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Consequences of new building regulations for modern apartment buildings in Sweden

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ABSTRACT

New evaluation rules have been introduced to the Swedish sound classification standard for dwellings. The sound reduction index *R*' is now calculated with the ratio, *V/S* (receiving room volume divided by the partition size) always being equal to or less than *3,1* m. This implies that *R*' always becomes greater than or equal to the standardized sound pressure level difference, D'_{nT}. For impact sound, the receiving room volume is restricted to *31* m^3, which implies that the most favorable value of L'_{nw} and L'_{nTw} is applied. These rules may have significant effect when the receiving room volume is large. Furthermore, measurement results within the same dwelling shall now comply with the required value on the average, and the most unfavorable deviation from this requirement must not exceed 2 dB. Previously, every single room had to comply with the requirement. The effect of these rules has been studied, on basis of statistical material for apartment houses as well as measurements in seven new buildings. The results show that is the new rules make it considerably easier to comply with the requirements, the difference is in the order of 2 dB for airborne sound insulation and 2-4 dB for impact sound.

1 INTRODUCTION

In this study, the effects of several new acoustic requirements on sound insulation have been studied, as applied to multi storey apartment houses in Sweden. There have been several reasons to make some changes. For instance, with the previous requirement on footfall noise, expressed as the highest normalized impact sound pressure level ($L'_{n,w}$), constructions face on to large rooms had to be upgraded, as compared to small and medium sized rooms, in spite of the fact that the actual impact sound was the same. This is due to the normalization to 10 m^2 sound absorption area. Now, the requirement is made equivalent to the standardized impact sound pressure level ($L'_{nT,w}$), i.e. the impact sound level is normalized to a more realistic sound absorption area of the actual room, taking the size of the room into account. A similar effect of the previous requirements caused a need to upgrade the airborne sound reduction index (R'_w) of small separating walls face on to large receiving room volumes. Now, the requirements state a requirement equivalent to the standardized sound pressure level ($D'_{nT,w}$), which takes the size of the room into account. These changes are intended to make the requirements correspond to the experienced sound insulation. The intended effect of the changes is also to facilitate to planners and contractors to actually fulfil the requirements with normal building techniques, which is not always the case with regard to the previous regulations. Verification with measurements *in situ* is still based on existing European and international standards EN ISO 140 [1]. Single numbers are calculated according to EN ISO 717 [2].

To make the changes less confusing to the building industry and other interested parties, the requirements still state the maximum $L'_{n,w}$ and minimum R'_w, with spectrum adaption terms (C_{50-}

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$_{3150}$, $C_{I,50\text{-}2500}$), but they also state new "limitation rules". For R'_w, the ratio of the receiving room volume V to the area of the separating partition S is limited to 3,1. For $L'_{n,w}$, the volume V is limited to 31 m^3. Following the expressions in ISO 140, the requirement will then always be the most favourable of (R'_w; $D'_{nT,w}$) and ($L'_{n,w}$; $L'_{nT,w}$) respectively. In rooms greater than a medium sized bedroom, the limitation rules apply in most cases. Retaining the old figures will hopefully facilitate the acceptance of new rules, not least since an adjustment to unknown quantities in the building industry commercial material is not required.

The acoustic regulations are stated in the Swedish sound classification standard SS 25267. The changed requirements are described in the third edition of SS 25267 issued 2004 [3], hereafter referred to as "edition 3". The previous requirements were stated in edition 2, issued 1998, hereafter referred to as "edition 2" [4].

Another important change of the requirement was made to the verification principles. Now, verification may be also made during construction, using calculations according to the standards EN 12354 (ISO 15712). As prerequisites, appropriate quality control and safety margins with respect to known uncertainties must be applied.

The main differences between edition 3 and edition 2 are:

- When airborne and impact sound insulation are evaluated, the ratio V/S is limited to 3,1 m and the receiving room volume, V, is limited to 31 m^3 respectively. This implies that R' always becomes greater than or equal to the standardized sound pressure level difference, D'_{nT}, and that the most favorable value of L'_{nw} and L_{nTw} is always applied.
- When the final results are verified with measurements, the requirement level will be compared to the average value taken within the dwelling being examined. However, the unfavorable deviation from any single measurement may not exceed 2,0 dB. In the former regulation every single measurement has to be fulfilled.
- The acoustic performance may be verified by calculations, which will support a more industrialized building technique, force the manufacturers to document their products appropriately and stress the importance of the early design work. The calculations will be made according to EN 12354 [5]. Averaging and unfavorable deviations are not accepted.
- The requirement levels have been changed to balance the changes to the evaluation rules
    - to 56 dB for impact sound and 53 dB for airborne sound in edition 3, from 58 dB and 52 dB in the edition 2
- During construction, margins to the requirements must be chosen with respect to known uncertainties. Margins will differ depending on the type of building structure.

In the work, some generalized statistical building data have been analyzed with respect to the effect of the changes, as well as data for seven "real world" new housing units. This work is commissioned by the committee "Forum for building costs" within the Swedish building authority *Boverket* (National board of Housing Building and Planning).

2 INITIAL STUDY – STATISTICS OF APARTMENT HOUSES

2.1 Effect of limitation rules, based on public statistics of new apartments

Statistical figures of new apartment houses built during 5 years have been collected by two Swedish authorities, *Boverket* and *SCB* (Bureau of statistics). The data comprised the number of apartments built, the number of rooms, and their overall size. Unfortunately, there are no data on sizes of rooms, nor walls or slabs. To enable calculation of the effect of the limitation rules, some schematic figures of room and wall sizes were estimated. The effect of higher structural losses at the borders of small rooms was included by an empirical correction of 1.5 dB, as compared to

the largest room. The sound insulation of the building was chosen with respect to the requirement of edition 2, where a margin of 3 dB was recommended with respect to the largest room and the measurement direction. When the same type of apartment was designed according to the new requirement of edition 3, a safety margin of 1 dB was applied to all rooms. The effect of the different safety margins and requirements indicated the effect of the new requirements relieved the requirement on the building constructions by

- 2,3 dB on the airborne sound insulation
- 2,4 dB on the impact sound insulation

2.2 Safety margin, comparison between measured and calculated sound insulation *in situ*

Earlier studies [7] of the uncertainty of calculated values as compared to measured (*in situ*), indicate that 3 dB is an appropriate margin to observe during design (calculations) of houses with concrete structures with respect to requirements on individual apartments and rooms (as in edition 2), but 1 dB would be sufficient for edition 3. For light weight structures greater margins should be applied. In this study, impact sound measurement data of 40 Finnish apartment houses with heavy slabs and exterior walls have been analyzed. The uncertainty of calculations compared to measurements, defined as a 10% risk of non-conformance to the requirement, agree with the recommended safety margin 3 dB. However, the deviations at high frequency are greater than expected, see figure 1. Hardening of soft flooring underlayers may be a reason.

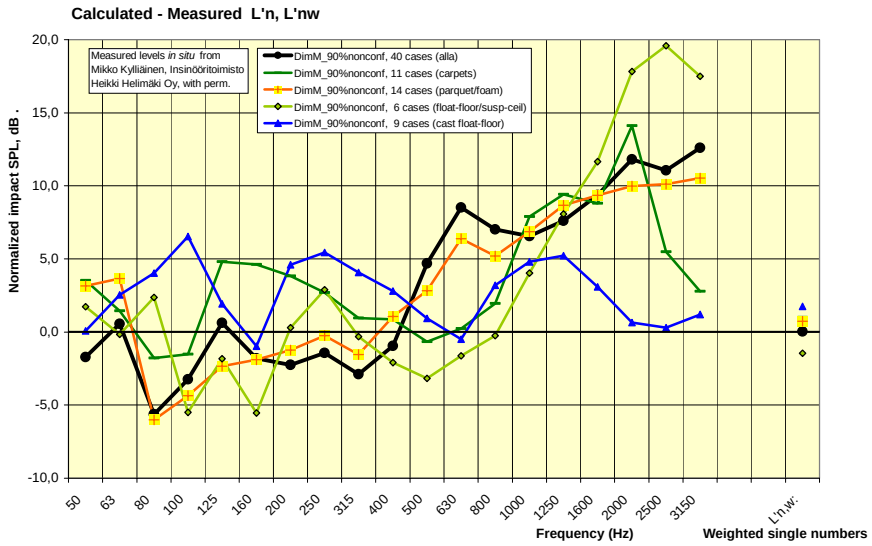


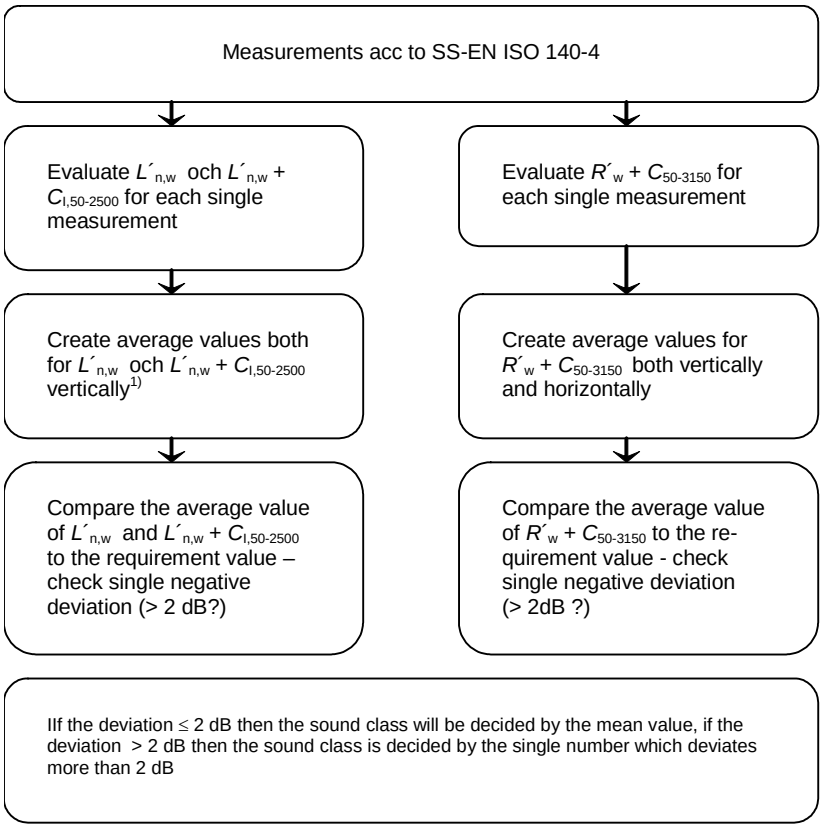
Figure 1: Difference between calculated and measured impact sound pressure levels, plotted as a margin. The margin is calculated as the average deviation increased by 1,28 times the standard deviation in each frequency band 50-3150 Hz and as weighted single numbers

3 FIELD STUDY OF NEW APARTMENT HOUSES

In this part of the study, measurements were made in seven new apartment houses according to ISO 140 [1]. Comparative calculations were made as well, according to EN 12354 [5] for the five houses with concrete structures. Two buildings with light weight structures were omitted from this comparison since the standard EN 12354 [5] is not applicable to buildings with light weight structures.

3.1 Evaluation of measurement results

The measurements were evaluated according to the rules corresponding to each of the two editions of the standards. This means that for edition 2 each single measurement is evaluated separately and then compared to the requirement and for edition 3 the evaluation follows the principles shown in the scheme in figure 2. The single numbers in the scheme include the effect of limitation rules and averaging within an apartment according to edition 3, as described in the introduction.



[1)] The fact that it should be mean value only using vertical measurements is not described in the new standard. This is suggested to lreach a more correct classification with regard to impact sound

Figure 2: Principle for verification of the acoustic performance according to edition 3 of the new Swedish standard, SS 25267 [3]

3.2 Margins of measured sound insulations to the requirements

The measured sound insulations of the buildings have been compared to the relevant requirement of each edition of the standard, and this difference is hereafter denoted “margin” for short. Figure 3 show the margins of airborne and impact sound insulation for each building 1-7, evaluated according to edition 2. Figure 4 shows the corresponding values according to edition 3.

The building cases being analyzed were all designed to meet a higher sound class (B) than required (C), according to the edition 2, i.e. with 4 dB higher airborne sound insulation and 4 dB lower impact sound levels. Thus, the margin should be in the order of 7 dB with edition 2 and 5 dB with edition 3, to ensure compliance with the requirements.

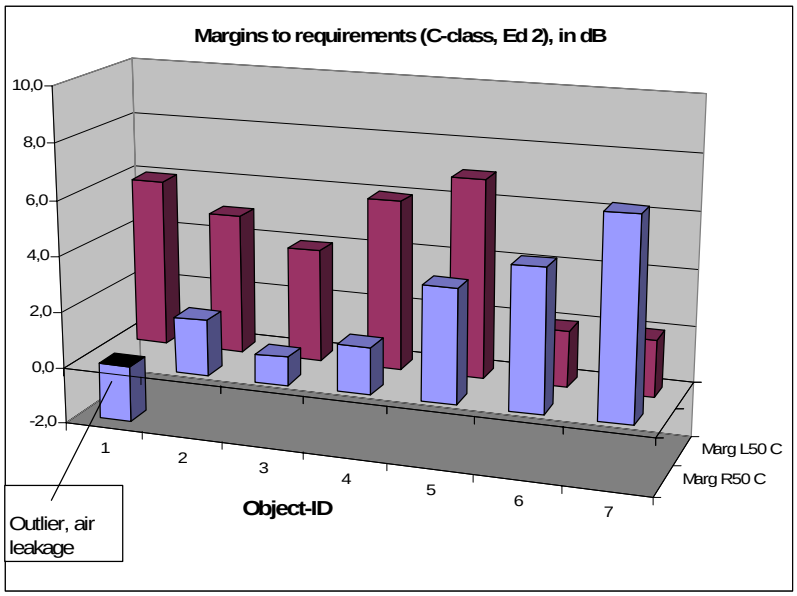


Figure 3: Margins between measurements and requirements in seven buildings evaluated according to edition 2

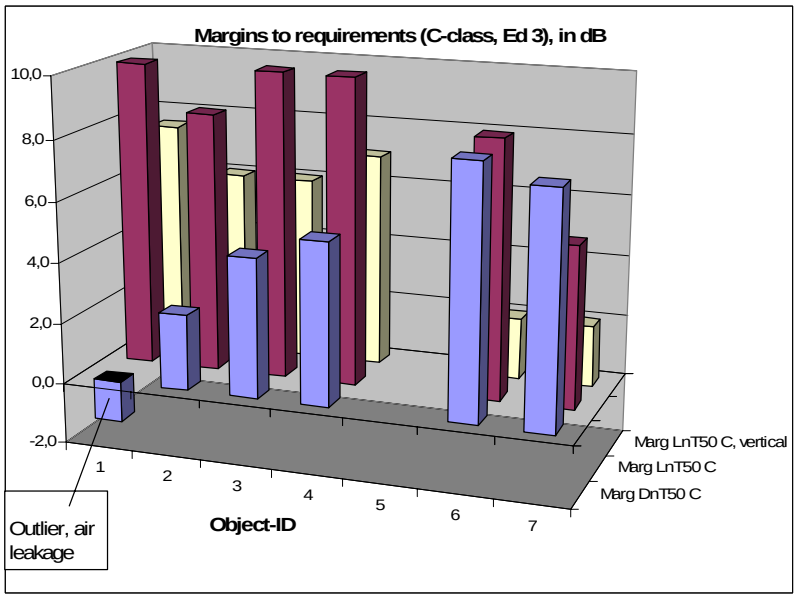


Figure 4: Margins between measurements and requirements in seven buildings evaluated according to edition 3. The white bars (back) show margins of impact sound insulation, when only vertical measurements are taken into account

In the buildings studied, it is clear from the figure 3, that appropriate margins have not been observed during design to ensure conformance with the requirements of the higher sound class B. Even for sound class C, which are minimum values according to the building codes, the margin is just about enough in some cases. In one case (#1), air leakage reduced the sound insulation considerably and the requirement was not fulfilled, but this case was omitted when the average margin was calculated (cf. table 1).

Comparing the results of figures 3 and 4, it is clear that the margins have increased considerably when edition 3 is applied, as compared to the previous edition 2. One effect not

intended, is that horizontal impact sound insulation in buildings with certain structural joints is considerably lower than the vertical, which reduce the average value of the apartment.

The figures 3 and 4 both indicates, that airborne sound insulation is critical for the choice of heavy constructions, whereas impact sound is the critical quantity for houses with light weight structures. With the new edition 3, the differences are reduced.

From the data of the figures 3 and 4, recommended margins for design have been computed as the average margin increased by 1,28 times the standard deviation of the 7 cases. This margin corresponds to a 10% risk of failure, i.e. not fulfilling the requirement when a measurement is carried out. Values for sound class C and class B, for each edition, are presented in table 1.

Table 1: Recommended changes of design margin, in dB, to reach sound class C and sound class B respectively depending on edition of the standard SS 25267. Based on measured data of 7 modern Swedish buildings.

Recommended margins	Edition 2		Edition 3	
	$R'_w+C_{50\text{-}3150}$	$L'_{n,w}+C_{I,50\text{-}2500}$	$D_{nTw}+C_{50\text{-}3150}$	$L_{nTw}+C_{I,50\text{-}2500}$
Design for sound class C, margins could **decrease** with	0.7	2.0	3.0	6.3 (1,9)[1]
Design for sound class B, margins should **increase** with	3.3	2.0	1.0	-2.3 (2,1)[1]

[1] If the requirement is applied separately to vertical measurements and horizontal measurements (proposal)

In edition 3, the direction of measurement is not specified. For impact sound, horizontal measurements typically include rooms with heavy slabs and walls, connected by rigid junctions. Thus, the horizontal impact sound is often much lower than the vertical, which reduces the average and increases the margin to the minimum requirement (compared to edition 2). The limiting rule is however effective, where the unfavorable deviation must not exceed 2 dB. It would be more attractive [6], to change edition 3 such that the mean value must be evaluated separately for vertical and horizontal directions. Then the margin decreases, which is shown in the right hand column of table 1.

When the values of table 1 is compared to the results of the initial study of statistics (clause 2.1), the results of the airborne sound insulation are similar, i.e. the requirements have been reduced about 2 dB. For impact sound, the results of table 1 show a larger reduction than calculated in the initial study. However, in the initial study, vertical impact sound insulation was calculated for each room, and included in the average of the apartment. For large apartments, with several small bedrooms, this would imply a systematic difference compared to the measurements of the field study, where typically one large room and one small room were measured. Taking this effect into account, it appears that the results of the initial study could be realistic if many measurements are performed in each apartment, but since common practice is to choose two rooms in each apartment, the values of table 1 are probably more relevant.

3.3 Uncertainty of calculations compared to measurements

Comparatitive calculations were made, according to EN 12354 [5], for the five houses with concrete structures. The calculations were all made using the BASTIAN software package and a common database of Nordic building products. The results are presented in figures 5 and 6, where the required values are marked by bold graph lines.

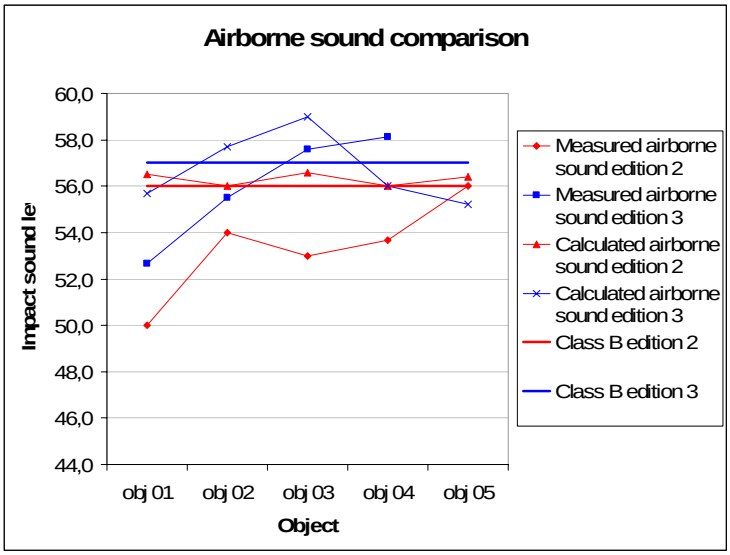


Figure 5: Calculated and measured airborne sound reduction index, with evaluation rules applied to editions 2 and 3

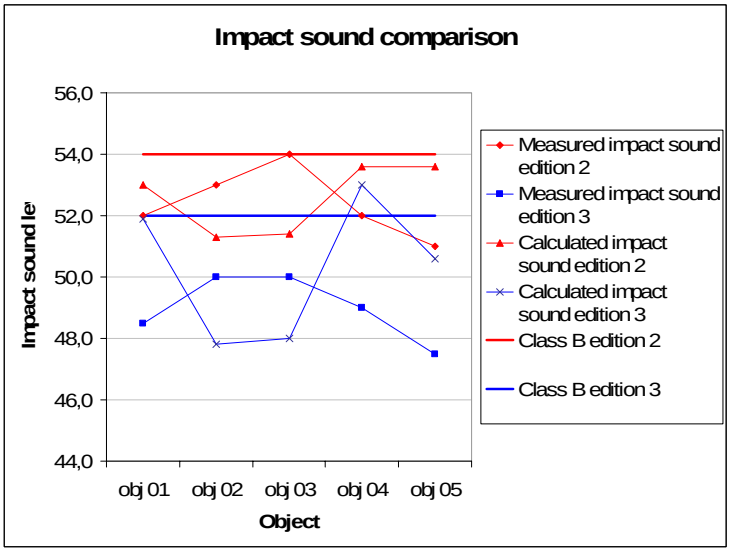


Figure 6: Calculated and measured normalized impact sound pressure level, with evaluation rules applied to editions 2 and 3

The figures 5 and 6 show some deviations between calculated and measured values. Calculated margins, taken as the average deviation increased by 1,28 times the standard deviation (10% risk of non conformance) result in a practical guidline for margins to be observed during design (calculations). These margins are about 1 dB higher than reported in [7]

- 3,7 dB for $R'_w + C_{50\text{-}3150}$
- 4,0 dB for $L'_{nw} + C_{I,50\text{-}2500}$

4 SUMMARY

Edition 3 of the Swedish standard SS 25267, to which is referred in the Swedish building regulations, imply that it has become easier to reach the expected requirement values. Design margins may be somewhat reduced compared to the previous edition. This could also be

interpreted as the new edition of the standard is an adaptation to the established practice of the local building industry. The requirements of the former edition 2 actually implied that the required sound class was not fulfilled in many cases. This appeared in particular in apartments with large receiving room volumes and for separating surfaces where the relationship *V/S* is large.

For impact sound, there are studies [6] which support the new requirement levels, however for airborne sound insulation, it would be appropriate to make further investigations of the experienced airborne sound insulation with respect to requirement levels of edition 3.

It shall be observed, this investigation is restricted to typical modern "family" apartments. For other types of dwellings, for example particularly small dwellings (for students, elderly people etc), or large dwellings, other results may appear.

During 2006, an investigation regarding subjectively experienced sound insulation will be performed for the housing units included in this project. This part of the project was added lately, and therefore it could not be included in this paper.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

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