



Aalborg Universitet

AALBORG UNIVERSITY
DENMARK

Could mandatory open access to sound insulation performance in housing promote "visibility" of acoustic quality?

Rasmussen, Birgit

Published in:
Proceedings InterNoise 2024

DOI (link to publication from Publisher):
[10.3397/IN_2024_4470](https://doi.org/10.3397/IN_2024_4470)

Publication date:
2024

Document Version
Accepted author manuscript, peer reviewed version

[Link to publication from Aalborg University](#)

Citation for published version (APA):
Rasmussen, B. (2024). Could mandatory open access to sound insulation performance in housing promote "visibility" of acoustic quality? In *Proceedings InterNoise 2024: International Congress and Exposition of Noise Control Engineering 2024* (pp. 10238-10245). Article 4470 Institute of Noise Control Engineering. https://doi.org/10.3397/IN_2024_4470

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.



Could mandatory open access to sound insulation performance in housing promote “visibility” of acoustic quality?

Birgit RASMUSSEN ¹

BUILD – Department of the Built Environment, Aalborg University
A.C. Meyers Vænge 15, 2450 Copenhagen SV, Denmark

ABSTRACT

Danish Health and Morbidity Surveys representing the population show that ~36% of people in multi-storey housing are annoyed by neighbour noise. National building regulations have existed since 1961 and included sound insulation limits, but complaints to housing organizations and builders appear for both old and new housing. A detailed analysis of national survey results shows that for occupants in multi-storey housing, a strong association exists between self-reported neighbour noise annoyance and various health issues. Building constructions have changed over time and consequently acoustic performance. The Danish standard DS 490 has six acoustic quality classes A-F representing housing built from before year 1900 until now, class C being minimum for new housing. Acoustic quality is invisible. However, the purpose of classification is enabling “visibility”, but such information is typically unavailable. With mandatory acoustic classification for new and renovated dwellings, negative “surprises”, when moving into new/renovated apartments could be foreseen. While prospective buyers and tenant organizations support acoustic labelling, strong resistance appears from e.g. real estate agents, and contractors. The paper presents advantages of acoustic quality transparency as well as resistance and also provides suggested steps towards implementation to the benefit of people moving to new places or understanding their current situation.

1. INTRODUCTION

Most countries in Europe – and several countries globally – have acoustic regulations for housing and other building categories. This paper focuses on housing and more specifically on airborne and impact sound insulation between apartments in multi-storey housing, where neighbour noise annoyance and complaints are more dominant than in other types of housing. Several countries in Europe also have national acoustic classification schemes (ACS). In Europe, limit values are included in building regulations in more than 30 countries, cf. [1]. More information about sound insulation descriptors and some updates for ACS are found in [2]. Descriptors and limits vary considerably between countries, which reduce the potential benefit of exchanging specific information about acoustic construction performance. However, a joint problem is that many people are annoyed by neighbour noise without knowing, if the roots of the problem are own expectations, the neighbours or the building. With open access to the acoustic performance of the building, communication and actions could be more efficient. The paper will present advantages of transparency of acoustic performance as well as resistance from some parties and some potential steps will be discussed towards implementation of such information to the benefit of people considering moving to a new place or understanding their current situation. To a wide extent examples from Denmark will be used, although a formal acoustic labelling process has not been established. Needed are e.g. regulations and constructions over time and related acoustic performance.

¹ bira@build.aau.dk

2. REASONS FOR INTRODUCING AN ACOUSTIC QUALITY LABEL FOR HOUSING

The acoustic quality of a dwelling is invisible, although it is an important quality in everyday life. If prospective buyers or tenants ask a builder, real estate agent or housing association about the acoustic performance, they would most often not get an answer. However, considering all resources in time and money to move to a new place, a dwelling is typically one of the largest investments in life for most people, and for that reason and due to the importance for everyday quality of life, such request is relevant

An interesting comparison could be to compare with buying other products or with studying other information available for dwellings. For example, for several household products, energy labelling is mandatory according to EU directives and the label also includes noise emission, cf. e.g. the directive [3] for washing machines. Consider buying an apartment – as an example with a price approx. 6000 EUR/m² – that could correspond to buying ~5 washing machines for the same price as *one* m² of the apartment. For a 60 m² apartment the price would match 300 washing machines! – and *each* washing machines would have an energy label with various information, including noise emission. For apartments (and other dwellings), there is another directive [4] stating that an energy label must be included in the advertisements for the dwellings, also if the apartments are just for rent, but no acoustic quality marking is included ☹

Thus, what could be done? It's definitely a huge task to implement an acoustic quality label for dwellings, but the same must have been the case for energy labelling of household products and dwellings! Thus, benefit from previous experiences could help. In the following some topics relevant to the process are being discussed.

3. ACOUSTIC REGULATIONS AND CLASSIFICATION SCHEMES

Acoustic regulations and acoustic classification criteria are typically about the following performances for the finished building: Airborne and impact sound insulation; traffic noise (airborne sound insulation of facades); service equipment noise; reverberation time or sound absorption. In Europe, limits typically refer to the ISO field test methods in [5],[6],[7],[8], [9], which are all implemented as EN standards and as national standards in CEN countries. In Table 1 is found the history of airborne and impact sound insulation limits, cf. [10]. The current Danish limit values for housing and other are found in [11] and some specific field test conditions in [12]. The limit values for housing are from the Danish classification standard for dwellings, DS 490 [13], Class C. Administration and enforcement of regulations is important, and [10] Ch.1 has a guideline [14] explaining documentation (completion notification) to be provided by the builder before receiving a permit for use.

Table 1: Sound insulation main requirements ⁽¹⁾ in the Danish building regulations for walls/floors between dwellings constructed in the period from 1961 until now [10].

Period	Housing type	Airborne sound insulation ⁽¹⁾	Impact sound insulation ⁽¹⁾
1961 ⁽²⁾ -2008	Multi-storey ⁽³⁾	$R'_w \geq 52$ dB (horizontal) $R'_w \geq 53$ dB (vertical)	$L'_{n,w} \leq 58$ dB
Since 2008	Multi-storey and row housing	$R'_w \geq 55$ dB	$L'_{n,w} \leq 53$ dB

Note 1: 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 2: Before 1961, there were no general national building regulations.

Note 3: For terraced housing (row housing), the limit values were:

$R'_w \geq 55$ dB from 1966 and $L'_{n,w} \leq 53$ dB from 1977.

The sound insulation limit values for all DS 490 classes A-F are found in Table 2, which also includes qualitative class descriptions that are useful for communication purposes and for making a qualified choice of class. Related to the topic of this paper, the classes and the descriptions could be considered applied for labelling purposes – similar to energy labelling.

Table 2: Occupants' expected satisfaction for different sound classes according to DS 490:2018 [13]. Summary based on information in DS 490.

Sound insulation between dwellings Main class criteria A-F in DS 490:2018			Characteristics of DS 490 sound classes for dwellings and occupants' expected evaluation Information from DS 490:2018		
Class	Airborne	Impact	Sound class descriptions	Good or very good	Poor
A	$R'_w + C_{50-3150} \geq 63$ dB	$L'_{n,w} \leq 43$ dB and $L'_{n,w} + C_{1,50-2500} \leq 43$ dB	Excellent acoustic conditions. Occupants will be disturbed only occasionally by sound or noise.	> 90 %	
B	$R'_w + C_{50-3150} \geq 58$ dB	$L'_{n,w} \leq 48$ dB and $L'_{n,w} + C_{1,50-2500} \leq 48$ dB	Significant improvement compared to minimum in class C. Occupants may be disturbed sometimes.	70-85 %	< 10 %
C	$R'_w \geq 55$ dB	$L'_{n,w} \leq 53$ dB	Sound class intended as the minimum for new buildings.	50-65 %	< 20 %
D	$R'_w \geq 50$ dB	$L'_{n,w} \leq 58$ dB	Sound class intended for older buildings with less satisfactory acoustic conditions, e.g. for renovated dwellings.	30-45 %	25-40 %
E	$R'_w \geq 45$ dB	$L'_{n,w} \leq 63$ dB	Sound class intended for older buildings with unsatisfactory acoustic conditions.	10-25 %	45-60 %
F	$R'_w \geq 40$ dB	$L'_{n,w} \leq 68$ dB	Sound class intended for older buildings with clearly unsatisfactory acoustic conditions.	< 5 %	65-80 %
Reference: DS 490:2018 "Lydklassifikation af boliger" (Sound classification of dwellings)			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.		

An overview of acoustic classification schemes in Europe is found in Table 3. Data are from 2022. Finland and Sweden and maybe others have changed their schemes since then. However, the point is to look at the columns in the right part of the table with the total number of classes and how many above and below the regulatory limits. These classes are potentially applicable for acoustic quality labelling of dwellings. Unfortunately, some acoustic classification schemes follow the original idea about having only classes for specification of better classes than the regulations, which is not enough for labelling in the real world with old housing or new housing with construction faults, where it could be convenient to explain what the actual label and how much improvement is needed.

Table 3: European schemes for acoustic classification (ACS) of dwellings, relation to building regulations (BR) and class information. ISO/TS 19488 (2021), included for comparison. Table from [2]. The notes and references [5-20] belonging to the table are found in [2].

Country	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) ⁽⁹⁾	A / B / C / D	+ ⁽⁹⁾	Class C ⁽⁹⁾	4	~2	~1
SE	1996-2015 (4 versions)	SS 25267 (2015)	A / B / C ⁽²⁾ / D	-	N/A (See note ⁽²⁾)	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) ⁽⁸⁾	III / II / I	-	N/A (BR - Class I ⁽²⁾)	3	3	~0
DEGA	2009 / 2018	DEGA Empfehlung 103 (2018) ⁽⁴⁾	A* / A / B / C / D / E / (F)	-	N/A (BR - Class D ⁽⁴⁾)	6+npd	4	1+npd
AT ⁽⁶⁾	2012 / 2021	ÖNORM B 8115-5 (2021)	A / B / C / D / (E)	-	N/A (BR - Class C ⁽⁶⁾)	5	~2	~2
ES	2021	UNE 74201 (2021)	A / B / C / D / E / (F) and npd	-	N/A (BR - Class D)	6+npd	3	2+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 ⁽⁷⁾	A / B / C / D / E / F	+	Class C	6	2	3
ISO/TS	2021	ISO/TS 19488 (2021) ⁽⁸⁾	A / B / C / D / E / F and npd	N/A	N/A	6+npd	N/A	N/A

In [15] (1994) is found information about acoustic conditions in housing in Denmark, including a brief summary of legislation over time and enforcement. Information from Austria (1994) about enforcement in different regions showed various strategies and policies. A recent survey in Spain [16] about compliance procedures in different regions also showed large variations.

4. HOUSING STOCK AND CONSTRUCTION YEAR

Knowledge about the national housing stock, constructions and acoustic performance is important when preparing acoustic quality labelling. In Figures 1 and 2 are found overviews of the Danish multi-storey housing stock with construction types in different time periods, number of dwellings and estimated acoustic performance. More information is found in [17]-[21].

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 No. of dwellings in Denmark: ~ 500.000	Period: ~ 1930 to 1960 No. of dwellings in Denmark: Up to ~ 100.000	Period: ~ 1960 to 2009 No. of dwellings in Denmark: ~ 400.000	Period: ~ 2010 to (2022) No. of dwellings in Denmark: ~ 115.000 (incl. 2022)
Regulations: None	Regulations: None	Regulations: BR1961-BR1995	Regulations: From BR2008
Estimated performance: $R'_w \sim 42-50$ dB $L'_{n,w} \sim 63-75$ dB	Estimated performance: $R'_w \sim 45-53$ dB $L'_{n,w} \sim 58-67$ 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

Figure 1: Overview multi-storey housing stock in Denmark, number of dwellings and construction types in various time periods. Building regulations, estimated acoustic performance and expected acoustic classes indicated. More information about constructions is found in [17]-[21].

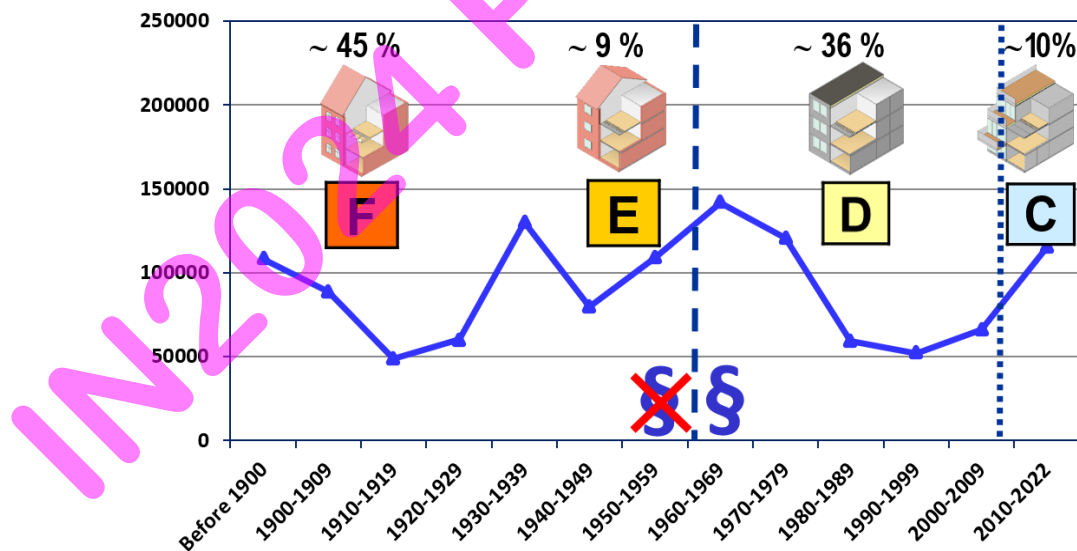


Figure 2: No. of Danish dwellings 1900-2022 in multi-storey housing according to construction year [22]. Estimated acoustic classes F, E, D, C according to DS 490:2018 are indicated.

Note: Time periods 10 years, except the first & last column. The dashed line indicates year 1961 with the first national building regulations. The dotted line indicates year 2008 with stricter sound insulation limit values.

In the COST TU0901 book 1 [23], general information is found about the housing stock in Europe, regulations, classification schemes, field monitoring, testing, common errors etc. Book 2 [24] provides information about individual countries (29 in Europe and 2 overseas) about regulations, housing stock, typical constructions and typical construction faults in design and workmanship.

5. DOES NEIGHBOUR NOISE INFLUENCE HEALTH?

While health implications of traffic noise have been recognized for decades and quite thoroughly investigated, neighbour noise has mainly been considered a “social” problem. Unfortunately, WHO and EAA also still on traffic noise and did seemingly not until now consider neighbour noise as a health problem. Nevertheless, sleep disturbances and other activity disturbances by neighbours may be unhealthier than those caused by traffic, since the information contents in neighbour noise is high, implying a high annoyance potential. Complaints typically point to specific noise sources like e.g. footsteps, playing children, music, parties and disturbed activity, e.g. severe sleeping problems, see Table 4. Danish Health and Morbidity Surveys performed for a representative part of the Danish population show that 36% of people living in multi-storey (MS) housing are disturbed/annoyed by neighbour noise. A detailed statistical analysis of the national survey results shows that for occupants in multi-storey housing, there is a strong association between self-reported neighbour noise annoyance and perceived stress, poor mental health, fatigue, sleeping problems and various physical health symptoms. For more information about the Danish studies, cf. [25], [26], [27], [28], [29]. For % annoyed in other types of housing than MS, see e.g. [27], also for traffic noise.

A German study [30] states that neighbour noise annoyance is the second most annoying noise source in Germany [31]. Recommendations for future studies mainly relate to social issues.

The only known noise policy that includes neighbour noise is “Policy Statement for England” (NPSE), [32]. In UK, there is a long tradition for doing research and surveys about neighbour noise and for registering noise complaints [33]. A coordinated approach for improving sound insulation in new housing is found in “Robust Details” [34] leading to ~98% compliance with limits and noise complaints reduced to 1/3 for new build attached housing, see [35] and [36].

In Figure 3 is illustrated the idea of quality classes and the implication for the residents’ protection and privacy in relation to neighbour noises. To be useful, it is important that that quality classes are relevant for the national housing stock.

Table 4: Examples of disturbing/annoying neighbour sounds and own activities being disturbed.

Annoying/disturbing neighbour noises	Own activities disturbed, e.g.:
<ul style="list-style-type: none"> ◆ Neighbours’ footsteps ◆ Children jumping/playing ◆ Voices/shouting/arguments ◆ Dogs ◆ Radio, TV, music ◆ Parties ◆ Neighbours’ DIY ◆ Doors banging ◆ Various “toilet sounds” ◆ Washing machines etc. 	<ul style="list-style-type: none"> ◆ Sleeping ◆ Using every room in the house ◆ Listening to TV, radio, music ◆ Quiet activities: Reading, resting ◆ Having a conversation ◆ Studying ◆ Activities that involve making noise (i.e. restrictions on own activities)

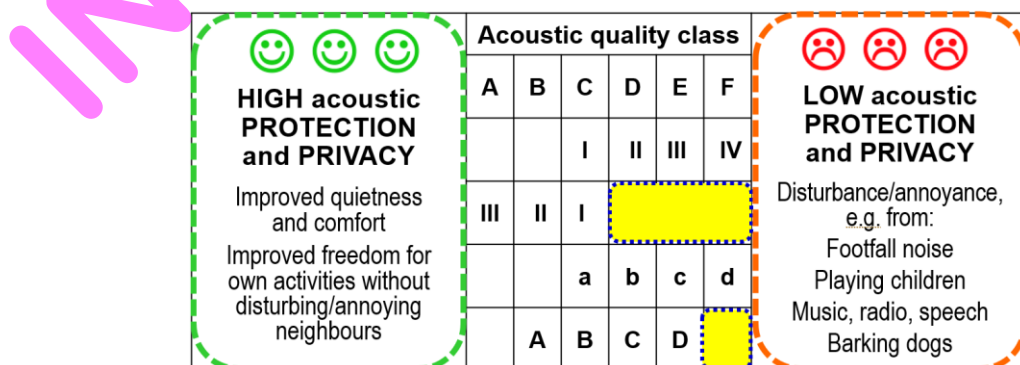


Figure 3: Illustration acoustic quality classes using various, partly FICTIVE ranges and denotations. Note: The yellow cells indicate that no acoustic class is available for old dwellings with low acoustic quality.

6. STEPS TOWARDS INTRODUCING ACOUSTIC QUALITY AS OPEN ACCESS

Considering facts about mandatory labelling of household equipment with energy and noise emission information according to the EU directive [3] (example for washing machines) and mandatory energy labelling for dwellings [4], it seems reasonable to expect that a similar label with acoustic quality included could be introduced for apartments. – To upgrade information level and awareness, examples of tasks to consider are found below:

- ◆ Overview history acoustic regulations.
- ◆ Housing stock - dwellings according to construction types and/or construction year.
- ◆ Housing stock - acoustic performance for dwellings in various time periods.
- ◆ If a national acoustic classification scheme exists, does it cover the housing stock?
- ◆ Verbal descriptions of classes in classification schemes.
– or alternatively for typical houses/constructions for various time periods.
- ◆ Include neighbour noise in national surveys for housing and split up into various housing types. (Multi-Storey; Row houses; One-family houses; Other)
- ◆ Procedures for verification of compliance with limits in acoustic regulations and classes.
- ◆ Qualification/approval of persons making field tests.
- ◆ Construction guidelines for new housing.
- ◆ Construction guidelines for sound insulation improvement of existing housing.

The points in the list are not ranked. Several countries already have information corresponding to some points and could jump to any other points, maybe by learning from other countries. Verbal descriptions of various sounds/noises and the perception in neighbour dwellings are found in [37], [38], [39] with the most extensive tables in DAGA103 [38] that has many classes and open access. - ISO/TS 19488 [40] was published in 2021, and for a working draft a similar verbal table was discussed, but declined by the WG, so only a simpler, more general table was included (Annex B Explanation of intent of classes). That table could be a starting point almost anywhere.

In France, related to discussion of a national grading system [41], the details of [40] were considered, but e.g. the procedure for assignment of class in ISO/TS 19488 was found too strict, since just one poor result determines the class. That procedure and some other issues will be discussed, when revising the ISO/TS. - Another point in the list is qualifications of people doing the field tests. In [16] about verification of compliance with Spanish regulations, it is mentioned that some communities have a registry of competent entities for doing such tests.

7. DISCUSSION – CONCLUSIONS – RECOMMENDATIONS

While energy labelling is mandatory for apartments as well as noise emission for many household products, many residents suffer from poor sound insulation in housing and don't have access to a label explaining the acoustic quality – likewise for prospective buyers and tenants. For comparison, it's interesting to notice *sound insulation* appearing among other room features at some hotel booking websites.

Some building contractors claim that sound insulation requirements are far too strict and want lower limits to reduce building costs and meet the climate targets. In [42] is described the adequacy of current regulations in Germany, and the current minimum limits are supported, although some viewpoints from e.g. architects suggest lower limits. The discussion/fight has increased significantly due to focus on wood. The building industry wants generic, simple, cost-effective construction solutions, but typically forget that product development with new materials is necessary.

Sometimes the noise sensitivity of people is discussed - not meant as an appreciation. But it might be fairer to discuss PREFERENCES – PROTECTION – PRIVACY?

The author of this paper recommends promoting “visibility” of acoustic quality for housing by implementation of a label indicating the performance. It is suggested starting with new-build and provide a simple short verbal statement and a one-page summary of documentation probably already made available to building authorities to obtain a permit for use.

ACKNOWLEDGEMENTS

The author is grateful to the acoustic colleagues, who in conferences and ISO working groups have participated in discussions about acoustic regulations and classification schemes.

REFERENCES

- [1] Rasmussen B. (2019) *Sound insulation between dwellings – Comparison of national requirements in Europe and interaction with acoustic classification schemes*. Proceedings of ICA 2019, 23rd International Congress on Acoustics, Sept. 2019, Aachen, Germany. Deutsche Gesellschaft für Akustik (DEGA e.V.). <https://doi.org/10.18154/RWTH-CONV-239983>.
- [2] Rasmussen, B. (2022). *Acoustic classification of dwellings – A growing diversity of sound insulation descriptors in national schemes in Europe*. In *ICA 2022 Proceedings of the 24th International Congress on Acoustics* (Paper 981, pp. 199-206).
- [3] European Commission. Household Washing Machines - Energy labelling and ecodesign requirements apply to this product. https://energy-efficient-products.ec.europa.eu/ecodesign-and-energy-label/product-list/household-washing-machines_en#energy-label. Note: Labelling includes noise emission.
- [4] Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L..2018.156.01.0075.01.ENG>
- [5] ISO 16283, Acoustics – Measurement of sound insulation in buildings and of building elements – Part 1: Field measurements of airborne sound insulation between rooms, 2014. – Part 2: Field measurements of airborne sound insulation of facade elements and facades, 2020. – Part 3: Field measurements of impact sound insulation of building elements, 2020.
- [6] ISO 717:2020, Acoustics – Rating of sound insulation in buildings and of buildings elements. – Part 1: Airborne sound insulation. – Part 2: Impact sound insulation.
- [7] ISO 10052:2021; Acoustics – Field Measurements of airborne and impact sound insulation and of service equipment sound – Survey method. ISO, Geneva, Switzerland. <https://www.iso.org/standard/76560.html>.
- [8] ISO 16032:2024. Acoustics – Measurement of sound pressure level from service equipment or activities in buildings – Engineering method. ISO, Geneva, Switzerland. <https://www.iso.org/standard/83874.html>.
- [9] ISO 3382-2:2008. Acoustics – Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms, 2008. ISO, Geneva, Switzerland. <https://www.iso.org/standard/36201.html>
- [10] Bygningsreglement 2018 (Building Regulations 2018). Danish Transport, Construction and Housing Authority, 2017. Copenhagen, Denmark. <https://bygningsreglementet.dk/> (the website includes links to all previous building regulations). Note: For administration of regulations, see Ch. 1 (§ 1 - § 47) and the guideline for documentation of technical provisions [14]. For acoustic conditions, see Ch. 17 (§ 368 - § 376), <https://bygningsreglementet.dk/Tekniske-bestemmelser/17/Krav>. Note: Acoustic limit values are found in [11].
- [11] Danish Authority of Social Services and Housing (2023). *Bygningsreglementets vejledning om lydforhold* (BR2018 guidance on acoustic conditions). <http://bygningsreglementet.dk/Tekniske-bestemmelser/17/Vejledninger>.
- [12] Rasmussen, B.; Hoffmeyer, D.; Olesen, H.S. (2017). *Udførelse af bygningsakustiske målinger* (Performing building acoustic field measurements). SBI-guideline No. 217, 2017 (2.ed.), Danish Building Research Institute, Aalborg University, Denmark.
- [13] DS 490:2018. *Lydklassifikation af boliger*. (Sound classification of dwellings). Danish Standards, Denmark.
- [14] Danish Authority of Social Services and Housing (2023). *Dokumentation af bygningsreglementets tekniske bestemmelser i forbindelse med færdigmelding af byggeriet* (Documentation of the building regulations' technical provisions in connection with the completion notification of the building). <https://bygningsreglementet.dk/Administrative-bestemmelser/BRV/Dokumentationsvejledning>
- [15] Rasmussen, B. & Rindel, J. H. (1994). *Lydforhold i boliger - 'State-of-the-art'* (Acoustic conditions in dwellings - 'State-of-the-art'). Bygge- og Boligstyrelsen, Ministry ofousing, Copenhagen, Denmark.
- [16] T. Carrascal, B. Casla-Herguedas, A. Romero-Fernández (2023). *Verification of Conformance with Spanish Regulations – Acoustic Sampling*. Proceedings of Forum Acusticum 2023, pp. 3709-3715. DOI: 10.61782/fa.2023.1159
- [17] Rasmussen, B. *Encouraging acoustic renovation of housing in Denmark by extending acoustic classification with two lower classes E and F for old housing*. In J. Yong Jeon (Ed.), *Proceedings of 2020 International Congress on Noise Control Engineering: INTER-NOISE 2020* The Korean Society of Noise and Vibration Engineering, Seoul, Korea. 2020.
- [18] Rasmussen, B. & Hoffmeyer, D. (2015). *Lydisolation mellem boliger i etagebyggeri – Kortlægning og forbedringsmuligheder* (Sound insulation between dwellings in multi-storey housing - Mapping and possibilities for improvements). Copenhagen, SBI Report No. 2015:27.
- [19] Rasmussen, B. & Petersen, C.M. (2014). *Lydisolering mellem boliger - eksisterende byggeri*. (Sound insulation between dwellings – existing housing). SBI guideline 243. Danish Building Research Institute, Aalborg University, Denmark.

- [20] Rasmussen, B. (2021). *Lydisolering mod nabostøj i etageboligbyggeri - GOD PRAKSIS* (Sound insulation against neighbour noise in multi-storey housing – GOOD PRACTICE). BUILD, Aalborg University, Denmark. <https://www.nabostoej.aau.dk>
- [21] Rasmussen, B., Petersen, C.M. & Hoffmeyer, D. (2011). *Lydisolering mellem boliger - nybyggeri* (Sound insulation between dwellings – new housing). SBI guideline 237. Danish Building Research Institute, Aalborg University, Denmark.
- [22] Statistics Denmark (2023). <http://www.statbank.dk/statbank5a/default.asp?w=1536>
- [23] Rasmussen B. and Machimbarrena M. (editors), *COST Action TU0901 – Building acoustics throughout Europe. Volume 1: Towards a common framework in building acoustics throughout Europe*. DiScript Preimpresion. 2014. <http://www.costtu0901.eu/tu0901-e-books.html>. Note: Ch. 1 Profiling Existing and New Build Housing Stock; Note: Ch. 9 Monitoring & Testing Sound Insulation Performance in New Homes in Europe; Note: Ch. 10 Common Errors and Good Practice in Design and Workmanship.
- [24] Rasmussen, B., Machimbarrena, M., & Fausti, P. (red.) (2014). *COST Action TU0901 – Building acoustics throughout Europe. Volume 2: Housing and construction types country by country*. DiScript Preimpresion, S. L. <http://www.costtu0901.eu/tu0901-e-books.html>
- [25] Rasmussen, B. & Ekholm, O. (2015). *Neighbour and traffic noise annoyance at home - prevalence and trends among Danish adults*. Proceedings of EuroNoise 2015, p. 1895-1900. Maastricht.
- [26] Jensen, H. AR., Rasmussen, B., & Ekholm, O. (2019). *Neighbour noise annoyance is associated with various mental and physical health symptoms: Results from a nationwide study among individuals living in multi-storey housing*. In: BMC Public Health. 19:1508. <https://doi.org/10.1186/s12889-019-7893-8>
- [27] Rasmussen, B., & Ekholm, O. (2019). *Is noise annoyance from neighbours in multi-storey housing associated with fatigue and sleeping problems?* In M. Ochmann, M. Vorländer, & J. Fels (Eds.), *Proceedings of the ICA 2019* (pp. 5071-5078). Deutsche Gesellschaft für Akustik (DEGA e.V.). <https://doi.org/10.18154/RWTH-CONV-239984>
- [28] Jensen HAR, Ekholm O, Davidsen M, Christensen AI. *The Danish Health and Morbidity Surveys: Study design and participant characteristics*. BMC Med Res Methodol. 2019; 19:91. <https://doi.org/10.1186/s12874-019-0733-9>
- [29] National Institute of Public Health, University of Southern Denmark. The Danish Health and Morbidity questionnaires [In Danish]. https://www.sdu.dk/da/sif/forskning/projekter/sundheds_og_sygelighedsundersoegelserne/sporgeskema
- [30] Benz, S.L.; Kuhlmann, J.; Schreckenber, D.; Wothge, J. (2021). Contributors to Neighbour Noise Annoyance. Int. J. Environ. Res. Public Health 2021, 18, 8098. <https://doi.org/10.3390/ijerph18158098>
- [31] Umweltbundesamt (UBA). <https://www.umweltbundesamt.de/themen/verkehr-laerm/nachbarschaftslaerm-laerm-von-anlagen/nachbarschaftslaerm>
- [32] DEFRA (2010). Noise Policy Statement for England (NPSE). <https://www.gov.uk/government/publications/noise-policy-statement-for-england>
- [33] Grimwood, C.J. *Complaints about Poor Sound Insulation between Dwellings in England and Wales*. Applied Acoustics, Vol. 52, No. 3/4, pp. 211-223, 1997.
- [34] Robust Details, <http://www.robustdetails.com/>.
- [35] S Smith, D Baker, R Mackenzie, J B Wood, P Dunbavin, D Panter, "The development of robust details for sound insulation in new build attached dwellings". J Build Appraisal 2006;2 (1):69-85.
- [36] NHBC (2014). Sound progress - A review of homeowner feedback on noise in new homes. NHBC Foundation. <https://www.nhbcfoundation.org/publication/sound-progress/>; <https://www.nhbcfoundation.org/wp-content/uploads/2016/05/NF56-Sound-progress.pdf>; <https://www.nhbc.co.uk/binaries/content/assets/nhbc/foundation/sound-progress.pdf>
- [37] VDI 4100:2012, *Schallschutz im Hochbau - Wohnungen - Beurteilung und Vorschläge für erhöhten Schallschutz* (Sound insulation between rooms in buildings - Dwellings - Assessment and proposals for enhanced sound insulation between rooms". VDI-Handbuch Lärminderung. Beuth, Germany.
- [38] DEGA-Empfehlung 103 (2018), *Schallschutz im Wohnungsbau – Schallschutzausweis*, DEGA, January 2018. https://www.dega-akustik.de/fileadmin/dega-akustik.de/publikationen/DEGA_Empfehlung_103.pdf
- [39] ÖNORM B 8115-5:2021, *Schallschutz und Raumakustik im Hochbau - Teil 5: Klassifizierung*. (Sound insulation and room acoustics in building construction – Part 5: Classification). ÖNORM, Austria.
- [40] ISO/TS 19488:2021. Acoustic Classification of Dwellings. ISO, Geneva, Switzerland. <https://www.iso.org/standard/77742.html>
- [41] N. Balanant and C. Guigou-Carter, *Grading system for dwellings acoustic performance implemented in French housing quality certification*, pp. 3717-3724.
- [42] Niemann, A.; Schanda, U. (2024) *Einfach Bauen und Schallschutz – ein Konflikt? – Untersuchung des Lärmempfindens von Bewohnern am Fallbeispiel der drei „Einfach Bauen“ – Forschungshäuser, Bad Aibling*. Bauphysik 46, H. 2, S. 84–94. <https://doi.org/10.1002/bapi.202400011>