Housing and construction types country by country - Denmark

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5
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CHAPTER 5 Denmark

5.1. Overview of housing stock in Denmark

The quantities of housing stock and total population

In Denmark there are approximately 2.7 million dwellings in total. Approximately 1 million of these are in multi-storey housing – having far the highest percentage of people being disturbed by neighbour noise. The number of dwellings in different housing types is shown in Figure 5.1. The total population in Denmark in 2013 is approx. 5.6 mill.

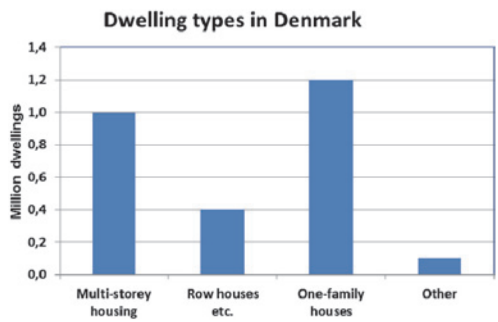


Figure 5.1. *Number of dwellings in Denmark 2012 according to dwelling type. Source: Statistics Denmark [2], rounded numbers.*

The most populated cities in Denmark

Table 5.1 shows the population in the four most populated cities in Denmark.

Table 5.1. *Danish cities with a population of 0.10 million or more. Source: Statistics Denmark [2], rounded numbers.*

City	Population
Urban Copenhagen/Copenhagen area	1.23 million
Aarhus	0.26 million
Odense	0.17 million
Aalborg	0.11 million

Proportion of apartments, terraced (row) and detached houses

The proportion of apartments, row houses and detached houses in Denmark are given in Table 5.2.

Table 5.2. *Existing housing stock in Denmark 2012 [2], rounded numbers.*

HOUSING STOCK (dwellings)	Number of dwellings	%
Total Housing	2700000	100
Flats / Maisonettes	1000000	38
Attached houses	400000	14
One-family Houses* (not attached) * Incl. farmhouses	1200000	44
Other	100000	4

Some examples of Danish housing are given in Figure 5.2.

Figure 5.2. *Examples of different existing housing in Denmark: Apartment houses from four periods, row houses and detached houses.*

The average floor area of Danish dwellings depending on building period can be found in Table 5.3.

Table 5.3. Number of dwellings and average dwelling size from 1981 to 2012. Table from Denmark in figures 2013 [3].

DWELLINGS

	Unit	1981	1990	2000	2010	2012
Dwellings, total	1 000	**2 180**	**2 372**	**2 519**	**2 749**	**2 749**
Of which:						
One-family houses	-	1 060	1 116	1 152	1 213	1 208
Multi-family buildings	-	902	923	967	1 055	1 062
Terraced houses	-	166	266	314	388	395
Student hostels	-	25	29	34	38	38
Occupied dwellings, total	1 000	**2 041**	**2 246**	**2 415**	**2 559**	**2 583**
0-49 m^2	per cent	7.6	6.8	6.6	5.7	5.8
50-99 m^2	-	43.8	44.5	44.7	43.4	43.2
100-149 m^2	-	33.1	32.5	31.2	30.7	30.5
Over 150 m^2	-	15.4	16.1	17.5	19.9	20.3
Average dwelling size	m^2	106.0	106.9	107.9	110.9	111.3
Average dwelling size per person	-	42.9	47.1	49.3	51.6	51.8
Persons per dwelling	average	2.5	2.3	2.2	2.1	2.1

www.statbank.dk/bol103 and bol201

Typical number of new homes built per year

Figure 5.3 shows the number of dwellings according to the year of construction – dwelling types being the same as in Figure 5.1.

As an example of a typical number, in total approx. 21000 new homes were built per year in Denmark in 2004-05.

5.2. Building regulations on sound insulation

Building Regulations

Building acoustic requirements are included in the Danish Building Regulations 2010 [4]. Acoustic requirements for dwellings are not found as figures in the Building Regulations. Instead, it is stated that the requirements are considered to be met, if the acoustic indoor climate in housing complies with sound class C in the Danish classification scheme DS 490:2007 [5], see Figure 5.4.

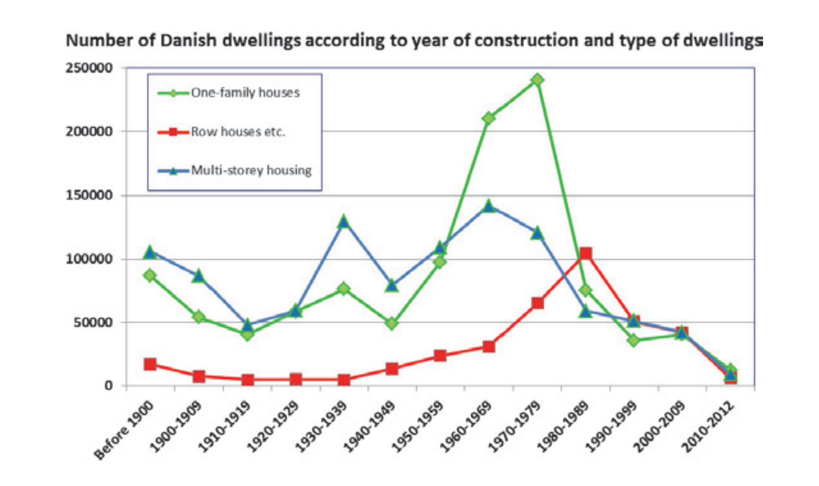


Figure 5.3. *Number of Danish dwellings according to year of construction and type of dwellings – 10 year periods from 1900-2009. Source: Statistics Denmark [2].*

Sound insulation between dwellings Main class criteria in DS 490:2007		
Class	Airborne	Impact
A	$R'_w + C_{50\text{-}3150} \geq 63$ dB	$L'_{n,w} \leq 43$ dB and $L'_{n,w} + C_{I,50\text{-}2500} \leq 43$ dB
B	$R'_w + C_{50\text{-}3150} \geq 58$ dB	$L'_{n,w} \leq 48$ dB and $L'_{n,w} + C_{I,50\text{-}2500} \leq 48$ dB
C	$R'_w \geq 55$ dB	$L'_{n,w} \leq 53$ dB
D	$R'_w \geq 50$ dB	$L'_{n,w} \leq 58$ dB
Reference: DS 490:2007, "Lydklassifikation af boliger" (Sound classification of dwellings).		

Characteristics of DS 490 sound classes for dwellings and occupants' expected evaluation Information compiled based on DS 490		
Sound class descriptions	Good or very good	Poor
Excellent acoustic conditions. Occupants will be disturbed only occasionally by sound or noise.	> 90 %	
Significant improvement compared to minimum in class C. Occupants may be disturbed sometimes.	70 to 85 %	< 10 %
Sound class intended as the minimum for new buildings.	50 to 65 %	< 20 %
Sound class intended for older buildings with less satisfactory acoustic conditions, e.g. for renovated dwellings.	30 to 45 %	25 to 40 %
Note: Within each sound class the percentage of satisfied or dissatisfied occupants may depend on the type of criterion. The grouping is mainly based on the subjective assessments of airborne and impact sound from adjacent dwellings.		

Figure 5.4. *Requirements according to the Danish Building Regulations 2010 are given as class C in the Danish classification scheme DS 490:2007 [5].*

Building acoustic requirements have been included in the Danish Building Regulations since 1956 [4],[6]. A summary of the main requirements for sound insulation between dwellings as found in the successive Danish Building Regulations since 1956 is shown in Figure 5.5 [8]. Since 1982, R'_w and $L'_{n,w}$ have been used as descriptors for sound insulation in the Danish

Building Regulations. Before 1982, various descriptors have been used in building regulations, but in Figure 5.5, the limit values have been converted to estimated values using the descriptors applied in the current regulations in Denmark.

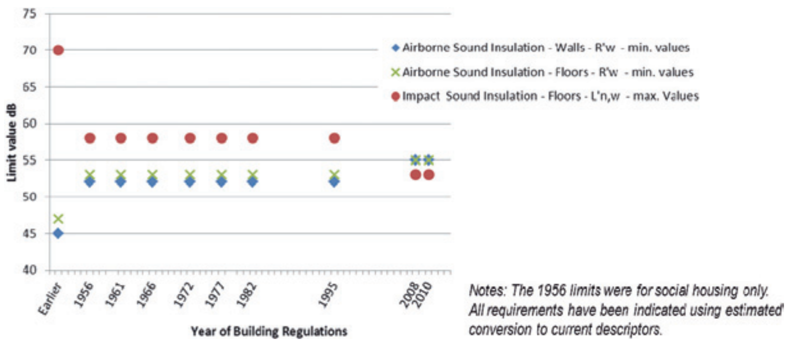


Figure 5.5. *Development in building acoustic requirements in the Danish Building Regulations. Refs: [4][6].*

As seen in Figure 5.5, the limit values for airborne and impact sound insulation in Denmark had been constant for more than 50 years, until an adjustment was made in the Building Regulations 2008. Before building acoustic requirements were introduced in Building Regulations, the quality of the Danish dwellings regarding sound insulation in general was lower. Figure 5.5 shows estimated values representing typical housing constructions from that period, i.e. thin brick walls and timber floor constructions [13],[14].

5.3. New build housing constructions

5.3.1. Terraced housing

Typical heavy constructions

Most new terraced houses have party walls made from concrete or light-weight concrete elements. Both solid walls and cavity walls are used as party walls in terraced housing. An example of a solid wall construction fulfilling the newest building requirements is shown in Figure 5.6 and an example of a heavy cavity wall in Figure 5.7 [7].

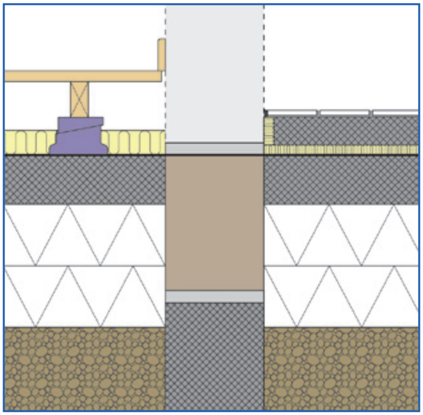


Figure 5.6. *Example of Danish heavy solid wall construction for new terraced housing fulfilling the Danish Building Regulations 2010. From [7], where more information about materials and dimensions can be found. The cross section shows party wall and foundations.*

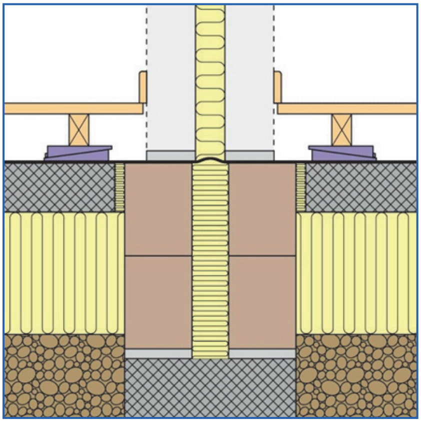


Figure 5.7. *Example of Danish heavy cavity wall construction for new terraced housing fulfilling the Danish Building Regulations 2010. From [7], where more information about materials and dimensions can be found. The cross section shows party wall and foundations.*

Typical errors in design and workmanship

Some examples of errors experienced with heavy cavity walls are illustrated in Figure 5.8.

For solid walls information about typical errors is found in Figure 5.10 and Figure 5.12.

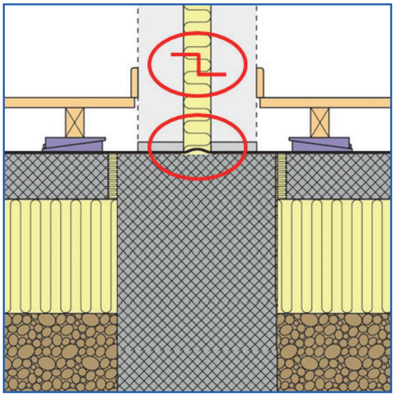


Figure 5.8. *Typical errors such as insufficiently separated double walls with wall ties bridging the cavity wall or both leaves of the cavity wall located on the same foundation, compare with Figure 5.7.*

5.3.2. Apartments/flats

Typical heavy constructions

Most new apartment houses are made from precast concrete elements. A recommended construction fulfilling the newest building requirements is shown in Figure 5.9.

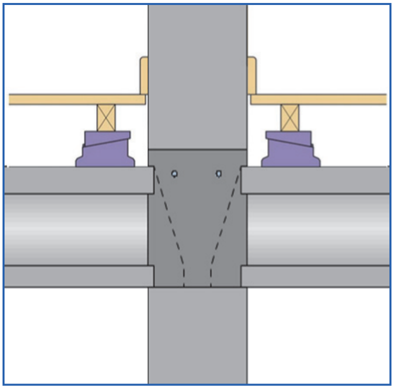


Figure 5.9. *Example of Danish heavy wall / heavy floor construction for new apartment houses fulfilling the Danish Building Regulations 2010 [4].*

It is recommended that the hollow core slabs have a surface mass of 440 kg/m^2 [7]. The joist floor consisting of a wooden floor finish on timber joist on polyethylene (PE) floor wedges has a total height of 170 mm. The wall is made from 200 mm full size wall concrete elements.

A typical heavy facade construction consists of full size wall concrete elements with e.g. 150 mm inner wall, mineral wool in the cavity and 70 mm outer wall.

Typical errors in design and workmanship

A typical design error may be to design the floors according to the former less strict requirements valid before 2008, see Figure 5.10. Although the requirements have been strengthened in 2008, the old way of building with 180-220 mm hollow core elements with surface mass 310-330 kg/m^2 is sometimes used. Depending on the flanking walls etc., this construction fails to meet the impact sound requirement, $L'_{n,w} \leq 53$ dB.

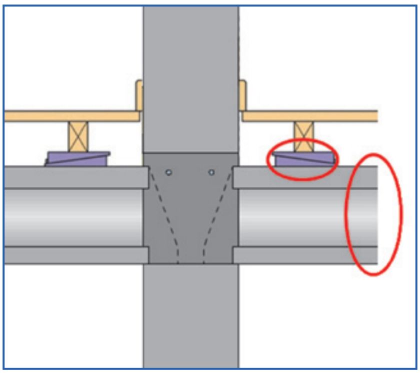


Figure 5.10. *An example of a typical design error in heavy built apartment houses (insufficient impact noise reduction in joist floor construction and insufficient surface mass of the hollow core elements).*

Workmanship errors related to heavy built apartment houses could be either leaks or unintended connections. These errors are illustrated in Figure 5.11 and Figure 5.12.

Typical light-weight constructions

Till now light-weight constructions in multi-storey houses have only been used on a limited scale. More often heavy floors are combined with light-

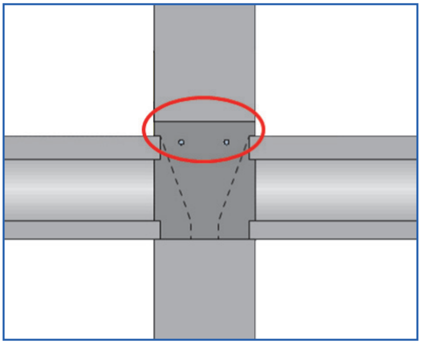


Figure 5.11. *Leaks at element joints (insufficient grouting) as an example of a typical error when using concrete elements.*

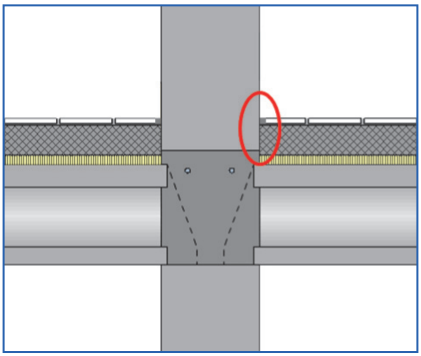


Figure 5.12. *Heavy floating floors with unintended connection to the wall is a typical workmanship error.*

weight party walls as described in Figure 5.13. Light-weight walls commonly consist of a double metal framework with plasterboard linings. The surface mass of the plasterboards on each side should be approx. 20 kg/m^2. The heavy floor shown is composed of 180 mm light-weight concrete slab (2000 kg/m^3). The wooden floor finish on joists on PE floor wedges must have an impact sound pressure level reduction of $\Delta L_w \geq 20$ dB [7].

Typical errors in design and workmanship

Insufficiently separated wall frames – either due to rigid connections limiting the sound insulation performance or due to a reduced wall cavity depth, which does not meet Danish low frequency requirements – can occur as a common design error in light-weight walls, see Figure 5.14.

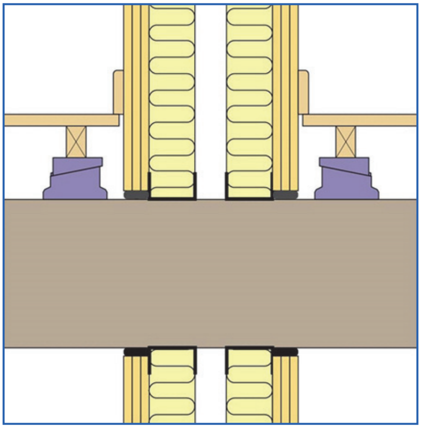


Figure 5.13. *Example with a heavy floor combined with a light-weight party wall, see detailed description in text. From [10].*

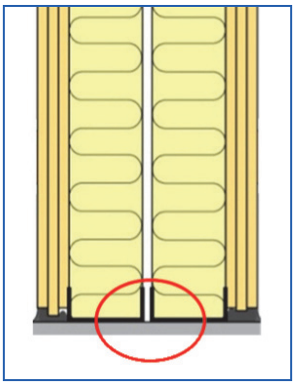


Figure 5.14. *Insufficiently separated wall frames (insufficient distance between linings or rigid connection through e.g. thin slabs) as an example of a typical design error.*

5.4. Existing housing

Typical constructions found in existing stock

Main building types in different time periods are shown in Figure 5.15 [8], [11], [12].

Below are presented an example of a building type built before 1950 (building type E1) and a building type built after 1960 (building type E3),

Building type E1

Old brick-built buildings with timber floors

Period: About 1850 to 1950

Number of dwellings in Denmark: Approx. 500.000 dwellings.

Building type E2

Brick-built buildings with in-situ concrete slabs

Period: About 1930 to 1960

Number of dwellings in Denmark:
Up to 100.000 dwellings.

Building type E3

Concrete element buildings

Period: From about 1960

Number of dwellings in Denmark: Approx. 400.000 dwellings.

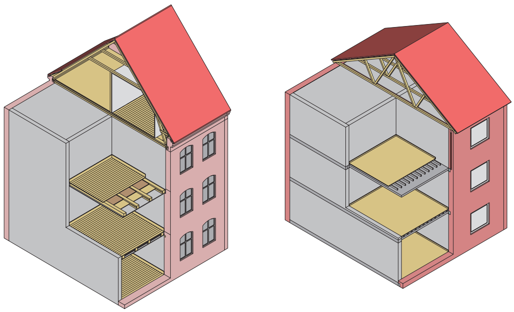


Figure 5.15. *Overview of the main building types and construction characteristics for multi-storey housing in Denmark. The building types are denoted E1-E3 as in a new Danish guideline [12].*

with the description of their most common separating walls and floors and their average sound insulation.

Buildings built before 1950 (type E1): Brick-built with timber floors

An example of a typical Danish apartment building built before 1950 is shown in Figure 5.16.

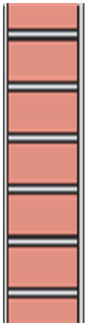
Period: 1890-1950

Brief description

Floor:	Timber floor construction
Party wall:	3/4 brick (168 mm) masonry wall with plaster (168 mm)
Inner wall:	½ brick or more / Light weight board partition with plaster
Regulations:	None

Figure 5.16. *Brief description of building type commonly used up to 1950. The photo shows a typical type of building from this period.*

Figure 5.17 and Figure 5.18 show the typical sound insulation performance between common Danish apartments built before 1950.



Wall description

Masonry wall

1. 10-15 mm plaster
2. ¾ (168 mm) solid brick
3. 10-15 mm plaster

Surface mass: approx. 290 kg/m^2

Sound insulation:

Measured/calculated

R'_w: 44-48 dB

Figure 5.17. *Wall performance in building type commonly used up to 1950.*

Floor description

Timber floor construction

7-8″ wooden beams and board floor

Pugging on pugging boards

Boards with plaster

Surface mass: -

Sound insulation

Measured

R'_w: 45-50 dB

$L'_{n,w}$: 63-70 dB

Figure 5.18. *Floor performance in building type commonly used up to 1950. Drawing from [9], [15].*

Methods of improving sound insulation

Two major projects [13] and [14] concerning improvements of the sound insulation between dwellings in the existing housing stock have been carried out in Denmark during the last years, and some examples and test results from field measurements of improved floor constructions in old housing with timber floors are shown in Figure 5.19.

The examples focus on impact sound insulation.

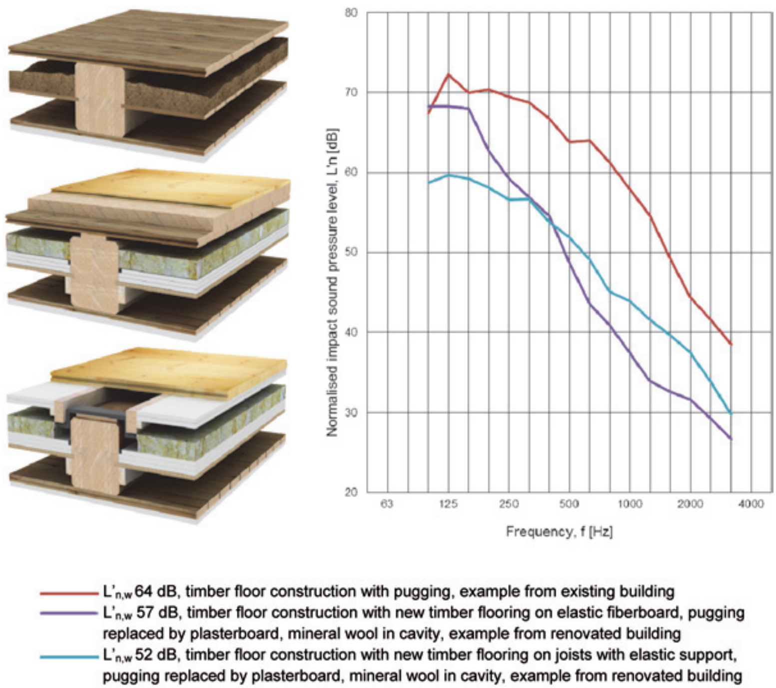


Figure 5.19. *Impact sound insulation, examples from measurements 2004-2005, [15], in old housing with timber floors. Two different solutions for improvements are shown. Drawings are from [9], [15].*

Buildings built after 1960 (type E3): Concrete element buildings with floor on timber joists

An example of a typical Danish apartment building built after 1960 is shown in Figure 5.20.

Figure 5.21 and Figure 5.22 show the typical sound insulation in a typical Danish apartment building built after 1960.

Methods of improving sound insulation

Examples and test results from field measurements [14] of improved heavy floor constructions are shown in *Figure 5.23*. The examples focus on impact sound insulation.

Period: 1970-2008

Brief description:

Floor: 180-220 mm hollow core concrete slabs with wooden floor on joists on PE wedges

Party wall: 150 mm precast concrete walls

Inner wall: Aerated concrete / Light weight plasterboard walls

Regulations: e.g. BR1982 and BR1995

Regulations Sound insulation	Airborne Horizontal ↔	Airborne Vertical ↕	Impact ↕
Descriptor	R'_w	R'_w	$L'_{n,w}$
Frequency range	100-3150	100-3150	100-3150
Value	52 dB	53 dB	58 dB

Figure 5.20. *Brief description of building type commonly used from about 1960. The photo shows a typical type of building from that period.*

150 mm

Wall description

150 mm precast concrete units

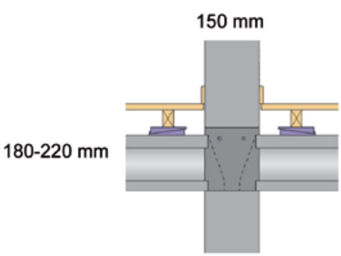
Surface mass: 350 kg/m²

Sound insulation

Measured/calculated

R'_w: 52-54 dB

Figure 5.21. *Wall performance in building type commonly used after 1960.*



Floor description:

180-220 mm hollow core concrete slabs with wooden floor on joists on PE wedges

Surface mass: 310-330 kg/m²

Sound insulation:

Measured/calculated

R'_w: approx. 53 dB

$L'_{n,w}$: approx. 58 dB

Figure 5.22. *Floor performance in building type commonly used after 1960.*

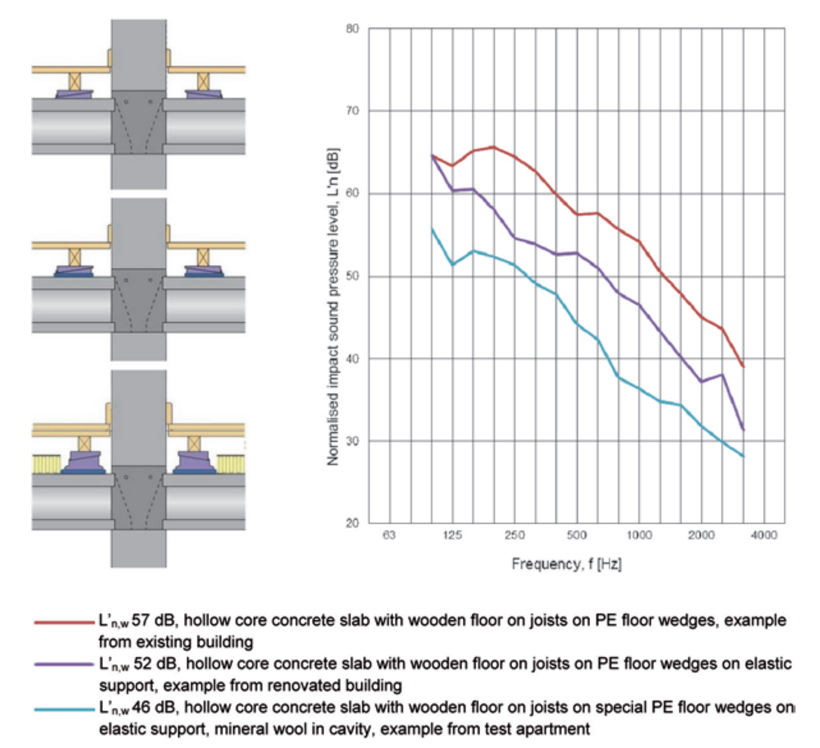


Figure 5.23. *Impact sound insulation, examples from in situ measurements performed in 2012 in existing housing with hollow core concrete slabs. Two different solutions are shown of improvements of wooden floor finishes, leading to the compliance with the new Danish requirements (max 53 dB), [14].*

5.5. References

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