Evaluation of impact sound in the field situation – research at Lund University

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Abstract

During the last years work has been carried out in collaboration between Lund University, WSP Acoustics and the Royal Institute of Technology (KTH) in Stockholm, to bring more basis for impact sound evaluation in the field situation. Results from this study so far, indicate that current international (ISO 717) method is unsatisfactory, and improvements are probably necessary. In this paper we discuss the results and propose new proper ways to evaluate impact sound, either by using single numbers and adaptation terms (modified or not modified) according to the international standard ISO 717/2 or by specifying new rules (modified single number rating) for evaluation. Furthermore, in this work we imply that the ISO impact sound source is an acceptable sound source simulating footstep and other impact sounds in a dwelling. Our study includes both evaluation from former investigations and new objective measurements and interviews with tenants. The latest results added are derived from modern housing design. Modern housing design differs a lot from earlier design, which seems to cause phenomenon that further complicate the use of prior standard evaluation methods.

1. Introduction

In the Nordic Countries the weighted normalized impact sound level, \( L_{n,w} \), is used to evaluate impact sound in the field situation. In Sweden the adaptation term, \( C_{L_{1/3-oct.,2500}} \), is added to the single number value, and the measured or calculated value has to be lower than the limit value both when the adaptation term is included and excluded. This way to express the impact sound limit value is far better than using only \( L_{n,w} \) [4].

In present paper we continue the work started slightly before the year 2000, presented in a paper at the ICA conference in Rome 2001 [4]. This continuation work implies that new 1/3-octave impact sound data (i.e. corresponding to new buildings constructions and buildings with new technical solutions), together with subjectively evaluated impact sound data, are gradually added to the original, and partly modified, data sample [3]. Altogether, these data will provide valuable information, which will facilitate wise statements concerning impact sound level in regulations and standards. Deeper knowledge within this topic has become of particular interest in modern housing design containing open plan solutions and slender hollow concrete floor structures and least but not less lightweight structures.

Furthermore the work has become of current interest since the Swedish national sound classification standard has been revised during the last year [8].

2. Investigation

2.1. Aim

The major aim with this work is to

- Investigate whether current impact single number ratings are applicable to modern frame structures
- If not, create basis for wise judgments concerning evaluation of impact sound level.

2.2. Data included

The work is based on field measurements of impact sound level and corresponding interviews with tenants. The measurements are made according to ISO 140-7 and the subjective evaluation is made with questionnaires and interviews, exactly in the same manner as the former investigation by Bodlund [2,3], here called the “original data sample”. In this paper we show some results from calculations when four new constructions (floor structures) are added to the original, but modified, data sample [3]. The modification implies that the calculated relationships are limited to vertical impact sound level and exceptional single outliers are taken away from the data sample due to uncertainties in the evaluation [4].

2.3. New data

The four new constructions are collected from typical modern houses, two lightweight timber floor structures [6,7] and two heavy, slender, structures, i.e prefabricated hollow concrete (HDF 120/19) covered with a typical modern dry floating floor construction (floor covering / surface of parquet)[9]. These new data are added to the original data and the correlation coefficient between different objective measures (using different shapes for the evaluation curve) and
subjective evaluation is determined for the whole sample.

The main, long range, idea with this work is to create an accessible database (built up in Microsoft Excel) containing substantial field information of housing buildings. Except carefully considered subjective evaluation, information important to make correct judgments concerning various parameters and their influence on the final result, i.e:

- Floor structure construction
- Connected flanking constructions
- Design of dwelling – receiving room volumes
- 1/3 octave band data from field measurement – not only normalized levels but also measured impact levels and reverberation time data, etc

As new building technique is developed and introduced on the market, new data might be inserted into the database and different shapes of reference curves (or other parameters) can be examined. New evaluation methods are easily calculated for the whole “new sample”. This will become a valuable tool for the authorities and for other institutions whose mission is to create building regulations and standards. Regulations might become better supported than today.

Another positive resulting effect in this database is the simplicity to exclude data, which for example might have turned out of date and therefore should no longer form a part of the calculations.

3. Results (so far)

In the calculations the impact sound level is normalized to 10 m$^2$ in each 1/3 octave band according to the rules valid for $L'_n$. Then single number values are evaluated both by using the ISO method ($L'_{n,w}$ and $L'_{n,w}+C_{1,50-2500}$) and by using different shapes of reference curves within the frequency range 50-3150 Hz. Hence, independently of which reference curve is used, the evaluation rules correspond to these given in ISO 717 part 2. In modern housing design the normalization to 10 m$^2$ causes mathematical errors large enough to call the single number field value in question, due to very large receiving room volumes. This phenomenon will be discussed further on. All data, four new constructions and twelve constructions from the original data [3] are included. Only vertical transmission is observed.

3.1. $L'_{n,w}$ and $L'_{n,w}+C_{1,50-2500}$

Using the whole new sample of data applied for the old figure, $L'_{n,w}$, causes a relationship between the objective and subjective measure which equals

$$\langle L'_{n,w} \rangle = 74,91 - 4,31S \ [r = 69\%, \ n = 16] \ (1)$$

The results verify earlier results [4], i.e. single number rating using $L'_{n,w}$ is not a proper way to describe the impact sound level. The correlation coefficient could be better and the spread around the mean values should decrease. According to present knowledge it is natural to assume that low frequencies have to be considered to a greater extent.

$$\langle L'_{n,w}+C_{1,50-2500} \rangle = 73,10 - 3,72S \ [r = 81\%, \ n = 16] \ (1)$$

There is a large spread in some of the max and min values, which is obvious studying the error bars. The largest spread is found for two types of wooden lightweight structures, one from the 1980’s and one from 1920’s.

The precision will be improved if the ISO adaptation term, $C_{1,50-2500}$, is added to the single number. This cause a relationship equal to

$$\langle L'_{n,w}+C_{1,50-2500} \rangle = 73,10 - 3,72S \ [r = 81\%, \ n = 16] \ (1)$$
It is obvious that low frequencies has to be considered to a greater extent \cite{4}, if the experienced impact sound level will be better adapted to objective measurements.

An improvement of one step in the horizontal scale of marks (subjective evaluation) corresponds approximately to an impact sound level decrease of 4 dB. The requirement in Sweden today states that both $L_{n,w} + C_{1,50-2500}$ and $L_{n,w}$ have to fall below the level 58 dB. But why not exclude $L_{n,w}$ since the linear regression figures 1 and 2 above show a lot better correspondence including the adaptation term? This is explained by the fact that the figure $L_{n,w} + C_{1,50-2500}$ is far too "generous" to concrete floor structures covered with hard floor coverings. $L_{n,w}$ alone is an "obstacle" necessary to include, to prevent such constructions in future buildings. However, this is not an easy type of construction to include in these calculations due to lack of available housing buildings with hard coverings. Hence, the purpose is to prevent the occurrence of a construction type that probably will cause problem, if permitted.

Assuming that the subjective score 4.4 is the score corresponding to a minimum requirement \cite{3} relevant to use in building regulations, then $L_{n,w} + C_{1,50-2500} \leq 56$ dB, which actually is in accordance to the results in \cite{4}.

3.2. New single number rating?

During these field studies some important aspects have been noticed. Lightweight structures and new slender hollow concrete floor structures cause low frequency disturbance below 50 Hz. Complaints occur in spite of low single number values (and in these cases the tenants report low frequency noise to be the main problem). Furthermore new dwelling design with large open plans causes receiving room volumes that create unacceptable errors evaluating $L_{n,w}$, due to the normalization to 10 m$^2$. To fulfill the requirement, the floor structure has to be oversized, at least within the $L_{n,w}$ frequency range, compared to experienced sound insulation, which accordingly might make new dwellings more expensive than necessary. However, the error caused by the room volume and reference absorption area has to be further examined.

In our sample of data we studied a large number of reference curve shapes to find one, optimized to give the best correlation coefficient compared to the subjective judgment, which is applicable independently of frame structure and floor construction. This resulted in a shape more concentrated to low frequencies (even more than Bodlund \cite{2}), see figure 3.

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{new_rating_curve}
\caption{A better reference curve?}
\end{figure}

Using the evaluation curve shape from figure 3, recalculating the single number, and finally, calculating the correlation relationship gives the following results:

$$\langle L'_{n,new} \rangle = 77.90 - 3.31S \quad [r = 83\%, n = 16] \quad (3)$$

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{linear_regression_new_curve}
\caption{Linear regression $L'_{n,new}$ vs subjective grading}
\end{figure}

The evaluation curve shown in figure 3 exhibit the best correlation to subjective evaluation ($r = 83\%$) among those examined in the test. Now a 3.3 dB reduction of the impact sound level corresponds to an experienced sound insulation improvement of one step on the horizontal scale of marks.

3.2.1. The "volume correction" $\Rightarrow L_{nTw}$

In the data sample there is one typical outlier concerning the receiving room volume – a single number mean value caught in receiving rooms equal to 107 m$^3$. If we assume (which might be doubtful generally) that the correct, fully furnished reverberation time equals 0.5 s in all 1/3 octaves, then there is automatically a five dB reduction in this particular
single number mean value which creates a relationship
equal to:

\[ (L'_{\text{0 dB}}) = 78.76 - 3.58S \quad [r = 85\%, n = 16] \quad (4) \]

The notation “n” is now put within brackets since
the normalization is no longer valid consistently. Other
single number values do not exhibit any improvements.
However, there are still uncertainties since all data have
to be corrected to their particular receiving room
volume until fairly certain conclusions might be drawn.
Furthermore, the furnishing does normally not
influence the reverberation time, in the lowest
frequencies, i.e. the 10 m² normalization might be
acceptable in the lowest frequency region. Hence, the
database and the evaluation will be further improved
and include all factors that might affect the correlation
between the objective and the subjective evaluation.

4. Conclusions

The results are (naturally) based on a finite number
of field floor structures, why the results still suffer from
shortcomings. It is necessary to recalculate the
correlation coefficients (taking certain aspects into
account) continuously as new data are included in the
database. As this work progress, we become more and
more aware of the complexity to find a proper, “one
way method”, to describe impact sound insulation in
the field situation, independent of the frame structure.
Nevertheless, the results yet indicate some important
aspects:

The low frequencies have to be considered to a
greater extent.

The high frequencies must be considered to avoid
new, heavy floor structures with hard floor coverings in
the future.

A decrease of approximately 4 dB gives an obvious
improvement of experienced impact sound level.

It seems proper to use 4 dB steps in sound
classification standards. At least as the Swedish sound
classification standard is designed – two better classes
above the minimum standard [8].

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