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Encouraging acoustic renovation of housing in Denmark by extending acoustic classification with two lower classes E and F for old housing

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ABSTRACT

In the five Nordic countries, first versions of acoustic classification schemes for dwellings were published in national standards in 1996-2004. The classification criteria were not identical, but originated in a joint Nordic INSTA-B proposal from the 1990s, thus having several similarities. Nevertheless, subsequent revisions of the standards led to increasing differences, e.g. sound insulation descriptors diversified. In Iceland, Norway, Sweden and Finland, the number of acoustic classes are still the same (A-D). However, in Denmark, a mapping of the multi-storey housing stock showed that less than half of the Danish dwellings could be classified within the DS 490 classes A-D. Consequently, the standard was revised in 2018 with two lower classes E-F for old housing built before the first national acoustic regulations in 1961. The goal is that acoustic labelling is feasible for all dwellings (like energy labelling) and thus acoustic quality could be visible to owners/tenants and initiate improvement of acoustic conditions, when renovating. The paper presents the main class criteria for sound insulation between dwellings in the Nordic countries and summarizes relations to national regulations. Construction examples for old housing in Denmark (DS 490 classes E-F) will be indicated as well as principles for upgrading to higher classes.

1. SOUND INSULATION PERFORMANCE OF MULTI-STOREY HOUSING IN DENMARK

The housing stock in Denmark consists of about 2.7 mio dwellings, of these almost 1.1 mio dwellings in multi-storey (MS) housing. In a sound insulation "mapping" project (completed 2015) for multi-storey housing [1], it was found – based on studies of previous publications and test reports combined with housing data from Statistics Denmark [2] – that that more than half of the Danish dwellings in multi-storey housing could not be classified according to DS 490:2007 [3] with acoustic classes A-D due to too low acoustic performance for old housing. Since DS 490 originated in a joint Nordic proposal [4], it is found relevant to study the current versions of building regulations [5]-[9] and acoustic classification schemes [10]-[14] for the Nordic countries and update overview ACS [10]-[23] for all European countries and the international proposal ISO/NP TS 19488 [24].

Acoustic regulations and acoustic classification criteria are typically about the following performance areas for the finished building: Airborne and impact sound insulation; Traffic noise, i.e. airborne sound insulation of facades; Service equipment noise; Reverberation time or sound absorption. This paper focuses on airborne and impact sound insulation between dwellings. Acoustic limits for sound insulation refer to field test methods in the ISO standards [25]-[26].

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This Section 1 deals with the Danish MS housing stock. In Section 2 is found information about acoustic regulations and classification schemes in the Nordic countries, and Section 3 provides a brief overview of classification schemes for dwellings in Europe. In Section 4 are found indications of principles for upgrading old housing to higher acoustic classes, and Section 5 includes summary and recommendations for initiatives.

National acoustic regulations have existed in Denmark since 1961, see Table 1. The diagram in Figure 1 shows number of Danish dwellings according to year of construction. The dotted line for year 1961 indicates the year of the first national building regulations. In 2008, see Table 1, the acoustic requirements for multi-storey housing were tightened, now referring to Class C in DS 490:2007 [3].

Table 1: Sound insulation main requirements in the Danish building regulations for walls/floors between dwellings in multi-storey housing constructed in the period from 1961 until now [5].

Period	Housing type	Airborne sound insulation	Impact sound insulation
1961-2008	Multi-storey	$R'_w \geq 52$ dB (horizontal) $R'_w \geq 53$ dB (vertical)	$L'_{n,w} \leq 58$ dB
Since 2008	Multi-storey	$R'_w \geq 55$ dB	$L'_{n,w} \leq 53$ dB

Note: Limit values until 1982 are estimated by converting to the descriptors, R'_w and $L'_{n,w}$ applied in the current Danish building regulations.

Note: Before 1961, there were no general national building regulations.

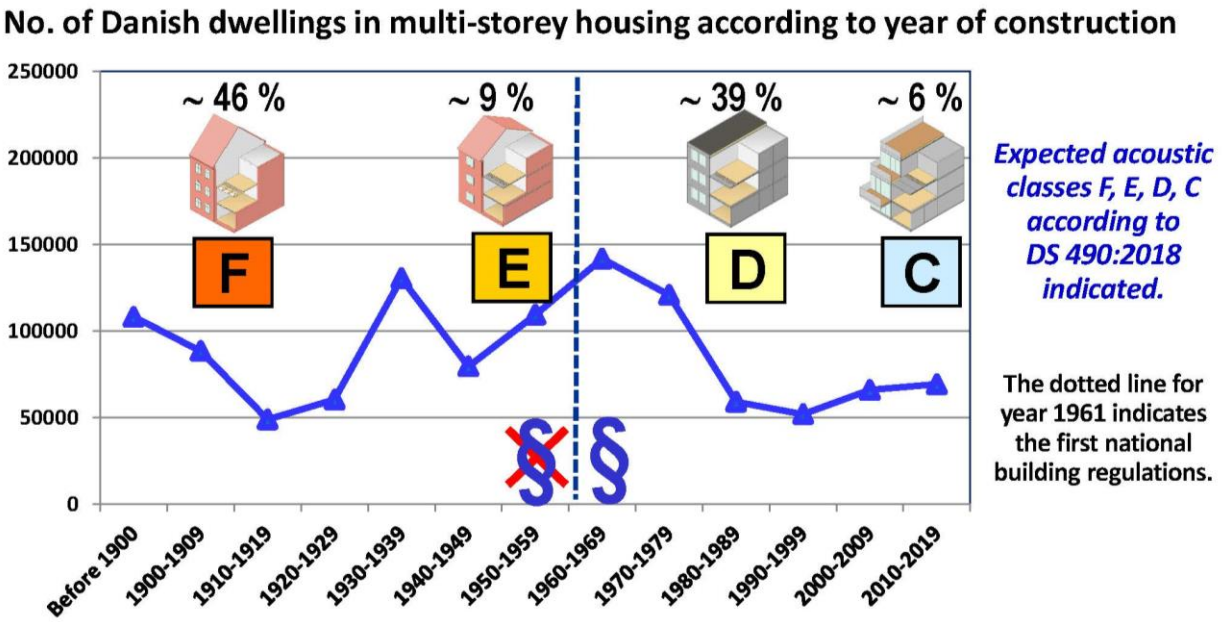


Figure 1: Dwellings in multi-storey housing in Denmark according to construction year. Number of dwellings for 2019 estimated. Sources: Statistics Denmark [2]; Acoustic performance [1].

Acoustic regulations were implemented in 1961, but more than half of the dwellings in multi-storey housing were built before that year and most of them have acoustic conditions far below the new limit values. The related construction types and sound insulation characteristics for multi-storey housing types E1, E2, E3 and NEW in Denmark are found in Table 2.

Since the acoustic classes in DS 490:2007 [3] did not include the building types E1 and E2 built before 1961, see Table 2, it was decided to revise DS 490 to include two lower classes E and F for such buildings. In the lower part of Table 2, the new classes E and F according to the revised standard DS 490:2018 [10] have been added.

Table 2: Overview multi-storey building types E1, E2, E3 and NEW in Denmark, construction types, time periods, number of dwellings, estimated sound insulation performance and acoustic class.

Building type E1	**Building type E2**	**Building type E3**	**Building type NEW**
Old brick-built buildings with timber floor constructions	Brick-built buildings with thin in-situ concrete slabs and wooden floors	Concrete elements with wooden floors	Concrete elements with wooden floors
Period: ~ 1850 to 1930/1950	Period: ~ 1930 to 1960	Period: ~ 1960 to 2009	Period: From ~ 2010
~ 500,000 dwellings	Up to 100,000 dwellings	~ 400,.000 dwellings	~ 65.000 dwellings (incl. 2019)
Regulations: None	Regulations: None	Regulations: BR1961-BR1995	Regulations: From BR2008
Estimated performance: R'_w ~ 42-50 dB $L'_{n,w}$ ~ 63-75 dB	Estimated performance: R'_w ~ 45-53 dB $L'_{n,w}$ ~ 58-67 dB	Estimated performance: $R'_w \geq$ 52-53 dB $L'_{n,w} \leq$ 58 dB	Estimated performance: $R'_w \geq$ 55 dB $L'_{n,w} \leq$ 53 dB
Acoustic classification DS 490:2007: None DS 490:2018: Class F	Acoustic classification DS 490:2007: None DS 490:2018: Class E	Acoustic classification DS 490:2007: Class D DS 490:2018: Class D	Acoustic classification DS 490:2007: Class C DS 490:2018: Class C

Qualitative descriptions of acoustic classes are useful for communication purposes and for making a qualified choice of class. Brief summarized information based on descriptions in DS 490 [10] is found in Table 3, including the new classes E and F.

Table 3: Occupants' expected satisfaction for different sound classes according to DS 490:2018 [10]. Summary based on information in DS 490.

Sound insulation between dwellings Main class criteria A-F in DS 490:2018		
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
E	$R'_w \geq 45$ dB	$L'_{n,w} \leq 63$ dB
F	$R'_w \geq 40$ dB	$L'_{n,w} \leq 68$ dB
Reference: DS 490:2018 "Lydklassifikation af boliger" (Sound classification of dwellings)		

Characteristics of DS 490 sound classes for dwellings and occupants' expected evaluation Information from DS 490:2018		
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.	**70-85 %**	**< 10 %**
Sound class intended as the minimum for new buildings.	**50-65 %**	**< 20 %**
Sound class intended for older buildings with less satisfactory acoustic conditions, e.g. for renovated dwellings.	**30-45 %**	**25-40 %**
Sound class intended for older buildings with unsatisfactory acoustic conditions.	**10-25 %**	**45-60 %**
Sound class intended for older buildings with clearly unsatisfactory acoustic conditions.	**< 5 %**	**65-80 %**
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.		

2. ACOUSTIC REGULATIONS AND CLASSIFICATION IN THE NORDIC COUNTRIES

The current building regulations (June 2020) for the five Nordic countries are found in [5]-[9] and the acoustic classification schemes in [10]-[14]. Tables 4 and 5 show the regulatory limit values for airborne and impact sound insulation between dwellings, and the main classification criteria are found in Tables 6 and 7. From Tables 4-5 with notes and compared to e.g. regulations in 2012, see [27], it is noticed that Finland and Sweden have changed descriptors, and Norway may change soon.

Unfortunately, there is no longer in general a close interaction or relation between the national acoustic regulations for housing and classification schemes. During some periods in the past, all five Nordic practised interaction. For example, in 2012 (cf. [27]) the national regulations in DK, IS, NO, SE referred to Class C in the national classification schemes, and Finland had the same limit values, although no official link. Now, in June 2020, it's only DK and IS with building regulations referring to Class C in current national acoustic classification schemes.

Table 4: Airborne sound insulation between dwellings. Main requirements in the Nordic countries June 2020.

Requirements [1] Status June 2020		Multi-storey housing	Comments
Country	**Descriptor [2]**	**Req. [dB]**	**See notes below table**
Denmark	R'_w	≥ 55	(3)
Finland	$D_{nT,w}$	≥ 55	
Iceland	R'_w	≥ 55	(4)
Norway	R'_w	≥ 55	(4),(5)
Sweden	$D_{nT,w} + C_{50\text{-}3150}$	≥ 52	

Notes
(1) Overview information only. Detailed requirements and conditions are found in the building codes.
(2) No generally applicable conversion between t. he different descriptors exists, as the relations depend on characteristics of rooms and constructions. Exact conversion can only be made in specific cases.
(3) For light-weight constructions (walls ≤ 100 kg/m² and floors ≤ 250 kg/m²) is recommended $R'_w + C_{50\text{-}3150} \geq 53$ dB.
(4) Use of $R'_w + C_{50\text{-}3150/5000}$ recommended. For further details, see regulations.
(5) Under revision. Update to Class C in NS 8175:2019 expected. Currently, reference in building regulations is still to NS 8175:2012.

Table 5: Impact sound insulation between dwellings. Main requirements in the Nordic countries June 2020.

Requirements [1] Status June 2020		Multi-storey housing	Comments
Country	**Descriptor [2]**	**Req. [dB]**	**See notes below table**
Denmark	$L'_{n,w}$	≤ 53	(3)
Finland	$L'_{nT,w} + C_{I,50\text{-}2500}$	≤ 53	
Iceland	$L'_{n,w}$	≤ 53	(4)
Norway	$L'_{n,w}$	≤ 53	(4),(5)
Sweden	$L'_{nT,w} + C_{I,50\text{-}2500}$	≤ 56	(6)

Notes
(1) Overview information only. Detailed requirements and conditions are found in the building codes.
(2) No generally applicable conversion between the different descriptors exists, as the relations depend on characteristics of rooms and constructions. Exact conversion can only be made in specific cases.
(3) For light-weight constructions (floors ≤ 250 kg/m²) is recommended $L'_{n,w} + C_{I,50\text{-}2500} \leq 53$ dB.
(4) Recommended that the same criteria are fulfilled by $L'_{n,w} + C_{I,50\text{-}2500}$.
(5) Under revision. Update to Class C in NS 8175:2019 expected. Currently, reference in building regulations is still to NS 8175:2012.
(6) The same criteria shall also be fulfilled by $L'_{n,w}$.

Table 6: Airborne sound insulation between dwellings. Main class criteria in the Nordic countries.

Airborne sound insulation between dwellings - Main class criteria in dB - Status June 2020							
Country		**Class A**	**Class B**	**Class C**	**Class D**	**Class E**	**Class F**
DK	[10]	$R'_w + C_{50\text{-}3150} \geq 63$	$R'_w + C_{50\text{-}3150} \geq 58$	$R'_w \geq 55$	$R'_w \geq 50$	$R'_w \geq 45$	$R'_w \geq 40$
FI	[11]	$R'_w + C_{50\text{-}3150} \geq 63$	$R'_w + C_{50\text{-}3150} \geq 58$	$R'_w \geq 55$	$R'_w \geq 49$	N/A	N/A
IS	[12]	$R'_w + C_{50\text{-}3150} \geq 63$	$R'_w + C_{50\text{-}3150} \geq 58$	$R'_w \geq 55$ [1]	$R'_w \geq 50$	N/A	N/A
NO	[13]	$R'_w + C_{50\text{-}5000} \geq 62$	$R'_w + C_{50\text{-}5000} \geq 58$	$R'_w + C_{50\text{-}5000} \geq 54$	$R'_w \geq 50$	N/A	N/A
SE	[14],[6]	$D_{nT,w} + C_{50\text{-}3150} \geq 60$	$D_{nT,w} + C_{50\text{-}3150} \geq 56$	$(D_{nT,w} + C_{50\text{-}3150} \geq 52)$ [2]	$D_{nT,w} \geq 48$	N/A	N/A

(1) Use of $C_{50\text{-}3150}$ is recommended also in Class C. If applied, the limit value may be reduced by 1-2 dB.
(2) SS 25267 (2015) does not include class C criteria, but refers to limit values in the building regulations as class C.

Table 7. Impact sound insulation between dwellings. Main class criteria in the Nordic countries.

Impact sound insulation between dwellings - Main class criteria in dB - Status June 2020							
Country		**Class A**	**Class B**	**Class C**	**Class D**	**Class E**	**Class F**
DK	[10]	$L'_{n,w} \leq 43$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 43$	$L'_{n,w} \leq 48$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 48$	$L'_{n,w} \leq 53$	$L'_{n,w} \leq 58$	$L'_{n,w} \leq 63$	$L'_{n,w} \leq 68$
FI	[11]	$L'_{n,w} \leq 43$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 43$	$L'_{n,w} \leq 49$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 49$	$L'_{n,w} \leq 53$ [1]	$L'_{n,w} \leq 63$	N/A	N/A
IS	[12]	$L'_{n,w} \leq 43$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 43$	$L'_{n,w} \leq 48$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 48$	$L'_{n,w} \leq 53$ [1]	$L'_{n,w} \leq 58$	N/A	N/A
NO	[13]	$L'_{n,w} \leq 46$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 46$	$L'_{n,w} \leq 50$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 50$	$L'_{n,w} \leq 54$ and $L'_{n,w} + C_{I,50\text{-}2500} \leq 54$	$L'_{n,w} \leq 56$	N/A	N/A
SE	[14],[6]	$L'_{nT,w} \leq 48$ and $L'_{nT,w} + C_{I,50\text{-}2500} \leq 48$	$L'_{nT,w} \leq 52$ and $L'_{nT,w} + C_{I,50\text{-}2500} \leq 52$	$(L'_{nT,w} \leq 56)$ [2] $(L'_{nT,w} + C_{I,50\text{-}2500} \leq 56)$ [2]	$L'_{nT,w} \leq 60$	N/A	N/A

(1) Use of $C_{I,50\text{-}2500}$ is recommended also in Class C.
(2) SS 25267 (2015) does not include class C criteria, but refers to limit values in the building regulations as class C.

The Nordic countries have had a long tradition for cooperation about acoustic regulations, and a joint Nordic draft proposal from INSTA-B [4] about acoustic classification of dwellings existed in the 1990s. However, lack of consensus and asynchronous revisions of building regulations in the Nordic countries, led to stop of coordination soon after, and differences between the Nordic countries have increased since then. The national schemes were finished and published at different times and since then revised in four of five countries, see Table 8 in Section 3. The INSTA-B proposal included dwellings only, but other types of premises, e.g. schools, kindergarten, offices, hotels, healthcare buildings have been implemented in FI, IS, NO, SE. Denmark is the only Nordic country with no other building categories than housing included. In [28] is found an overview table of acoustic classification schemes in Europe with indication of housing, schools, offices etc. in the national schemes.

3. OVERVIEW ACOUSTIC CLASSIFICATION SCHEMES FOR HOUSING IN EUROPE

Acoustic classification schemes (ACS) – defining a number of quality classes reflecting different levels of acoustic comfort and protection – exist in more than ten countries in Europe. The first ACS were published in the 1990s. Regulatory sound insulation requirements for dwellings exist in more than 30 countries in Europe, cf. [29]. For more detailed information about regulations and ACS, see [30]-[35]. In some countries, requirements have existed since the 1950s or even before, while in others, regulations came later or do not yet exist. The ACS are national, cf. [10]-[23], and – like regulations – very different due to lack of coordination between countries. An overview of existing national acoustic classification schemes in Europe for dwellings is found in Table 8. For each scheme listed, the class denotations, number of classes and relation to the national building code are indicated. The international proposal ISO/NP TS 19488 [24] is included for comparison, see also [32].

Table 8: European schemes for acoustic classification of dwellings, [10]-[23], relation to building regulations and class information. ISO/NP TS 19488 (2019), [24], included for comparison.

Acoustic classification of dwellings - Schemes in Europe and relation to building regulations – Status June 2020								
Coun-try	Year of publication	CS Reference (latest version)	Class denotations(1)	BR link to CS	BR ref. to CS & Comments	No. of classes	No. of classes > BR	No. of classes < BR
DK	**2001 / 2007 / 2018**	**DS 490 (2018)**	**A / B / C / D / E / F**	**+**	**Class C**	6	2	3
FI	**2004**	**SFS 5907 (2004)**	**A / B / C / D**	**–**	**N/A (BR ~ Class C)**	4	2	1
IS	**2003 / 2011 / 2016**	**IST 45 (2016)**	**A / B / C / D**	**+**	**Class C**	4	2	1
NO	**1997–2019 (5 versions)**	**NS 8175 (2019)**	**A / B / C / D**	**+(7)**	**Class C(7)**	4	2(7)	1
SE	**1996–2015 (4 versions)**	**SS 25267 (2015)**	**A / B / C / D**	**–**	**N/A (See note(4))**	4	2	1
LT	**2003**	**STR 2.01.07 (2003)**	**A / B / C / D / E**	**+**	**Class C**	5	2	2+npd
LV	**2011/2015**	**LBN 016-15 (2015)**	**A / B / C / D**	**+**	**Class C**	4	2	~ 0
IT	**2010**	**UNI 11367 (2010)**	**I / II / III / IV**	**–**	**N/A (BR ~ Class III**	4	2	1
DE	**1994 / 2007 / 2012**	**VDI 4100 (2012)(2)**	**III / II / I**	**–**	**N/A (BR ~ Class I(2))**	3	3	~ 0
DEGA	**2009 / 2018**	**DEGA Empfehlung 103 (2018)(3)**	**A*/ A / B / C / D / E / (F)**	**–**	**N/A (BR ~ Class D(3))**	6+npd	4	1+npd
AT	**2012**	**ÖNORM B 8115-5 (2012)**	**A / B / C / D / (E)**	**–**	**N/A (BR = Class C)**	4+npd	2	1+npd
NL	**1999**	**NEN 1070 (1999)**	**I / II / III / IV / V**	**–**	**N/A (BR ~ Class III)**	5	2	2
PL	**2017**	**PN-B-02151-5:2017**	**AQ-4 / AQ-3 / AQ-2 / AQ-1 / AQ-0**	**–**	**N/A (BR ~ Class AQ-0)**	5	4	0
TR	**2017**	**Noise Protection and sound insulation in Buildings(6)**	**A / B / C / D / E / F**	**+**	**Class C**	6	2	3
ISO/WI	**ISO/WI 19488**	**ISO/NP TS 19488 (2019)**	**A / B / C / D / E / F and npd**	**N/A**	**N/A (See note(5))**	6+npd	N/A	N/A

Abbreviations: BR = Building Regulations (regulatory requirements); CS = Classification scheme

(1) Classes are indicated in descending order, i.e. the best class first. Denotations in brackets correspond to npd.

(2) The revised version of VDI 4100 published in 2012 changed descriptors from R'_w and $L'_{n,w}$ to $D_{nT,w}$ and L'_{nT} (as had been discussed for years for the regulations), and class criteria were made stricter, i.e. above and regulations. After tightening of DIN 4109-1 in 2016, the basic criteria for the lowest class I for MS-housing are again similar to regulations, but VDI 4100 has additional criteria, e.g. on internal sound insulation.

(3) In addition to VDI 4100, the German Society of Acoustics (DEGA) has published a recommendation, DEGA-Empfehlung 103, "Schallschutz im Wohnungsbau – Schallschutzausweiz". For MS-housing, Class D criteria in general correspond to regulations, but there are additional criteria.

(4) SS 25267 (2015) does not include class C criteria, but refers to values in the BR as class C.

(5) Original proposal prepared by COST TU0901 in 2013. ISO/WI 19488 from 2014, ISO/NP TS in Jan. 2019.

(6) "Regulation on Protection of Buildings against Noise" www.resmigazete.gov.tr/eskiler/2017/05/20170531-7.htm (May 2017).

(7) The current building regulations (June 2020) still refers to NS 8175:2012, implying that the connection between BR and CS is momentarily not clear.

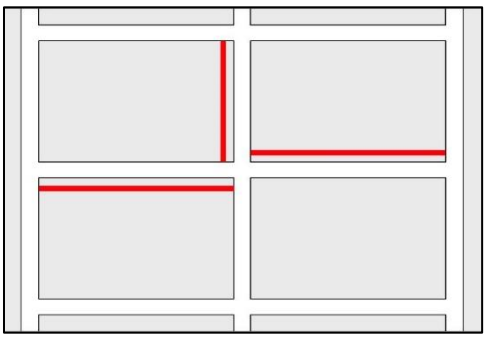
Table 8 also includes numbers of acoustic classes below and above the national regulations. For the Nordic countries, interaction with regulations is included in Section 3. For all countries in Table 8, interaction between ACS and building regulations is described and discussed in [29]. Since major parts of the European housing stock was built before acoustic regulations were implemented, it is obvious that acoustic classification could be relevant for existing housing before renovation by using classes suitable for existing housing. From Table 8 it is seen that four (FI, IS, NO, SE) of the Nordic countries and IT have one quality class below regulations, LT and the NL have two classes, AT and DE (DEGA 103) 1+npd. DK and TR have three classes below regulations, implying a much higher chance of classifying older housing. DE (VDI 4100) and PL have none, thus following the original idea of acoustic classes to be only/mainly for specifying better acoustic conditions than regulations. To sum up briefly, the existing acoustic classification schemes do in general not include acoustic classes fitting all major parts of the existing housing stock. An extension for old housing could pave the road for a future acoustic labelling in a similar way as for the mandatory energy labelling.

4. IMPROVEMENT OF SOUND INSULATION IN HOUSING

In Denmark, a Health and Morbidity Survey carried out in 2017 showed about 36 % of people in multi-storey housing slightly or very annoyed by neighbour noise, while for row/double housing only 12 %, see [36] and [37]. The disturbing/annoying neighbour noises include for example footsteps, voices/shouting/arguments, playing/jumping children, parties, barking dogs, see e.g. [36], [37], [38], and for many people, the implications are e.g. sleep disturbances and strong negative influence on own "freedom" and activities. The result is adverse influence on quality of life.

In many old dwellings, people experience an almost total lack of privacy, since they hear, what they don't want to hear, which reminds them that even one's own ordinary activities being a part of a normal life are no longer possible without involuntarily "informing" the neighbours.

The relevant sound insulation improvement solutions depend on the actual performance of the existing building, the wishes/goals for the future acoustic conditions and the resources available for the upgrading. For the Danish multi-storey housing stock, the highest need is for building types E1 (almost half of Danish dwellings) and E2, cf. Figure 1, Table 2 and [33] Figure 7. The main principles for improvement of sound insulation are indicated in Figure 2. Laboratory test methods are found in ISO 10140-1 [39]. Construction details are found in the Danish guideline [40].



Main advice and example for Danish multi-storey housing

- Solutions need to be designed for the actual building.
- Contact/involve acoustic consultant and housing owner/agency.

Building type E1, Class F: ~500,000 dwellings (46 %)
New independent ceiling; Wall linings; Sealing of leaks.

Building type E2, Class E: ~100,000 dwellings (9 %)
New ceiling; Improved floors; Wall linings; Sealing of leaks.

Building type E3, Class D: ~400,000 dwellings (39 %)
Improved floors; Sealing of leaks.

Note: In most cases one or maximum two classes up are technically/economically possible..

Figure 2: Main principles for improvement of sound insulation: New ceilings, wall linings, floors, see indications with red lines, as well as sealing of leaks in/between/around constructions and pipes.

5. SUMMARY AND RECOMMENDATIONS

Based on indications from the field, very low sound insulation between dwellings implies both annoyance, restraints on own activities, lack of privacy and not least sleep disturbances, many of them leading to reduced quality of life and health implications. Thus, it seems necessary to increase awareness on the importance of acoustic conditions in dwellings.

Recommendations

- For housing renovation projects, increase awareness of the need for upgrading sound insulation.
- Prepare *Good Practice Guides* with indications of solutions for improving sound insulation.
- Prepare a "mapping" of the national housing stock (especially multi-storey housing) with year of construction, number of dwellings and estimated acoustic performance, including acoustic classes, if available.
- Extend existing acoustic classification schemes to include old housing (if not already included).
- Revise regulations to include acoustic regulations or recommendations for renovated housing.
- Perform national, representative surveys about neighbour noise annoyance in housing with data analysis including also specific results for multi-storey housing, row housing and other housing.

Sound insulation is a hidden quality, which cannot be seen on drawing, and it's often too late to get the real-life information after moving in. Thus it is important for future tenants and owners to have this information available on beforehand, e.g. by an acoustic labelling made according to the same principle as for energy labelling. In Denmark, it is hoped that the new classes E and F can help creating awareness on sound insulation of old housing and promote attention in renovation projects.

6. ACKNOWLEDGEMENTS

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