Sound insulation between dwellings in multi-storey housing in Greenland - Need and feasibility of increased requirements?

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Published in:
Proceedings of the Joint Baltic-Nordic Acoustics Meeting 2014

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Sound insulation between dwellings in multi-storey housing in Greenland: Need and feasibility of increased requirements?

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Greenland is the world's largest island, area 2,2 million km^2, but has a population of less than 60.000 inhabitants. There are 22.000 dwellings, of these 9.500 in multi-storey housing. Due to many complaints about neighbour noise, the Government of Greenland initiated an investigation with two goals, one of them being check of fulfilment of the current regulatory sound insulation requirements, the other one being an evaluation of the possibilities to strengthen the requirements in the next building regulations. Sound insulation measurements between dwellings were made in three newly constructed housing estates, 4-8 storeys. Main constructions are in-situ cast concrete. Unexpectedly, the results showed fulfilment of requirements, in most cases with a high margin. It was concluded that strengthening of requirements could be made without big changes in building practice or enforcement. The reasons for complaints were not investigated, but one of the hypotheses is that due to very quiet surroundings, neighbours are heard better and thus perceived more disturbing than in typical European cities.

Due to reflections on how much requirements could be tightened and implications, calculations according to EN12354 are relevant. The paper presents measurement results and comparison with calculations for selected constructions. Furthermore, strengthening options will be discussed.

1 Introduction

Greenland belongs geographically to North America, but is a part of the Kingdom of Denmark and thus politically a part of Europe, although not a part of the EU. In 2009, self-government was established in Greenland. However, in most areas, legislation is the same or similar to Danish legislation, like e.g. building regulations. The present building code in Greenland is from 2006, in the following referred to as GBR2006 [1]. Acoustic requirements in GBR2006 were identical to the previous Danish requirements, and it is now considered to strengthen acoustic requirements in Greenland to the same level as in the present Danish Building Regulations, DBR2010 [2], or even stricter, as there have been many complaints about neighbour noise. As first steps, it was decided to check fulfilment of the current regulatory sound insulation requirements in three newly constructed housing estates, 4-8 storeys, and to evaluate the possibilities to strengthen the requirements in the next building regulations [3]. Table 1 present the most relevant criteria to consider.

Table 1: Main sound insulation criteria for dwellings according to GBR2006, DBR2010 and DS 490:2007, Class B.

Document	Ref.	Airborne	Impact	Comments
GBR2006	[1]	H: $R'_w \geq 52$ dB V: $R'_w \geq 53$ dB	$L'_{n,w} \leq 58$ dB	
DBR2010	[2]	$R'_w \geq 55$ dB $^{(1)}$	$L'_{n,w} \leq 53$ dB $^{(1)}$	The limit values indicated are the same as for DS 490 [4], Class C.
DS490, Class B	[4]	$R'_w + C_{50\text{-}3150} \geq 58$ dB	$L'_{n,w} \leq 48$ dB and $L'_{n,w} + C_{I,50\text{-}2500} \leq 48$ dB	
$^{(1)}$ Additional recommendations in case of separating lightweight constructions [5]: $R'_w + C_{50\text{-}3150} \geq 53$ dB and $L'_{n,w} + C_{I,50\text{-}2500} \leq 53$ dB				

2 Housing stock in Greenland

Greenland has a population of about 56.300. The population lives in towns and small settlements along the coast. About 30% (16.800) live in the capital, Nuuk. The area of Greenland is 2.166.086 km2 (the largest island in the world), and the ice-free area is 410.449 km2 (< 20% of total area), cf. [6]. The population density is 0,14 per km2 of ice-free area (Jan. 2014), i.e. less than 1/100 of Finland, the EU country with the lowest population density.

There are about 22.000 dwellings in Greenland distributed on housing types like indicated in Figure 1. In the past, only very few people lived in multi-storey housing. The traditional dwellings were single-family houses (made of wood). Now, most new dwellings are in multi-storey housing made of in-situ cast concrete.

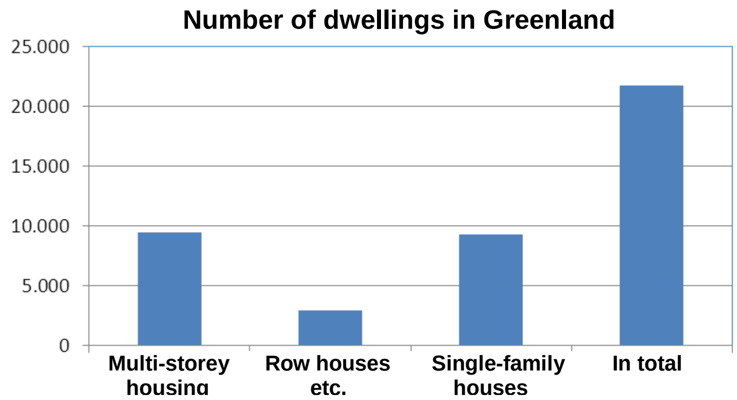

Figure 1: Number of dwellings in Greenland 2010 according to dwelling type.
Source: Statistics Greenland, see [3], rounded numbers

The majority of dwellings in Greenland are owned by the public. Due to many complaints about neighbour noise, there is a reporting system with forms to be filled in, see [3] or www.ini.gl. The quality of the existing housing stock is varying, including sound insulation. Sound insulation measurements in three newly constructed housing estates are described below and in more detail in [3].

3 Measurements in 3 housing estates in Nuuk

3.1 Description of housing estates

The main characteristics for three newly constructed housing estates are described in Table 2, and the number of sound insulation measurements are indicated in the table. In the following, results from Pingorsuaq are presented as examples, and Pingorsuaq has been described in more detail in Figures 2 and 3.

Table 2: Main characteristics for housing estates Tuapannguit, Pingorsuaq and Pisissia.

Main characteristics for housing estates Tuapannguit, Pingorsuaq and Pisissia and number of sound insulation measurements carried out					
Name of estate Year of completion	No. of blocks and storeys	Number of dwellings	Storey partition[(1)]	Walls[(1)] between dwellings	No. of measurements
Tuapannguit Completed 2011	7 blocks 8-storey	210	180 mm concrete Floor construction[(2)]	200 mm concrete See also note (3)	7 airborne 7 impact
Pingorsuaq Completed 2013	10 blocks 8-storey	300	180 mm concrete Floor construction[(2)]	200 mm concrete See also note (3)	8 airborne 10 impact
Pisissia Completed 2013	6 blocks 4-storey	84	220 mm concrete Floor construction[(2)]	150 mm concrete	6 airborne 9 impact

Notes
(1) All concrete constructions are cast in-situ.
(2) Floor constructions are in most cases wooden floors on joists on supports of PE wedges and fibre board and with mineral wool in the cavity, ($\Delta L_w \geq 18$ dB), or floating floors of in-situ cast concrete on mineral wool.
(3) At each storey, one separating wall was a light-weight single wall with gypsum fibreboards on steel studs.

Figure 2: Pingorsuaq. Vertical section A-A and photo from building site.

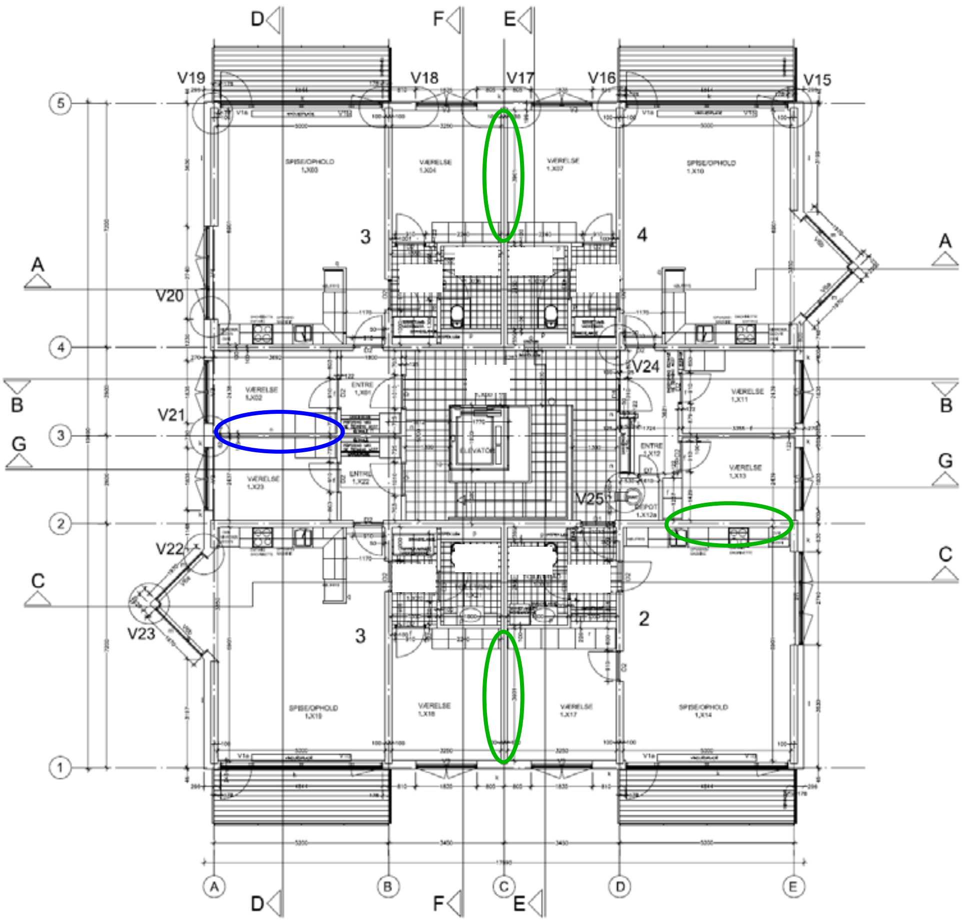

Figure 3: Pingorsuaq. Horizontal section with indication of room numbers. X = Storey number.
Light-weight wall indicated in blue; Concrete wall in green. All separating constructions described in Table 2.

3.2 Measurement methods & equipment

Sound insulation requirements in [1] and [2] are indicated with reference to ISO 717 [7] referring to measurements according to ISO 140 parts 4 and 7 [8]. Measurements were carried out according to ISO 140-4 and ISO 140-7, with the exception that the microphone was handheld, and that the person holding the microphone was present in the room during measurements, according to ISO/FDIS 16283-1 [9] and ISO/DIS 16283-2 [10]. It should be noted that the "corner" method for rooms smaller than 25 m^3 was not used.

Normally the uncertainty of measurements of R'_{w} / $L'_{\mathrm{n,w}}$ according to ISO 140-4 and ISO 140-7 is in the range of ± 1 dB, when a mechanized continuously moving microphone is used.

For measurements according to ISO 140-4 and ISO 140-7 with handhold microphone with one person present the uncertainty of R'_{w} / $L'_{\mathrm{n,w}}$ is estimated to about ± 2 dB.

For measurements including low frequencies, i.e. $R'_{\mathrm{w}} + C_{50\text{-}3150}$ / $L'_{\mathrm{n,w}} + C_{\mathrm{I},50\text{-}2500}$, the uncertainty for rooms larger than 25 m^3 is estimated to be about the same as for the normal frequency range. But for measurements including low frequencies in small rooms, less than 25 m^3, the uncertainty is estimated to be somewhat higher, when not using the corner method described in ISO/FDIS 16283-1 and ISO/DIS 16283-2.

3.3 Sound insulation results and comparison with building regulations

All measurement results are described in [3]. Representative examples of results are shown in Tables 3 and 4 for airborne and impact sound, respectively. Constructions are briefly described in Table 2. The rooms included in Tables 3 and 4 have wooden floors. In the tables are indicated locations of rooms (corresponding to Figure 3), measurement direction and measurement results. Furthermore are shown limit values from GBR2006 [1], DBR2010 [2] corresponding to DS 490 [4], Class C, and DS 490 [4], Class B, as well as compliance for the measurements. Finally, calculated values for a few selected situations have been shown in the end of the tables.

Table 3: Airborne sound insulation in Pingorsuaq. Overview representative results and indication of compliance with building regulations in Greenland and Denmark and with DS 490, Class B.

Airborne sound insulation				Measurement results		GBR 2006		DBR 2010 DS 490 Class C		DS 490 Class B		Calculated results EN 12354-1	
Measure-ment No.	Source room	Receiving room	Meas. Direction	R'_{w}	$R'_{\mathrm{w}} + C_{50\text{-}3150}$	Req. R'_{w}	Ful-filled	Req. R'_{w}	Ful-filled	Req. $R'_{\mathrm{w}} + C_{50\text{-}3150}$	Ful-filled	R'_{w}	$R'_{\mathrm{w}} + C_{50\text{-}3150}$
1 (Light wall)	Room 702	Room 723	→	54 dB	48	≥ 52 dB	Yes	≥ 55 dB See also (1)	No (-1 dB) See also (1)	≥ 58 dB	No (-10 dB)	57 dB	46 dB
2	Room 623	Room 723	↑	63 dB	59	≥ 53 dB	Yes	≥ 55 dB	Yes	≥ 58 dB	Yes		
4 (Heavy	Room 618	Room 617	→	59 dB	57	≥ 52 dB	Yes	≥ 55 dB	Yes	≥ 58 dB	No (-1 dB)	59 dB	58 dB
5 (Heavy	Kitchen/Living 614	Room 613	→	60 dB	59	≥ 52 dB	Yes	≥ 55 dB	Yes	≥ 58 dB	Yes		
6	Kitchen/Living 514	Kitchen/Living 614	↑	60 dB	57	≥ 53 dB	Yes	≥ 55 dB	Yes	≥ 58 dB	No (-1 dB)		

Note (1): The additional recommendation $R'_{\mathrm{w}} + C_{50\text{-}3150}$ ≥ 53 dB for light-weight walls is not fulfilled, as $R'_{\mathrm{w}} + C_{50\text{-}3150}$ = 48 dB and thus 5 dB below the recommendation.

Table 4: Impact sound insulation in Pingorsuaq. Overview representative results and indication of compliance with building regulations in Greenland and Denmark and with DS 490, Class B.

Impact sound insulation				Measurement results		GBR 2006		DBR 2010 DS 490 Class C		DS 490 Class B		Calculated results EN 12354-2	
Measure-ment No.	Source room	Receiving room	Meas. Direction	$L'_{\mathrm{n,w}}$	$L'_{\mathrm{n,w}} + C_{\mathrm{I},50\text{-}2500}$	**Req.** $L'_{\mathrm{n,w}}$	Ful-filled	**Req.**	Ful-filled	Req. $L'_{\mathrm{n,w}}$ and $L'_{\mathrm{n,w}} + C_{\mathrm{I},50\text{-}3150}$	Ful-filled	$L'_{\mathrm{n,w}}$	$L'_{\mathrm{n,w}} + C_{\mathrm{I},50\text{-}2500}$
9 (Light wall)	Room 702	Room 723	→	52 dB	57	≤ 58 dB	Yes	≤ 53 dB	Yes	≤ 48 dB	No (-9 dB)	49 dB	51 dB
10	Room 723	Room 623	↓	46 dB	52	≤ 58 dB	Yes	≤ 53 dB	Yes	≤ 48 dB	No (-4 dB)		
12 (Heavy	Room 618	Room 617	→	44 dB	48	≤ 58 dB	Yes	≤ 53 dB	Yes	≤ 48 dB	Yes	40 dB	41 dB
13 (Heavy	Kitchen/Living 614	Room 613	→	38 dB	42	≤ 58 dB	Yes	≤ 53 dB	Yes	≤ 48 dB	Yes		
16	Kitchen/Living 614	Kitchen/Living 514	↓	56 dB	57	≤ 58 dB	Yes	≤ 53 dB	No (- 3 dB)	≤ 48 dB	No (-9 dB)		

The R'_w and $L'_{n,w}$ results from Tables 3 and 4 are presented in Figure 4 with R'_w values to the left and $L'_{n,w}$ values to the right. Limits from GBR2006 [1] and DBR2010 [2] have been indicated as horizontal lines.

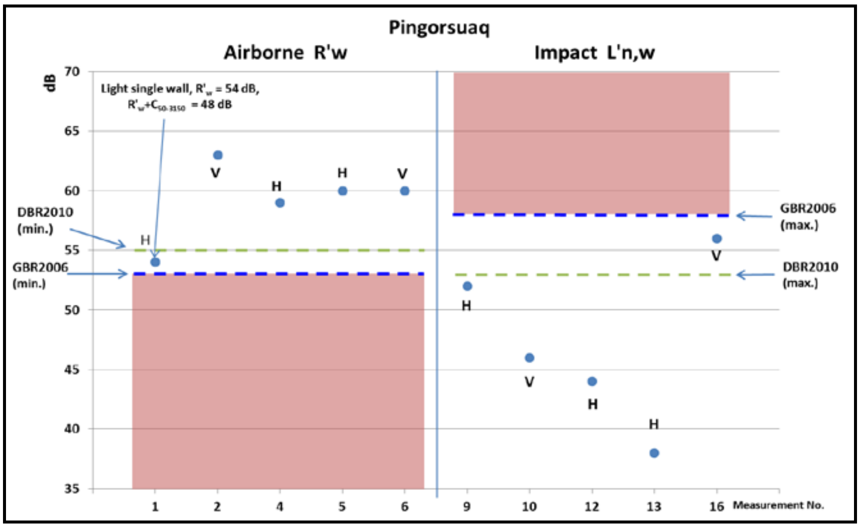

Figure 4: Airborne and impact sound insulation in Pingorsuaq. Graphical presentation of representative results, horizontal (H) and vertical (V), and indication of compliance with building regulations in Greenland and Denmark.

From Tables 3 and 4 and Figure 4 and all other results from Pingorsuaq reported in [3], it is seen that all results comply with GBR2006 [1] and only two measurement results (one airborne, Pin1, and one impact, Pin16) do not comply with the stricter limits in DBR2010 [2]. The situation is similar for the two other housing estates Tuapannguit and Pisissia, although for those estates, only one measurement for each did not fulfil the requirements in DBR2010.

Table 5: Comments on two measurements in Pingorsuaq not fulfilling DBR2010.

Measurement No.	GBR2006 [1]	DBR2010 [2] (DS 490, Class C [4])	Recommendation for light-weight [5]	Comments
Pin1 (airborne)	Fulfilled	1 dB missing	5 dB missing	A thicker lightweight wall with separate studs may suffice?
Pin16 (impact)	Fulfilled	3 dB missing	N/A	Large floor area reduces performance. Better floor supports sufficient?

Considering the intentions to tighten the sound insulation requirements in Greenland, e.g. to the same as in DBR2010 as a first step, it was found appropriate to make some airborne and impact sound insulation calculations according to the EN 12354 Parts 1 and 2 [11] for some of the situations not fulfilling or least robust to the potential new limits in DBR2010. Examples from Pingorsuaq are shown in Section 4.

4 Calculations using EN 12354 and comparison with measurements

In Figure 5 are shown measured and calculated airborne sound insulation between two rooms (702 and 723) separated by a light-weight single wall (125 mm, 2x12,5 mm gypsum fibre boards on steel studs, mineral wool in cavity, total weight approx. 62 kg/m^2) and two other rooms (618 and 617) separated by a heavy wall (200 mm concrete, 480 kg/m^2), see Table 2 and Figure 3. For the heavy wall, the calculated and measured sound insulation fit very well. For the light-weight wall, the differences are bigger, but still reasonable. When comparing the heavy wall with the light-weight wall, it is seen that main differences are below 200 Hz and above 2000 Hz, and the sound insulation of the heavy wall, especially for the low frequencies taking into account, when determining $R'_w + C_{50\text{-}3150}$, is (as expected) better. For further comments and improvement potential, see Table 5.

Fig. 6 shows the impact sound pressure level for the same two sets of rooms. Here, the calculated results are significantly better than the measured results in both cases, but it should be added that calculations of horizontal impact sound transmission has a high uncertainty, cf [12]. The situation with the heavy wall performs better, the main reason probably being that impact sound is transmitted between the two rooms with much higher attenuation through the junction between the concrete wall and slab than is the case with the light-weight wall.

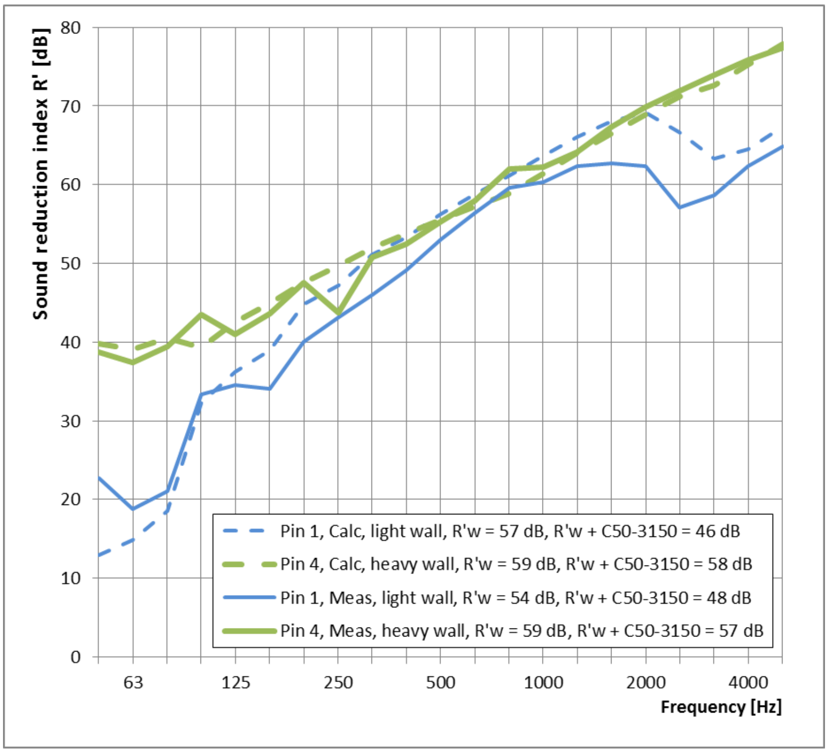

Figure 5: Measured and calculated airborne sound insulation *R*' between dwellings, horizontal. The floor constructions are wooden floors as described in Table 2. The blue curves represent a separating light-weight single wall with gypsum fibreboards on steel studs (total wall thickness 125 mm) and the green curves a concrete wall (200 mm).

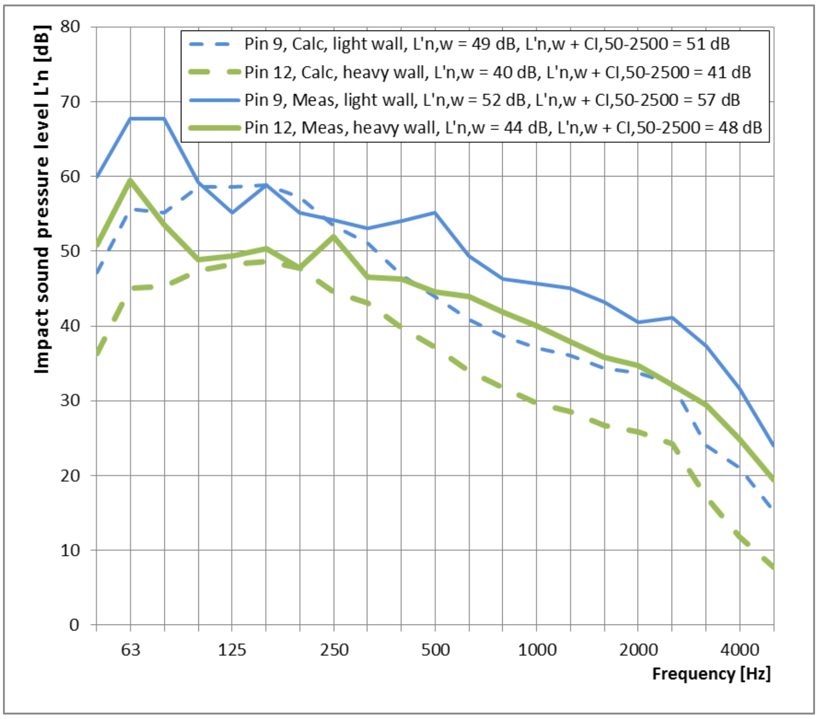

Figure 6: Measured and calculated impact sound pressure level L'_n between dwellings, horizontal. The floor constructions are wooden floors as described in Table 2. The blue curves represent a separating light-weight single wall with gypsum fibreboards on steel studs (total wall thickness 125 mm) and the green curves a concrete wall (200 mm).

5 Discussion and feasibility of increased requirements

On beforehand – due to several complaints about neighbour noise – it was expected that requirements in GBR2006 were not fulfilled. This fact also raises the question what could be the reasons for the extent of dissatisfaction, not only in older housing, but also in new housing like the building estates tested.

Although there will always be a certain proportion of occupants being unhappy with a given sound insulation, this is not considered to be the main cause. Other reasons for dissatisfaction could be:

- Change of housing type from single-family to multi-family housing means a new situation in terms of neighbour noise. People moving to multi-family housing may get disturbed more easily, as they are not used to hear neighbours.
- The character of the neighbour noises / sound sources and time of the day for noisy activities. Rhytm of day and night could also be challenged during those parts of the year, where it’s light or dark 24 hours/day or a high proportion of the day/night.
- Very quiet environment outdoors implies that neighbour noises are much more easily heard, because they are not masked by noise from the surroundings, e.g. by traffic noise. It is a common experience from European cities that when noise from the surroundings is reduced, the need for sound insulation between flats increases.

However, whatever the reasons are, there seems to be a clear need for increased sound insulation. Combined with a high chance of feasibility, there seems to be good reasons to increase requirements minimum – as a first step – to the level of those in the Danish Building Regulations [2] (DS 490 [4], Class C), which correspond also to the regulations in the other Nordic countries, see [13], and several other countries in Europe, see [14].

Considering the specific needs for improvement of construction solutions to comply with proposed new requirements, they seem quite uncomplicated to overcome. Light-weight wall constructions could be improved quite easily by using a slightly thicker similar wall with independent steel studs. Higher performing floor support systems could be chosen. Similarly, solutions for stairs and floating concrete floors might need a review and modifications.

Further improvement to e.g. DS 490 Class B in future, require more extensive changes.

6 Summary/Conclusions

In summary, it is concluded that the sound insulation requirements in the current building regulations GBR2006 in Greenland are fulfilled for the three new housing estates Tuapannguit, Pingorsuaq and Pisissia in Nuuk, in most cases with a good or even high margin. Of importance for such results is not only the construction types applied, but also good workmanship. Furthermore, it is found that the stricter requirements in the Danish regulations DBR2010 are fulfilled by more than 90 % of the measurements carried out, and that only minor changes of construction solutions are needed to comply fully with DBR2010.

Based on residents' need for better sound insulation and the findings described, it could be recommended for the planned revision of GBR2006 [1] to strengthen sound insulation requirements to DS 490 [4], class C corresponding to DBR2010 [2] and with the additional recommendation in [5] for light-weight constructions. Feasibility of further tightening of requirements to e.g. DS 490 [4], class B, seems low on a short-term basis, but could be possible in the future, after further design development.

It must be emphasized that findings are valid for the heavy construction types and design applied, and cannot be transferred to light-weight housing, which have not been investigated. It is recommended to investigate such housing types, as there is high risk that the sound insulation performance does not comply with neither the present GBR2006 nor the recommended stricter requirements.

Acknowledgements

The authors want to thank the Government of Greenland, Ministry of Housing, for permission to publish measurement results and findings from the study of the three housing estates in Nuuk. Furthermore, thanks are also given to Dan Hoffmeyer, DELTA Acoustics, for valuable discussions on constructions and measurement results.

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Websites *Note: In Greenlandic and Danish only*

www.byginfo.gl: Byginfo contains relevant information on construction in Greenland. You can find laws, regulations, notices, reports and other information of relevance for construction. The site is for anyone, who has an interest in construction in Greenland. Byginfo is managed and operated by the Government of Greenland, Ministry of Housing, Building Authority.

www.ini.gl: Website for the Housing Association INI. Here, among other things, you can find actual occupant information in Iserumina, which is also published in local newspapers, approx. monthly. All previous editions of Iserumina are found at: www.ini.gl/default.aspx?func=article.view&id=694370&lang=DK.
A form for complaints about neighbours is found at: www.ini.gl/default.aspx?func=article.view&menuid=695267&id=687659&lang=