Are laboratory tests and prediction models useful in building construction projects?

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Summary
The EN12354 calculation method is widely used for air born noise insulation and impact noise predictions. Material properties tested in laboratories are used as input. But, what is the value of the product information given by the manufacturers and suppliers of these materials? It is known that the same products tested in different laboratories yield different results. Is this in practice a problem? Or is the difference between the laboratory setup and the in situ application more important. There is a big competition between manufactures of resilient layers. They throw easily with ΔL values and official test reports to show that their products are in compliance with the requirements in the bidding documents. The same can be told for the manufactures of wall materials. The doors suppliers know that the door insulation measured in laboratory are difficult to be compared with in situ tests. What is the effect of all these parameters and uncertainties, combined with the limits of the prediction method on the final acoustic results in a building? What to do when a building promoter and a contractor want to invest as little as possible in acoustics and still want to comply with the legal acoustic limits? This paper describes the enormous discrepancy between the academic acoustic information and the real life application. Measurement results will be presented and general guidelines will be given.

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1. Introduction

The acoustic knowledge for the building industry has increased a lot since the introduction of the Belgian NBN S 01-400-1 standard in 2008 [1, 2]. However, many architects and contractors complain that different acousticians advice or demand different requirements for materials, design and construction methods for the same type of projects (e.g. standard apartment dwellings). How can you explain the remark : “This is not necessary according to your colleague.”? I will give them this paper in the future, to find the answer. But I will briefly answer them that there is a high uncertainty in building acoustics, which is managed in different ways by the acousticians [3]. This paper will only discuss airborne and impact sound insulation, not installation noise, nor façade insulation. Lightweight (wooden) constructions are not considered in this text. Low frequency expanded single number ratings are not discussed in this paper.

2. Spectral data versus one value rating

The acoustical requirements to be checked in situ are always one value “$D_{nT,w}$“ or “$L'_{nT,w}$ “ (dB) according to ISO 717 [4]. The spectral analysis is never investigated. The relevance of single value evaluations have been questioned in many papers [5, 6]. The repeatability “r” and reproducibility “R” is in any case better to achieve with single value criteria than with 1/3 octave spectral evaluations. ISO 12999 [7] also deals with this problem. From Figures 1a and 1b you can see that the spectral contents can differ a lot yielding the same $D_{nT,w}$ and $L'_{nT,w}$ values when the correction values C are ignored. These corrections are very important.

3. Laboratory data

Many inter-laboratory projects were organized in the past to compare the sound reduction index “R_w“ (dB) and the impact sound pressure levels “$L_{n,w}$” of the same materials in different laboratories [3, 8, 9].

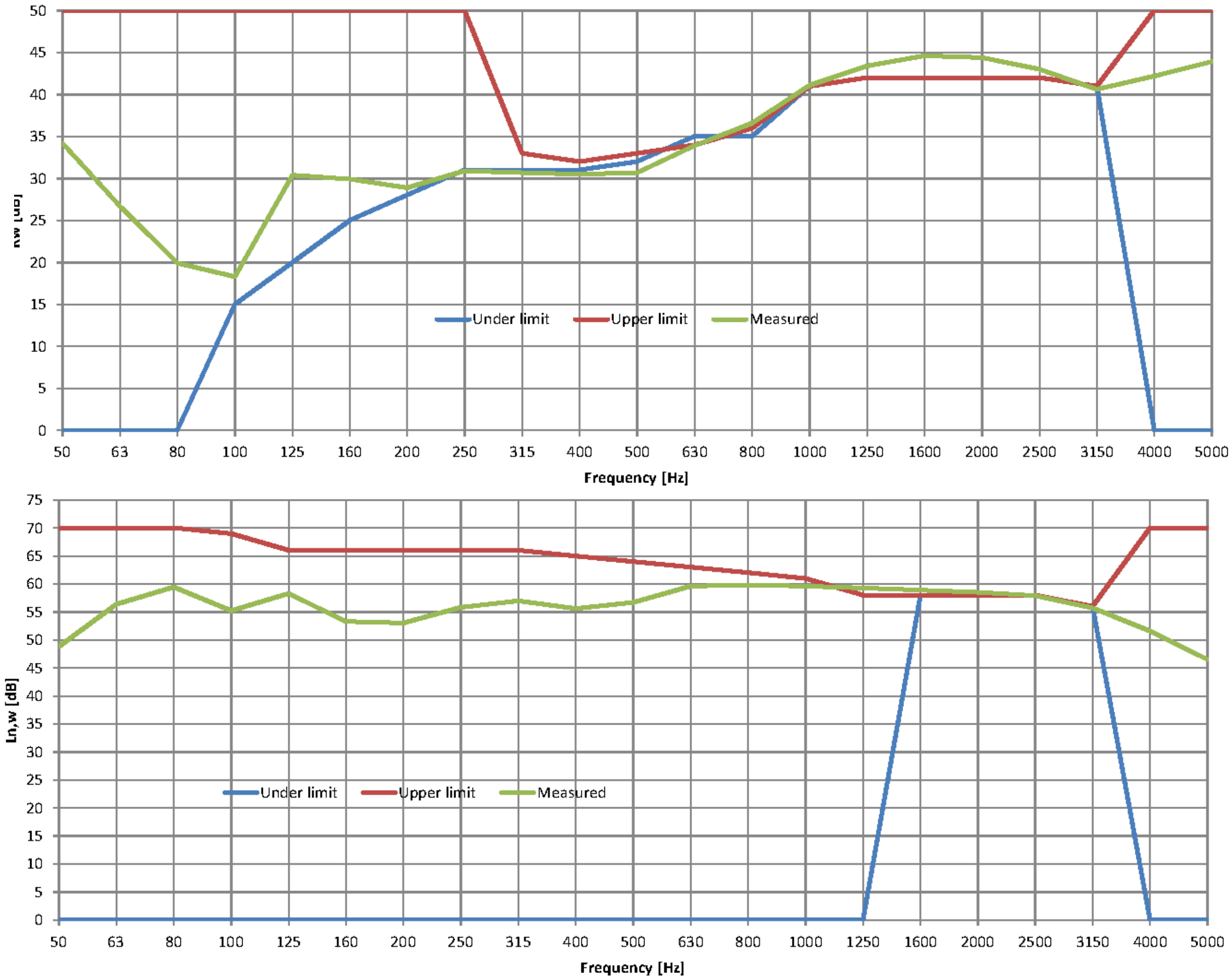


Figure 1. Spectral comparison for the same (a) R_w = 38 dB and (b) for the same $L_{n,w}$.

Plenty of papers [9, 10] show that big differences can be noted for the same products between different laboratories. The next paragraphs tries to summaries the general conclusions.

3.1. Airborne noise insulation

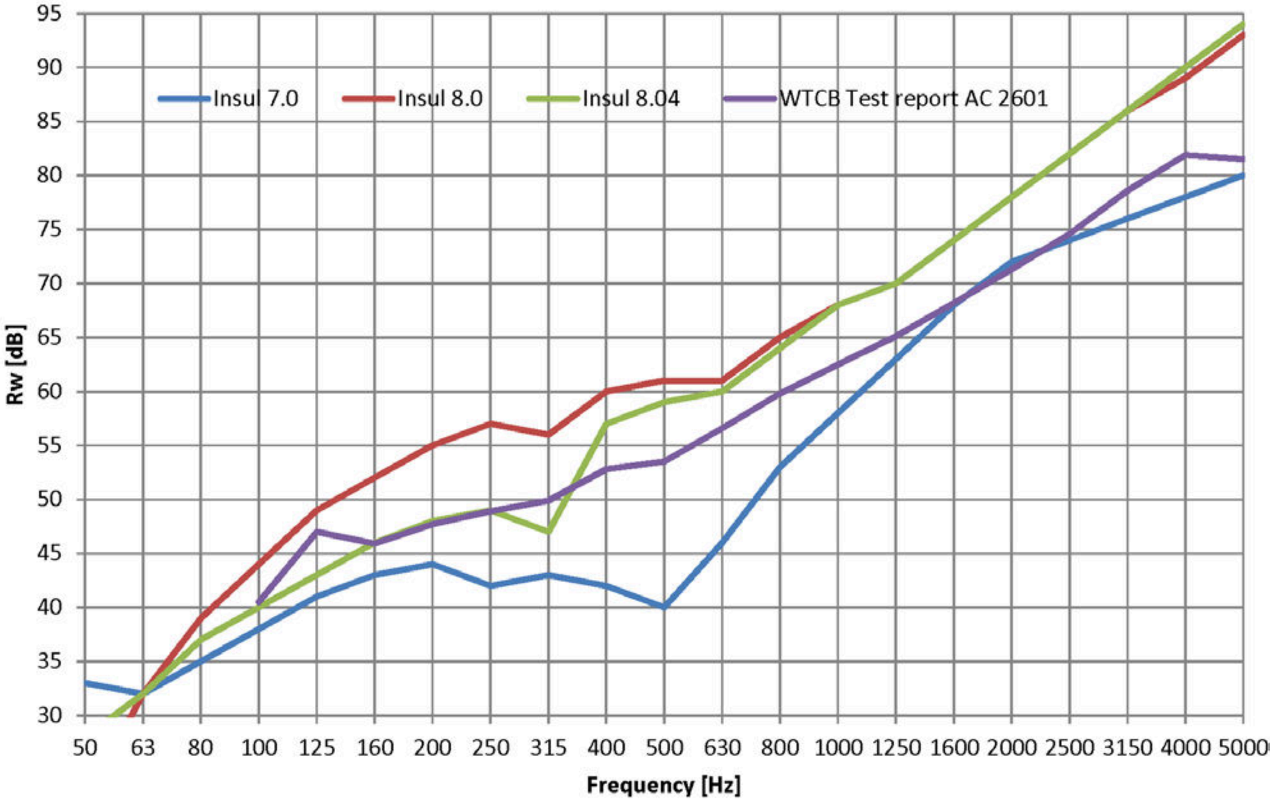
It has been shown [3] that the maximum standard deviation "σ" of R_w for limestone walls can go up to 6 dB under 100 Hz and 3 dB over 100 Hz. Plaster board can have a maximum σ of 3 dB under 315 Hz and 6 dB over 315 Hz. The R_w of a window can differ up to 10 dB under 160 Hz. The same can be found for r and R [8]. In general acoustician must be prepared for an average σ of 2 dB on R_w and 0,2 s on the reverberation time T.

3.2. Impact noise insulation

In the same way as for R_w, $L_{n,w}$ values have a reproducibility between 2 and 4 dB [9].

4. Commercial data

Building material manufactures and suppliers are for many acoustic laboratories economic customers in a commercial competitive world. Some acoustic laboratories have their own patented products. The beneficial parties want to show the world the best possible acoustical results to boost their sales. Sometimes (e.g. the glass industry) one product is tested and all the other products are interpolated or extrapolated with the necessary imagination. It would not be the first time that even experienced acoustical consultant are misled by sales people, manufactures and laboratories. But let us for the remaining part of this paper, suppose that we deal with honest people. Anyhow, laboratory certificates older than 10 years should not be accepted. These reports should also mention clearly the uncertainty of the measured values.



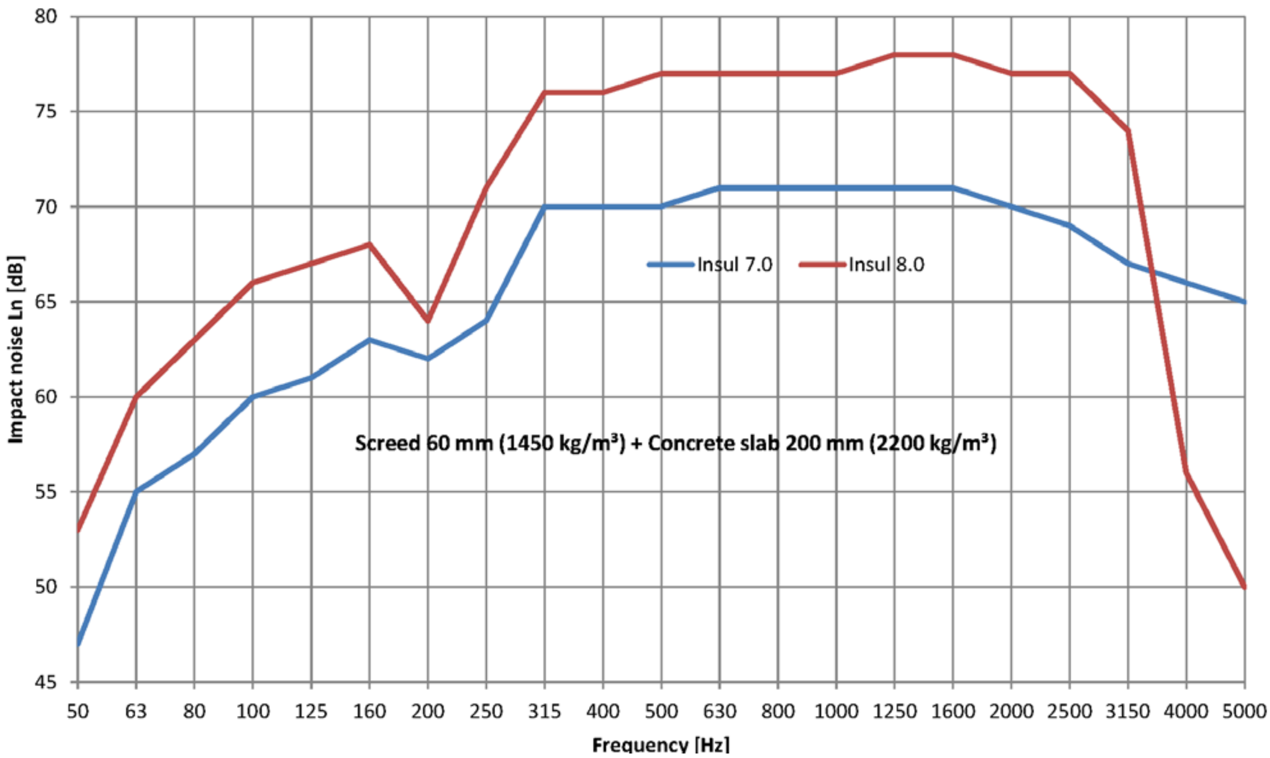


Figure 2. Insul® version comparison for R_w (a) and for L_n (b).

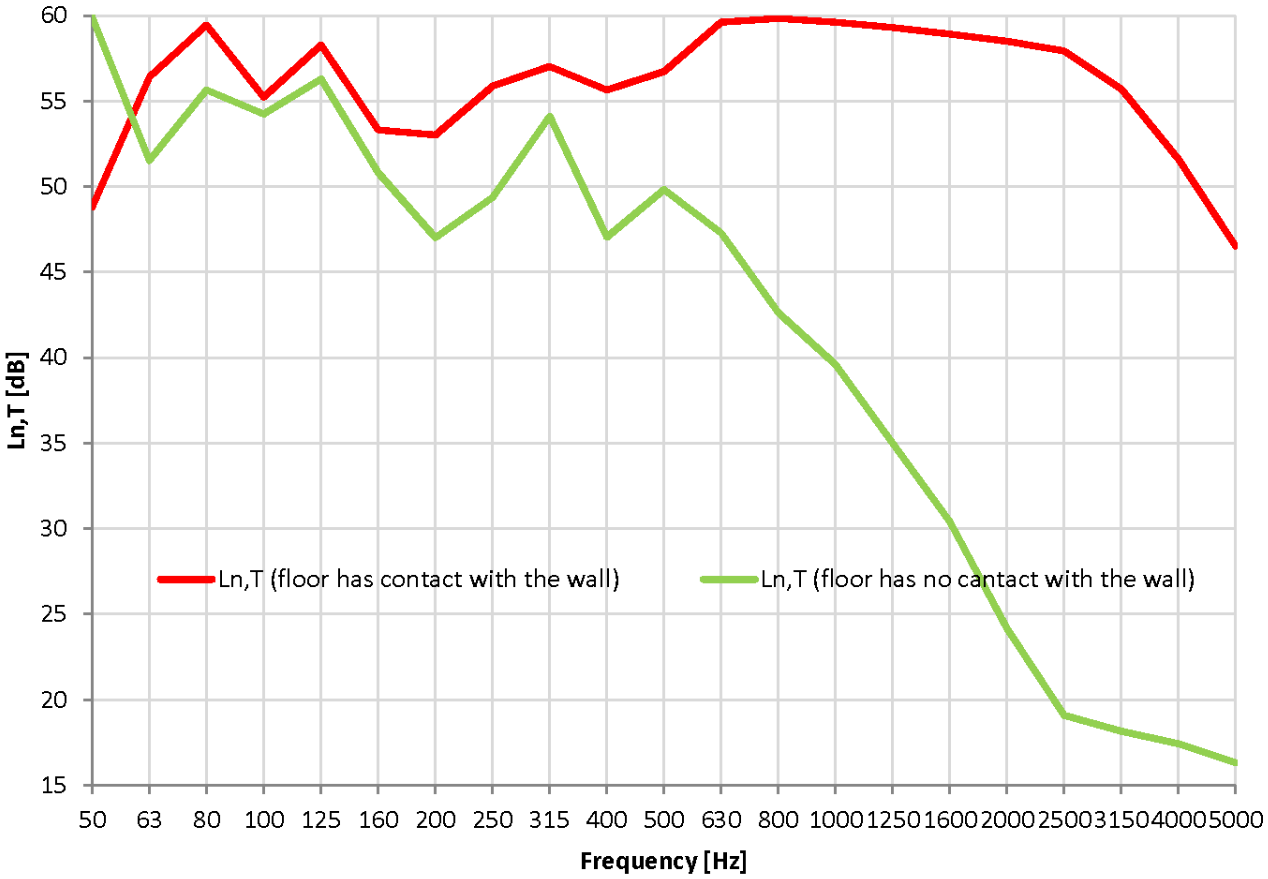


Figure 3. Influence of bad workmanship.

5. Predicted data

The uncertainty of acoustic predictions is related with the knowledge of the user and with the trustworthiness of the software itself. Software producers can lose under the commercial pressure the discipline to compare and validate their
Figure 3. Influence of the workmanship.

software versions. Figures 2a en 2b show the results for 2 versions of Insul® for the same case. The problem should now be fixed. But still differences up to 20 dB can be noted between the 2 software versions. It is also not clear which version is the closest to the laboratory measurements. Models, ignoring code errors in software, have their limitations. The limitations of the ISO 12354 [11] are also known [2]. The uncertainty of the prediction models depends a lot on the frequency.

6. In situ measured data

The uncertainty on the in situ measurements is has been investigated by many authors. Uncertainty values between 2 and 4 dB can easily be found in the literature [12].

7. Difference between predicted and in situ measured data

Comparisons between sound insulation predictions and in situ measured acoustic parameters have been performed during probably the very beginning of the acoustic science. The goal was to predict as close as possible the “real world”. But what is the real world? Paragraph 8 shows it.

8. The real world

Figure 3 show the enormous influence of bad workmanship on the $L'_{nT,w}$. Differences up to 40 dB were measured in the higher frequencies between a floor with a contact and without a contact with a wall. How can a software predict that?

Figure 4 shows the comparison of 53 rooms before and after finishing the floors. Differences up to 13 dB were noted on the single value rating. This is also not predictable. The conclusion is that prediction models can only be compared with laboratory measurements. But how can you deal with the high uncertainty on the laboratory measurements?

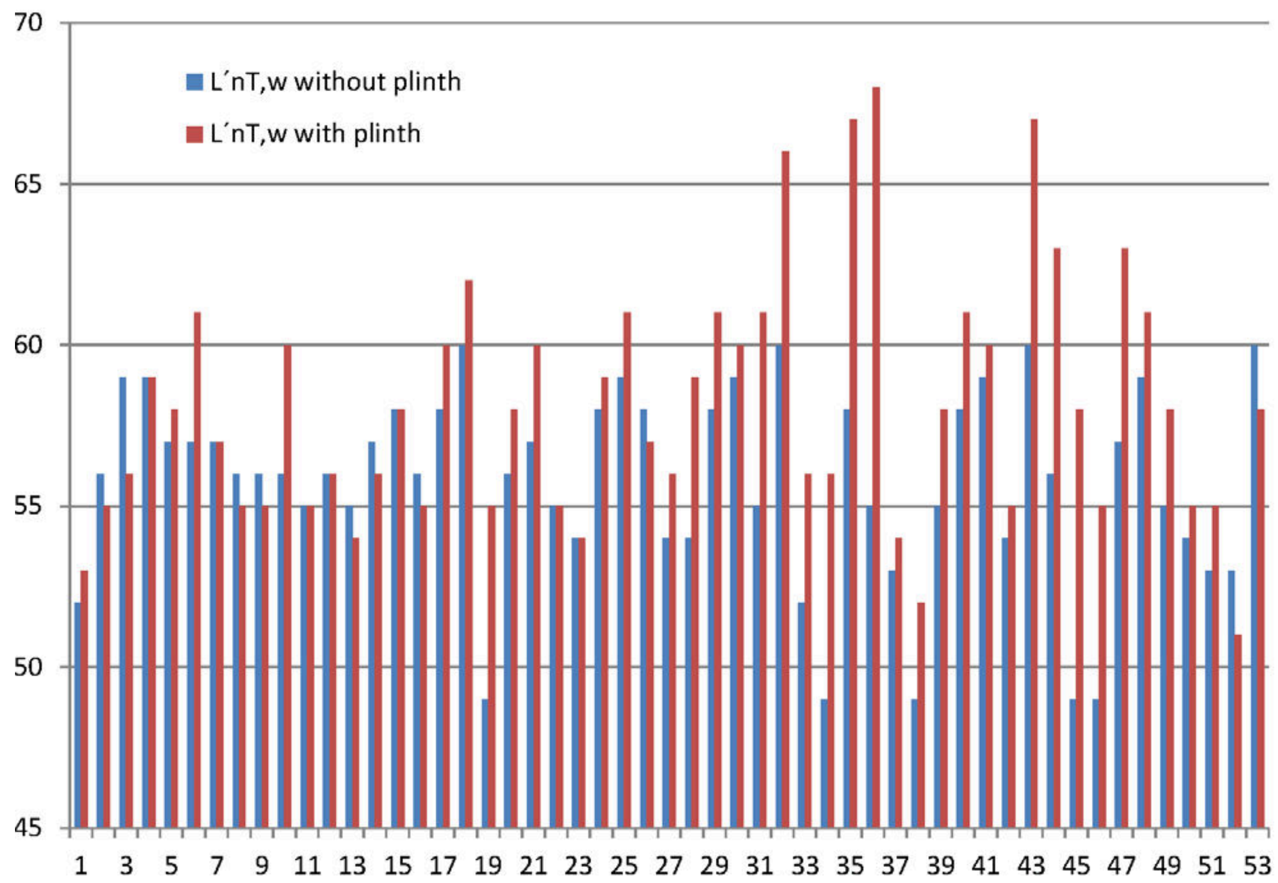


Figure 4. 53 rooms were measured twice.

9. The end result

The final goal in a building project is that in situ measured values are respecting the legal values. Architects, contractor, building promoters are mostly ignorant about acoustics and acousticians sometimes make use of it to hide the uncertainty on their conclusions. Sometimes it is used to confuse lawyers and judges. The uncertainty in acoustics is from a jurisdictional, contractual and liability viewpoint, not acceptable. If we roughly calculate the minimum and maximum accumulated uncertainties $D_{nT,w}$ or $L'_{nT,w}$ values in Table I, than you can easily get a standard deviation σ between 4 and 8 dB. The 95% uncertainty interval is too big to avoid discussions among different parties.

Table I. Minimum and maximum σ in dB.

Data	*Min*	*Max.*
Laboratory	2	4
Prediction	2	4
Overall	**4**	**8**

This is the reason why acousticians almost never dispute among themselves about the data, but about the interpretation of the data.

10. Conclusions

Experienced acoustic consultants can fairly easy determine the “danger zone” and the “safe zone” in building projects. There is unfortunately a big “don’t know” or “grey zone”. Laboratory data and prediction models help to reduce the grey zone. However, the uncertainty on the data, the calculation models and the realization in the field, limits the size of the grey zone. Acoustics is a science although sometimes it appears as an art.

Young acousticians must be very careful and better take a big safety margin, experienced acousticians can take some more risks.

References

[1] NBN S 01-400: 2008 standard. Acoustics – Acoustical criteria for dwellings.

[2] F. Verbandt: 5 Years of in situ experience with the Belgian building NBN S 01-400-1:2008 standard. Proc. ICSV 21, Beijing 2014.

[3] C. Simmons: Managing uncertainty in building acoustics, Lulea 2009. Doctoral Thesis.

[4] ISO 717: 1996 Acoustics – Rating of sound insulation in buildings and of building elements.

[5] F. Verbandt: Impact noise annoyances. Inter-noise, San Francisco 2015.

[6] C. Scrosati, F. Scamoni: Sound insulation uncertainty of field measurements, Forum Acusticum, Krakow 2014.

[7] ISO 12999: 2014 Determination and application of measurement uncertainty in building acoustics.

[8] A. Farina, P. Fausti, R. Pompoli, F. Scamoni: Intercomparison of laboratory measurements of airborne sound insulation of partitions, Inter-noise Liverpool 1996.

[9] Griffin: Accuracy of prediction methods for impact sound pressure levels, Inter-noise Melbourne 2014.

[10] E. Reynders. Parametric uncertainty quantification of sound insulation values. Journal of the Acoustical Society of America, 135(4):1907-1918, 2014.

[11] EN 12354: 2000 calculation method. Building acoustics - Estimation of acoustic performance of buildings from the performance of elements.

[12] Accuracy of prediction methods for impact sound pressure levels, Inter-noise Melbourne 2014.