requirements

In Norway the choice of building method and material use vary significantly. Concrete and hollow-core slabs, light-weight wooden and concrete constructions, and CLT are commonly used, depending on the specific building, preference of the constructors, and project ambition for sustainability. The SINTEF Building Research Design Guides [14] have already started to incorporate the lower frequency requirements into their publications, which are frequently seen to in Norway.

It is important to emphasize that the revision of the sound requirements is not done in order to exclude or affect certain building methods or products, but solely to obtain adequate sound insulation. The needed measures and adaptions to meet the new requirements when employing the different building methods and materials will lead to better building and higher quality for the residents – in many cases without significant increase in building cost.

Given requirements can be met in certain ways, but in some cases climate footprint and requirements might become a factor that influence which constructions emerge as standard solutions in certain building types. Passive house standards [15], BREEAM [16] and other methods or standards for sustainability assessment of buildings are commonly used and are likely to affect material choices even more in the future.

In the following, the suitability of typical example constructions presently employed in dwellings are discussed. All example constructions are considered representative and typical. Still, the total sound insulation values obtained by field measurements naturally depend on the flanking conditions, which are considered good and not to govern the total sound insulation as such.

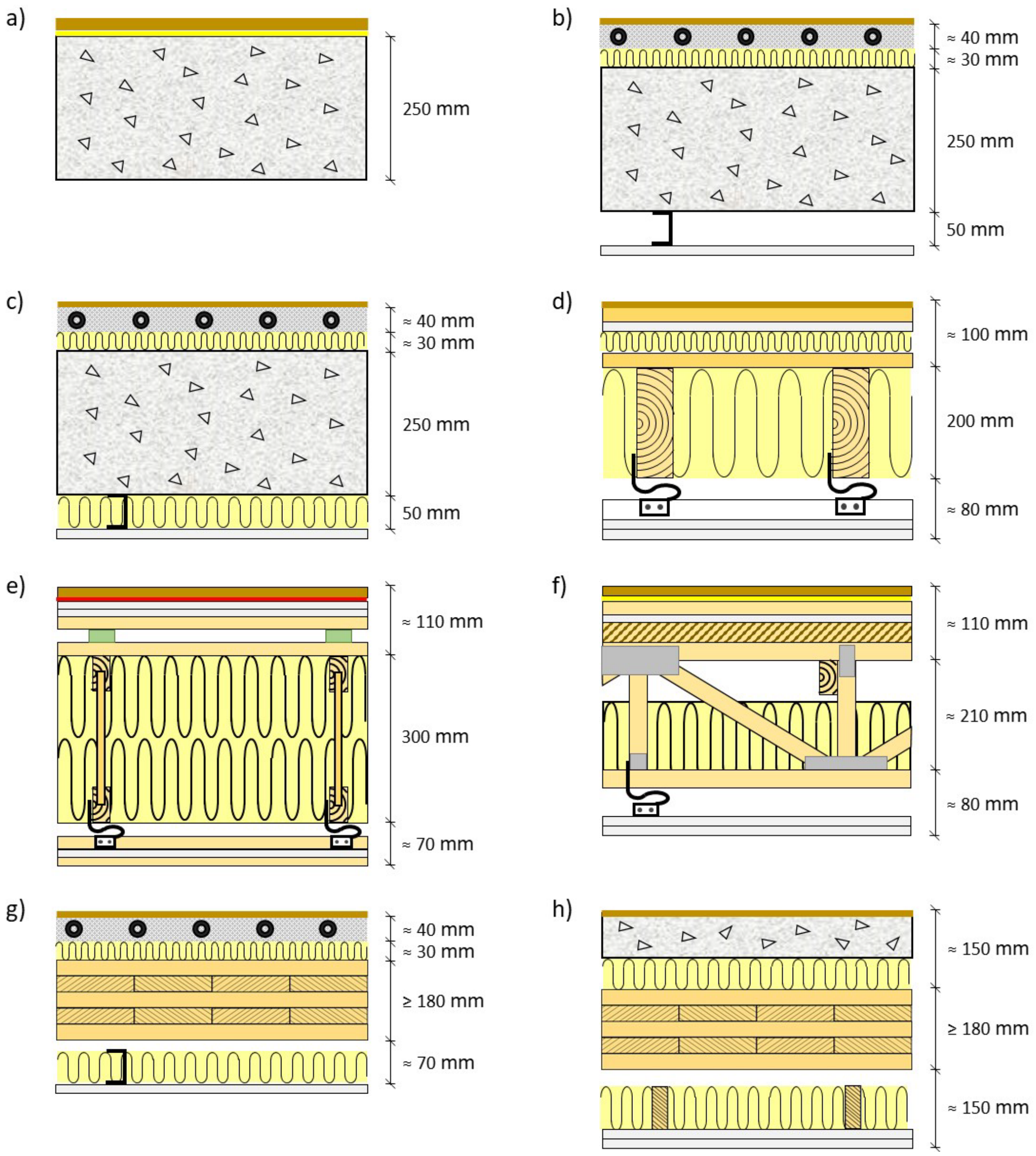

Figure 1: Examples of slabs between dwellings. a-c) show concrete slabs, d-f) light-weight wooden constructions (adapted from SINTEF Building Research Design Guide 522.511 [17], and g-h) cross-laminated timber (CLT) constructions.

3.1 Floors

A selection of typical slabs is shown in Figure 1, where a-c) show concrete slabs, d-f) light-weight wooden constructions and g-h) cross-laminated timber (CLT) constructions. The light-weight wooden constructions are adapted from SINTEF Building Research Design Guide 522.511 [17].

3.1.1 Concrete slabs

Typical thickness of concrete slabs between dwellings are 250 mm. With directly mounted thin impact sound reducing layers typical sound insulation values are R'_{w} = 59-61 dB and $L'_{\mathrm{n,w}}$ = 49-52 dB, with spectrum adaptation terms 0-1 dB. Thus, the revised requirements are expected to be met.

However, heated floors are commonly installed in living- and bedrooms in dwellings. These are commonly installed in thin floating floors, as shown in Figure 1b) and c). Typical thin floating floors consisting of 35-50 mm lightweight concrete (1600-2000 kg/m^3) on 20-30 mm impact sound reducing layers (mineral wool, softened EPS etc.) will typically have resonances in the extended frequency range from 63-80 Hz, resulting in undesirable spectrum adaptation terms. Additionally, if non-isolated suspended ceilings are built to install recessed light spots and/or hide technical installations, the resonance frequency of the suspended ceiling and floating floor may coincide and result in spectrum adaptation terms of up to 15-20 dB. Figure 1b) outlines the construction, for which an example field measurement result is shown in Figure 2. In this specific case the measurement results were R'_{w} = 64 dB with $C_{50\text{-}5000}$ = -15 dB and $L'_{\mathrm{n,w}}$ = 46 dB with $C_{\mathrm{I},50\text{-}2500}$ = 17 dB, thus meeting the requirements in NS 8175:2012, but not the revised requirements. The limited low-frequency sound insulation of such floating floor has also been pointed out by other researchers [18, 19].

Depending on the thickness and type of material used in the floating floor, the cavity above the board layers in the suspended ceiling, and whether the suspended ceiling is insulated or not, the spectrum adaptation terms may be somewhat smaller, and the sound insulation values may be within the revised requirements. Still, such imbalance in the sound insultation spectra should be avoided. If the suspended ceiling is insulated, as shown in Figure 1c), the resonance in the suspended ceiling is not as prominent, reducing the spectrum adaptation terms. This solution is likely to fulfil the requirements for airborne sound insulation and in some cases also the impact sound requirement, especially in smaller rooms, but to our experience can exceed the impact sound requirement in larger living rooms unless thicker floating floors and/or upgraded ceiling constructions are used.

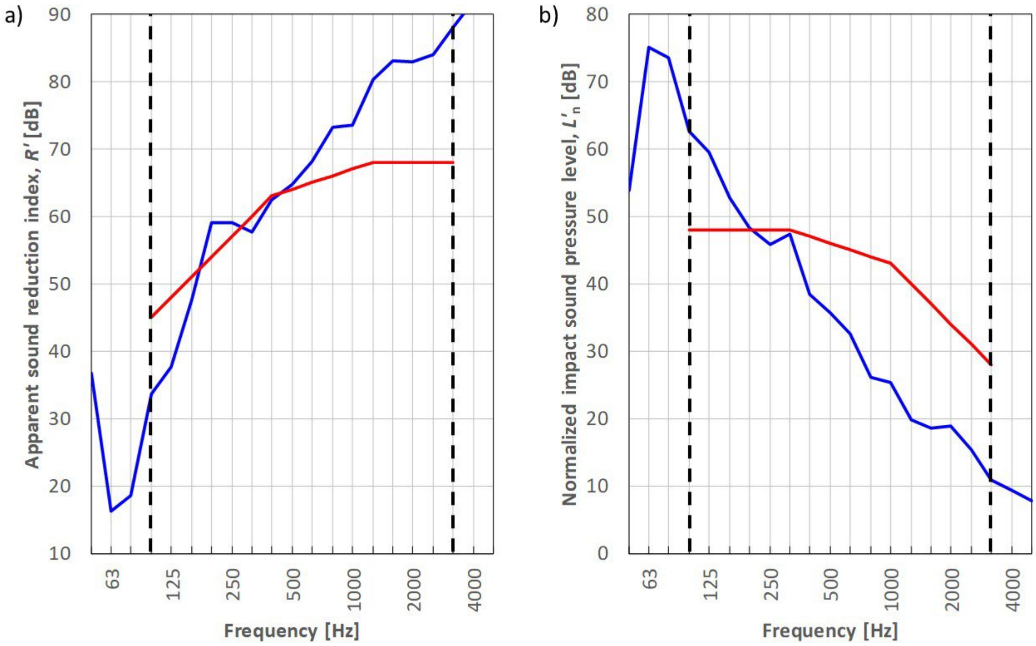

Figure 2: Example measurement of a 250 mm concrete slab with a floating floor of 40 mm lightweight concrete on 30 mm softened EPS, and 1x13 mm gypsym suspended 50 mm without mineral wool, see Figure 2b). Measurement results in blue lines, and reference curve according to ISO 717-1 and -2 in red lines. Dashed lines indicate the octave band limits included in the calculation of R'_{w} and $L'_{\mathrm{n,w}}$. a) Apparent sound reduction index, R', and b) Normalised impact sound pressure level, L'_{n}.

3.1.2 Hollow-core slabs

For hollow-core slabs similar considerations as for concrete slabs apply with some modifications. 320 mm hollow-core slabs with surface mass of 530 kg/m^2 can be used with similar measures as with 250 mm solid slabs. For thinner HD-slabs improved floors and/or suspended or separate mounted ceilings are needed. Concrete floating floors with sufficient surface mass on a combination of mineral wool-based impact sound reducing layer and softened EPS have given good results, meeting the revised requirements both for airborne and impact sound insulation.

It should be noted that especially when thinner hollow-core slabs are used, the construction is more sensitive to flanking issues, as many constructions give little margin of error.

3.1.3 Light-weight wooden floors

Wooden light-weight floors are typically not employed in newer larger multi-storey buildings, but commonly used in townhouses and smaller two-storey buildings with horisontally separated flats. Figure 1d)-f) shows three examples of typical constructions, where d) can be said to be the classical solution. This construction is expected to meet the revised airborne sound insulation requirement as $R'_{w} + C_{50\text{-}5000}$ = 57-59 dB is typically obtained, but will not fulfil the impact sound requirement as $L'_{n,w} + C_{I,50\text{-}2500}$ = 55-59 dB is expected. This is in good agreement with [17].

Figure 1e) and f) show improved constructions expected to meet the revised requirements due to improved stiffness, additional layers in the floating floor and/or suspended ceiling, use of point supported floating floors, or larger dimensions in total which gives improved sound insulation at lower frequencies. Additionally, constructions where concrete or concrete slabs are constructively added to wooden floor mounted onto the main wooden beams give good results.

3.1.4 Cross laminated timber (CLT)

Buildings constructed using CLT are built with in accelerating quantity. Figure 1g) fulfils the sound insulation requirements given in the 2012 edition of NS 8175, as R'_{w} = 55-57 dB and $L'_{n,w}$ = 52-53 dB is expected. The airborne sound spectrum adaptation term, $C_{50\text{-}5000}$, is 2-3 dB, so the revised requirement may marginally be fulfilled, but as $L'_{n,w} + C_{I,50\text{-}2500}$ = 55-57 dB should be expected the construction is not good enough.

The CLT slab must be built with increased mass in the floating floor, or to constructively add mass to the slab commonly using quarry stones or concrete, and improved suspended, preferably separate, ceiling with increased number of board layers. Figure 1h) shows a promising construction estimated at $R'_{w} + C_{50\text{-}5000}$ = 59-61 dB and $L'_{n,w} + C_{I,50\text{-}2500}$ = 49-52 dB.

It must be stressed that flanking constructions and use of appropriate type and placed elastic layers is vital when building with CLT. Despite rapidly growing experience with CLT, the documentation and experience are far from that of concrete and light-weight wooden constructions. Figure 3 shows a typical selection of measured CLT constructions by Brekke & Strand Akustikk up until early 2019, where the red triangles and blue circles indicate vertical and horizontal measurements, respectively. The revised requirements are indicated by the dashed lines. Thus, only constructions in the lower right quadrant indicated in green meet both the airborne and impact sound limits. Since few buildings are built to meet the new requirements yet, it is not surprising that few measurement results fulfil them, but it indicates that extra considerations must be taken, especially to obtain sufficient impact sound insulation.

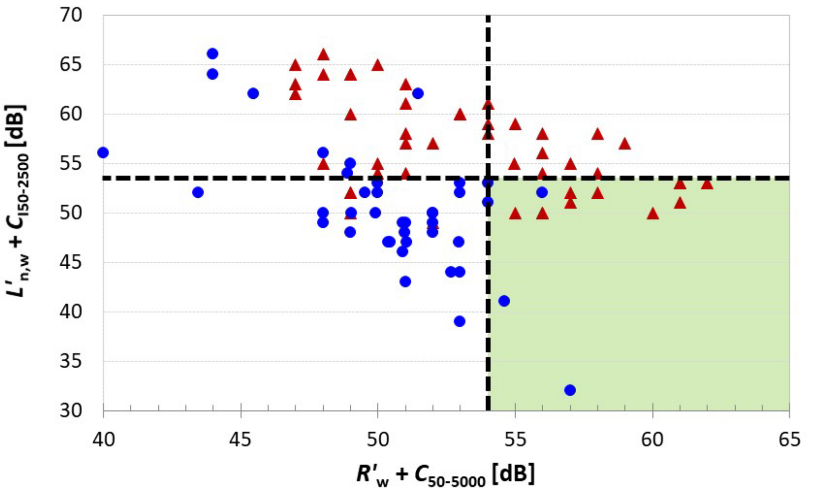

Figure 3: Selection of measured CLT constructions by Brekke & Strand Akustikk.

3.2 Walls

Figure 4 shows typical wall constructions used between dwellings. The 200 mm concrete wall shown in a) usually gives $R'_w + C_{50\text{-}5000}$ = 57-58 dB slabs, thus complying with the revised requirement given in Table 1.

The most commonly used light-weight wall is shown in b), and consists of 2x13 mm gypsum boards mounted on separate 70 mm steel studs insulated with mineral wool, giving a total cavity of 160 mm. With the revised requirement this solution is marginal at best and will frequently fail to comply with $R'_w + C_{50\text{-}5000} \geq 54$ dB. Improving the solution is likely done either by adding gypsum or layers of other types or increasing the cavity width of the wall. E.g. with 3x13 mm gypsum boards mounted onto each stud, $R'_w + C_{50\text{-}5000}$ = 57-59 dB could be expected, while intermediate solutions with two boards on one side and three on the other may also be sufficient, possible combined with slightly increased cavity width. Presumably a few *standard* wall types will emerge in this case, as these are a very common walls to build between dwellings. Recently the use of heavier gypsum and fibre cement boards have become increasingly common to use, so it is likely that an alternative or two using such boards will emerge as well.

Two wall types with CLT are shown in Figure 4c) and d), where the CLT is visible from both sides in c), and from one side only in d). The construction in c) gives an expected airborne sound insultation of $R'_w + C_{50\text{-}5000}$ = 51-53 dB, which is insufficient. Increasing the dimensions of the CLT elements and/or the cavity might be sufficient, but leads to extensively thick walls. The construction in d) on the other hand complies with the revised requirement as $R'_w + C_{50\text{-}5000}$ = 54-55 dB is typically achieved. However, more measurements are needed to confirm its adequacy fully.

Additionally, as mentioned above, flanking constructions and correct use of elastic layers is vital to obtain the above estimated airborne sound insulation. The experience with these walls is still not comprehensive, as the measurement results for horizontally separated constructions shown in blue circle in Figure 3 indicate.

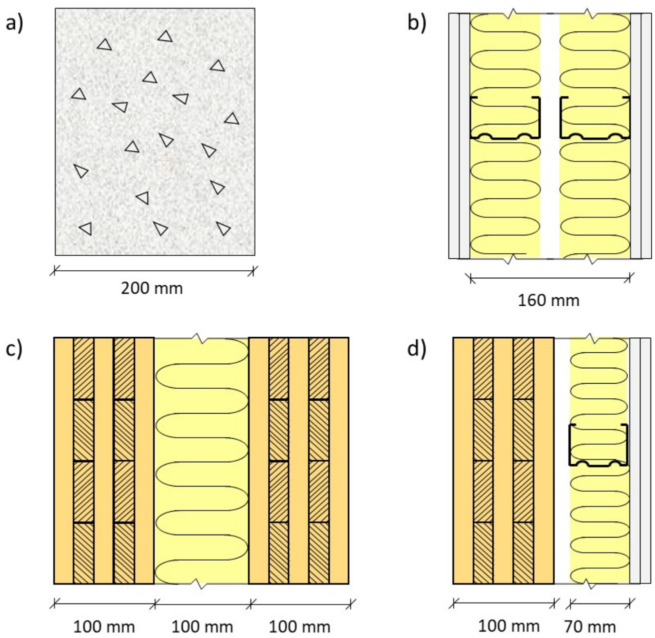

Figure 4: Typical wall constructions used between dwellings.

4 Summary

The consequences of revised requirements for sound insulation between dwellings vary with construction type. Concrete and hollow-core slabs will meet the requirements with thin directly mounted impact sound reducing layers. With thin floating layers and/or suspended ceilings care must be taken to avoid prominent resonances. Light-weight wooden floors require constructions with increased stiffness and/or mass to obtain improved low frequency sound insulation. Similarly, CLT constructions are likely to require floating floors and suspended ceilings that are heavier and with increasing building height.

Concrete walls can be built as before, while CLT walls and light-weight board-based walls require increased cavities and/or number of board layers.

A set of new standard constructions are expected to emerge, as increased experience with the new requirements are gained, securing better sound conditions, less annoyance and fewer complaints from residents.

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