Building acoustics throughout Europe
Volume 2: Housing and construction types country by country

5

Denmark

Authors:
Dan Hoffmeyer
Birgit Rasmussen

1 DELTA Acoustics, Hørsholm, Denmark
e-mail: dh@delta.dk

2 SBi, Danish Building Research Institute, Aalborg University (AAU-CPH), Copenhagen, Denmark
e-mail: bir@sbi.aau.dk
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.

![Dwelling types in Denmark](image)

*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.

<table>
<thead>
<tr>
<th>City</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Copenhagen/Copenhagen area</td>
<td>1.23 million</td>
</tr>
<tr>
<td>Aarhus</td>
<td>0.26 million</td>
</tr>
<tr>
<td>Odense</td>
<td>0.17 million</td>
</tr>
<tr>
<td>Aalborg</td>
<td>0.11 million</td>
</tr>
</tbody>
</table>
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.**

<table>
<thead>
<tr>
<th>HOUSING STOCK (dwellings)</th>
<th>Number of dwellings</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Housing</td>
<td>2 700 000</td>
<td>100</td>
</tr>
<tr>
<td>Flats / Maisonnettes</td>
<td>1 000 000</td>
<td>38</td>
</tr>
<tr>
<td>Attached houses</td>
<td>400 000</td>
<td>14</td>
</tr>
<tr>
<td>One-family Houses* (not attached) * Incl. farmhouses</td>
<td>1 200 000</td>
<td>44</td>
</tr>
<tr>
<td>Other</td>
<td>100 000</td>
<td>4</td>
</tr>
</tbody>
</table>

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].

<table>
<thead>
<tr>
<th>Dwellings, total</th>
<th>Unit 1981 (1 000)</th>
<th>1 990</th>
<th>2 000</th>
<th>2 010</th>
<th>2 012</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-family houses</td>
<td>1 060</td>
<td>1 116</td>
<td>1 152</td>
<td>1 213</td>
<td>1 208</td>
</tr>
<tr>
<td>Multi-family buildings</td>
<td>902</td>
<td>923</td>
<td>967</td>
<td>1 055</td>
<td>1 062</td>
</tr>
<tr>
<td>Terraced houses</td>
<td>166</td>
<td>266</td>
<td>314</td>
<td>388</td>
<td>395</td>
</tr>
<tr>
<td>Student hostels</td>
<td>25</td>
<td>29</td>
<td>34</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Occupied dwellings, total</td>
<td>2 041 per cent</td>
<td>2 246</td>
<td>2 415</td>
<td>2 559</td>
<td>2 583</td>
</tr>
<tr>
<td>0-49 m²</td>
<td>7.6</td>
<td>6.8</td>
<td>6.6</td>
<td>5.7</td>
<td>5.8</td>
</tr>
<tr>
<td>50-99 m²</td>
<td>43.8</td>
<td>44.5</td>
<td>44.7</td>
<td>43.4</td>
<td>43.2</td>
</tr>
<tr>
<td>100-149 m²</td>
<td>33.1</td>
<td>32.5</td>
<td>31.2</td>
<td>30.7</td>
<td>30.5</td>
</tr>
<tr>
<td>Over 150 m²</td>
<td>15.4</td>
<td>16.1</td>
<td>17.5</td>
<td>19.9</td>
<td>20.3</td>
</tr>
<tr>
<td>Average dwelling size</td>
<td>106.0 m²</td>
<td>106.9</td>
<td>107.9</td>
<td>110.9</td>
<td>111.3</td>
</tr>
<tr>
<td>Average dwelling size per person</td>
<td>42.9 m²</td>
<td>47.1</td>
<td>49.3</td>
<td>51.6</td>
<td>51.8</td>
</tr>
<tr>
<td>Persons per dwelling</td>
<td>average 2.3</td>
<td>2.3</td>
<td>2.2</td>
<td>2.1</td>
<td>2.1</td>
</tr>
</tbody>
</table>

**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.
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

**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].

**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 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].](image)

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 lightweight 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].
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](image)

**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](image)

**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/m² [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/m² 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-
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/m². The heavy floor shown is composed of 180 mm light-weight concrete slab (2000 kg/m³). 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.
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),
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.

**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].

**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.

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

![Wall description](image)

- **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/m²

- **Sound insulation**
  - Measured/calculated
  - $R'_{w}$: 44-48 dB

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

![Floor description](image)

- **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

**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.
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 |

<table>
<thead>
<tr>
<th>Regulations</th>
<th>Airborne Horizontal</th>
<th>Airborne Vertical</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptor</td>
<td>$R'_{w}$</td>
<td>$R'_{w}$</td>
<td>$L'_{n,w}$</td>
</tr>
<tr>
<td>Frequency range</td>
<td>100-3150</td>
<td>100-3150</td>
<td>100-3150</td>
</tr>
<tr>
<td>Value</td>
<td>52 dB</td>
<td>53 dB</td>
<td>58 dB</td>
</tr>
</tbody>
</table>

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

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

**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


