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ASSESSMENT OF AIRBORNE AND IMPACT NOISE FROM NEIGHBOURS

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1. INTRODUCTION

People living in apartment houses often complain about noise from neighbours. In buildings with light-weight constructions the acoustic problems can often be localized to low frequencies, typically under 100 Hz, which by tradition is the lower limit for building acoustical measurements. However, the new version of ISO 717 [1, 2] offer new methods to include the low frequencies between 50 and 100 Hz in the objective evaluation, both for airborne and impact sound. In order to throw more light over the relationship between subjective and objective evaluation of the sound insulation, some laboratory experiments have been initiated and information has been collected from earlier field investigations. The goal is to define which sound insulation should be required in order to obtain satisfactory acoustical conditions in new houses. As a basis for this, dose-response relationships should be derived for airborne and impact noise from neighbours.

2. PILOT INVESTIGATIONS IN THE LABORATORY

A laboratory experiment has been carried out as a pilot project in order to investigate how the assessment of noise from neighbours is influenced by various factors. 20 test persons have been asked to evaluate series of typical noise from neighbours, i.e. two kinds of airborne noise (music and the sound track from a film) and two kinds of impact noise (footfall noise with and without shoes). The noise examples were presented with two different shapings of the frequency spectrum in order to simulate either a heavy building construction or a typical lightweight construction. The two frequency shapings were different in the frequency range 25 - 200 Hz, but identical at higher frequencies. The noise examples were presented at four different levels, 17, 27, 37 and 47 dB A-weighted. Continuous street noise was used as background noise, and it was presented at two different levels, namely 27 and 42 dB A-weighted.

Dose-response curves have been derived for annoyance, disturbance of concentration and subjective loudness. For annoyance was found a considerably steeper slope of the dose-response curve than for disturbance and loudness, see Table 1. Generally, airborne sound was evaluated slightly higher than impact sound.

Type of noise	Annoyance	Disturbance	Loudness
Airborne	0.24	0.15	0.16
Impact	0.21	0.13	0.12

Table 1. Slope of dose-response curves for annoyance, disturbance and loudness (unit per dB), using a subjective scale of 10 units.

Type of noise	Level of noise from neighbour, A-weighted			
	17 dB	27 dB	37 dB	47 dB
Airborne	16%	49%	96%	100%
Impact	8%	46%	85%	100%

Table 2. The percentage of test subjects who felt annoyed by the noise at four different levels of the noise.

The percentage of test persons who felt annoyed was also investigated, see Table 2. It was found that 50 % of the subjects felt annoyed by the airborne or impact noise at an A-weighted level of 27 or 28 dB, respectively. For both types of noise the interval between 20 % and 80 % annoyed corresponded to a level difference of 16 dB. It was not possible to draw any firm conclusions about the influence of light or heavy building constructions, but the pilot project has given useful information for the design of future experiments on this topic.

3. REVIEW OF FIELD INVESTIGATIONS ON NOISE FROM NEIGHBOURS

3.1 Canada 1982

This investigation by Bradley [3] involved interviews with 98 subjects living in eleven different sites, 82 in two-storey row houses and 16 in apartment houses. The measured airborne sound insulations of the party-walls varied from 39 dB to 60 dB (STC-values, may be approximated by R'_w). From this investigation it can be derived that with an airborne sound insulation of 55 dB around 10% would be annoyed by noise from their neighbours. The residents would generally be prepared to pay 3$ per month to reduce annoying noises. It is found that an airborne sound insulation of 60 dB should be required if most residents should be satisfied.

3.2 Germany 1986

The investigation included 16 areas with dwellings of different age, the oldest from the 1920'es with wood joist floors and the newest from the 1980'es. In total 471 people living in the houses were interviewed.

The average airborne sound insulation R'_w of partition floors varied from 44 dB to 61 dB. The results indicate that if less than 15% should evaluate the airborne sound insulation as insufficient, the airborne sound insulation should be at least 58 dB. One of the conclusions was, that the acoustic conditions in new and old dwellings are rated according to different criteria. The conditions of the building influence the expectations significantly and consequently the ratings of the occupants.

The average impact sound pressure level of the partition floors in the different areas varied from 56 to 26 dB. The relation between subjective evaluation and measured impact noise values did not correlate very well, and in the case of hearing impact noise an approximate interval was given instead of a single curve. As an example, if a value of 53 dB is considered for the required impact sound pressure level, the results indicate that between 30% and 60% of the persons may hear and notice the impact noise, and around 20% of the persons can be expected to be annoyed by impact noise from the neighbours.

The sound pressure level was also measured from a live, adult walker, and a relation was found between the A-weighted maximum sound pressure level under the partition floor and the impact sound pressure level as measured with the standard tapping machine, see Table 3.

Tapping machine. Impact sound pressure level $L'_{n,w}$	Live walker. A-weighted maximum sound pressure level under the partition floor
53 dB	35 dB
43 dB	29 dB
33 dB	23 dB

Table 3. Relation between impact sound pressure level and the A-weighted maximum sound pressure level generated by a live walker [4].

3.3 Germany 1988

The investigation by Kötz [5] is based on a collection of measured data of sound insulation in dwellings in cases of complaints due to dissatisfaction with the sound insulation. 70% of the measured data are from the years 1984-1986. Some key numbers from the investigation are contained in Table 4. From these data it is possible to estimate which sound insulation would be necessary to eliminate a certain percentage of the cases of complaints. If for instance the number of complaints should be reduced to 10%, it can be seen that the airborne sound insulation in apartment houses should be $R'_w \geq$ 58-60 dB, and the impact sound level should be $L'_{nw} \leq$ 48 dB.

	Percentage of cases of complaints			
	80 %	50 %	20 %	10 %
Airborne sound insulation, R'_w Party walls, row houses Number of cases: 519	≥55 dB	≥59 dB	≥64 dB	≥67 dB
Party walls, apartment houses Number of cases: 63	≥51 dB	≥53 dB	≥55 dB	≥58 dB
Party floors, apartment houses Number of cases: 90	≥54 dB	≥56 dB	≥58 dB	≥60 dB
Impact sound insulation, L'_{nw} Party floors, apartment houses Number of cases: 79	≤64 dB	≤58 dB	≤52 dB	≤48 dB

Table 4. Extracts from measuring results in cases of complaints due to dissatisfaction with the sound insulation [5].

3.4 Sweden 1985 and 1996

A survey of the sound insulation between dwellings was made in Sweden 1983-85, [6]. A total of 22 different floor constructions were investigated, comprising 160 impact sound pressure level measurements and 464 scores obtained by interviews with 398 tenants. Both timber joist floors and concrete floors with soft and hard floorings are represented.

The subjective evaluation was given on a scale from 1 to 7, where 7 is the top score with the wording "Quite satisfactory" and 1 is the bottom score with the wording "Quite unsatisfactory". The following relationship was established between the percentage T of persons rating the sound insulation as quite or nearly quite satisfactory and the subjective mean score S [6]:

$$T = 22.4 \cdot S - 47 \quad (\%) \tag{1}$$

For the normal frequency range Bodlund found the following relationship between the average impact sound pressure level in a building and the subjective mean score S:

$$L'_{n,w} = 80.6 - 5.48 \cdot S \qquad (r{=}75\%,\ n{=}22) \tag{2}$$

Here r is the correlation coefficient and n is the number of building sites used for the correlation. In this investigation there is a quite large spread of the data, from 37 dB up to 70 dB in terms of $L'_{n,w}$ or from 2.2 to 7 in terms of S. Using eqn. (1), the relationship can also be expressed in terms of the percentage quite or nearly quite satisfied, T:

$$L'_{n,w} = 69.1 - 0.24 \cdot T \qquad (3)$$

All measurements in this investigation were made in an extended frequency range including 50 Hz, and Bodlund found the highest correlation between subjective and objective data when he used a special evaluation curve including the low frequencies. This is here denoted L_B, and the regression is:

$$L_B = 86.3 - 5.53 \cdot S \qquad (r=87\%,\ n=22) \qquad (4)$$

Recently, a new standardized method for evaluation of impact sound in an extended frequency range has been introduced in the new ISO 717-2 by a spectrum adaptation term $C_{i,50\text{-}2500}$, which is added to $L'_{n,w}$. In a project from the acoustics group of NKB, Hagberg [7], measured data from 146 floor constructions with $L'_{n,w}$ values between 31 dB and 78 dB were analyzed, and a very high correlation of 96% was found between Bodlund's proposed measure and the new ISO measure including the low frequency spectrum adaptation term:

$$L'_{n,w} + C_{i,\ 50\text{-}2500} = L_B - 6.4 \qquad (r=96\%,\ n=146) \qquad (5)$$

Without the spectrum adaptation term the correlation coefficient was only 76%.

From these two investigations it may be concluded that the new low frequency spectrum adaptation term offers an improved evaluation method for impact sound pressure level. Combining eqn. (1), (4) and (5) gives:

$$L'_{n,w} + C_{i,\ 50\text{-}2500} = 68.3 - 0.25 \cdot T \qquad (6)$$

The difference between the results for the normal frequency range or the extended frequency range is only about 1 dB. However, it should be observed that the correlation is rather weak for the normal frequency range (75%) but stronger for the extended frequency range (87% and 96% combined). From eqn. (6) follows that the interval from 20% to 80% in the subjective evaluation corresponds to a 14 dB change of impact sound pressure level. This finding is close to the 16 dB found in the laboratory experiments mentioned in section 2.

As an example a value of 53 dB for the impact sound pressure level with the extended frequency range would mean that the expected percentage of satisfied or quite satisfied persons is T = 62%. This would change to T = 83% if the limit is 48 dB.

4. CONCLUSION

Laboratory experiments have shown that airborne and impact noise from neighbours are evaluated in approximately the same way. The derived dose-response curves for annoyance had a considerably steeper slope than those for disturbance and loudness. 50 % of the subjects felt annoyed by the noise at an A-weighted level of 27-28 dB.

The extended frequency range including low frequencies between 50 and 100 Hz should be used in accordance with the new ISO 717, as this probably will give a better correlation between objective and subjective evaluation of the sound insulation. This has been demonstrated for impact sound pressure level (increase of correlation coefficient from 76% to 96%), and a similar effect may be expected for airborne sound insulation although this has not yet been verified. Especially when light-weight constructions are considered the frequencies under 100 Hz are very important.

The results from the various field investigations lead to the conclusion that in order to meet the users' demands for acoustic quality in dwellings, the airborne sound insulation between flats in new buildings should fulfil 60 dB and the impact sound pressure level should fulfil 48 dB, preferably in the extended frequency range. It can be assumed that this level of sound insulation will be characterized as 'satisfactory' by most people, and only a very limited number of complaints can be foreseen.

5. REFERENCES

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