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A LOOK INTO THE LOW FREQUENCY DEFICIENCIES OF ISO 717-2

Gjermund V. Holøyen[1*]
[1] SINTEF Community, Børrestuveien 3, 0373 Oslo, Norway

ABSTRACT

As the world of building acoustics is moving towards a stronger emphasis on low frequency sounds, certain standards are lagging behind. In particular, the lack of low frequency spectra for the calculation of the weighted improvement of impact sound insulation, ΔL_w, in ISO 717-2 might soon prove to be a significant issue as countries are moving in the direction of including the low frequency spectrum adaption term $C_{\mathrm{I},50-2500}$ in their building legislation. However, it is no straightforward task to find a functional solution to this problem, and a simple extension of the spectra given in the standard today, may not alone be enough. In the work leading to this paper, potential solutions for the heavyweight reference floor have been investigated and assessed. The results are presented and discussed in this paper.

Keywords: *improvement of impact sound reduction, floating floor, low frequencies, spectrum adaption terms*

1. INTRODUCTION

In recent years, the focus on low frequency sound insulation has increased. In Norway, the standard NS 8175 was revised in 2019, where a significant change from the previous version was the inclusion of low frequency spectrum adaption terms in class C for dwellings [1]. Class C in NS 8175 is referred to in the Norwegian building code (TEK), and by ensuring compliance with class C in NS 8175, one is also ensuring compliance with TEK [2]. At the time of writing, the 2019-version of the standard is yet to be adopted into TEK, but signals from the authorities are suggesting that an adoption may be on the cards within 2026 or at the latest when TEK is fully revised.

When this eventually happens, low frequency spectrum adaption terms must be considered for both airborne and impact sound, which from a construction technology point of view is likely going to be relatively undramatic [3]. However, one critical issue is the single number quantity ΔL_w, which is defined in ISO 717-2 [4]. The calculation procedure for ΔL_w relies on reference spectra given in ISO 717-2, which are limited downwards to 100 Hz. That means ΔL_w cannot be calculated including frequencies below 100 Hz, and no corresponding low frequency spectrum adaption terms can be calculated either. This could in theory be solved by simply extending the existing spectra down to 50 Hz, but previous studies have shown that it's not quite so straightforward [7]. This paper looks at other options for calculating low frequency spectrum terms to go along with ΔL_w for the heavyweight reference floor.

2. METHODOLOGY

Two paths have been considered, both based on $C_{\mathrm{I},50-80}$ as an alternative to $C_{\mathrm{I},50-2500}$. For both, extensions of the current spectrum in ISO 717-2 are essential. For this paper, four possible extensions have been suggested. The extensions, denoted as α, β, γ and δ and presented in Fig. 1, are simple extensions of the current heavyweight reference floor spectrum in ISO 717-2. α represents a linear extension of the current spectrum (a reduction of 0.5 dB per third octave), and the other three extensions with reductions of 2, 3 and 4 dB per octave respectively. For both paths, measurement results from five measurements performed at SINTEF have been used, see Fig. 2. The five floors are all floating floor constructions with a concrete screed. An average of measured impact sound levels from the 140 mm bare concrete reference floor at SINTEF is also shown in Fig. 1.

**Corresponding author*: gjermund.holoyen@sintef.no.

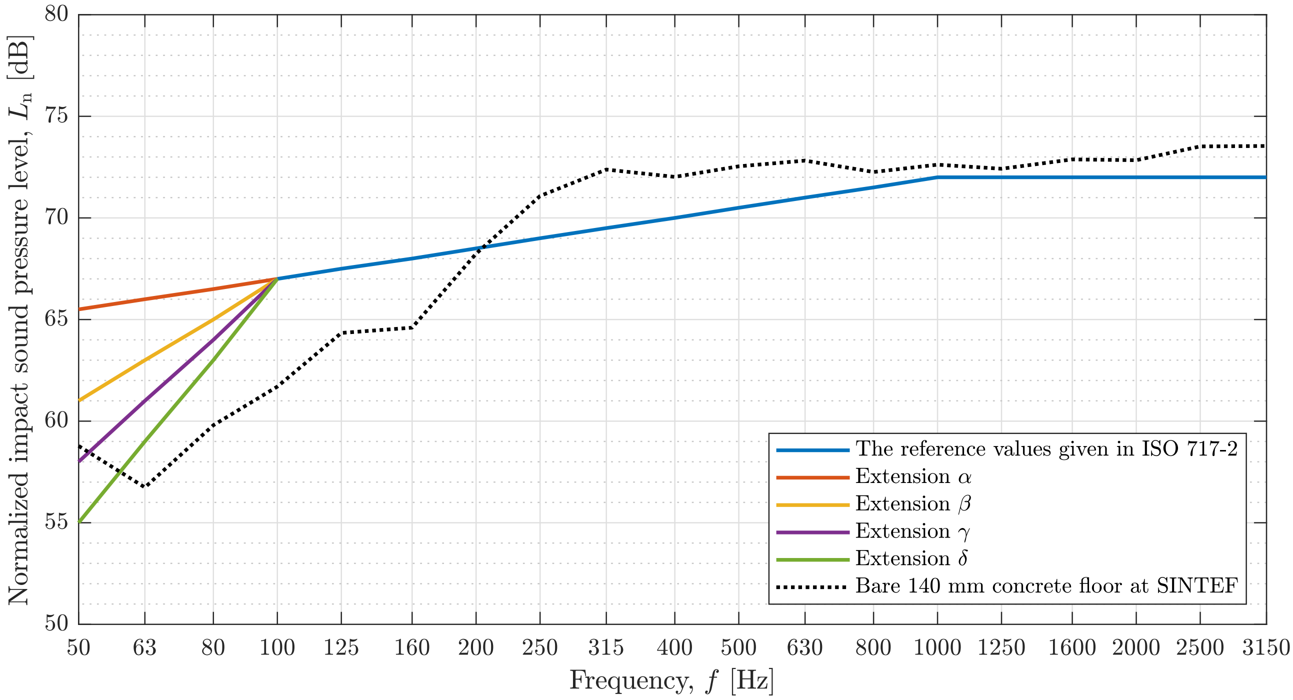

Figure 1. A graphical representation of the suggested extensions of the reference values in ISO 717-2, as well as an average of measured impact sound levels for SINTEF's bare 140 mm concrete floor

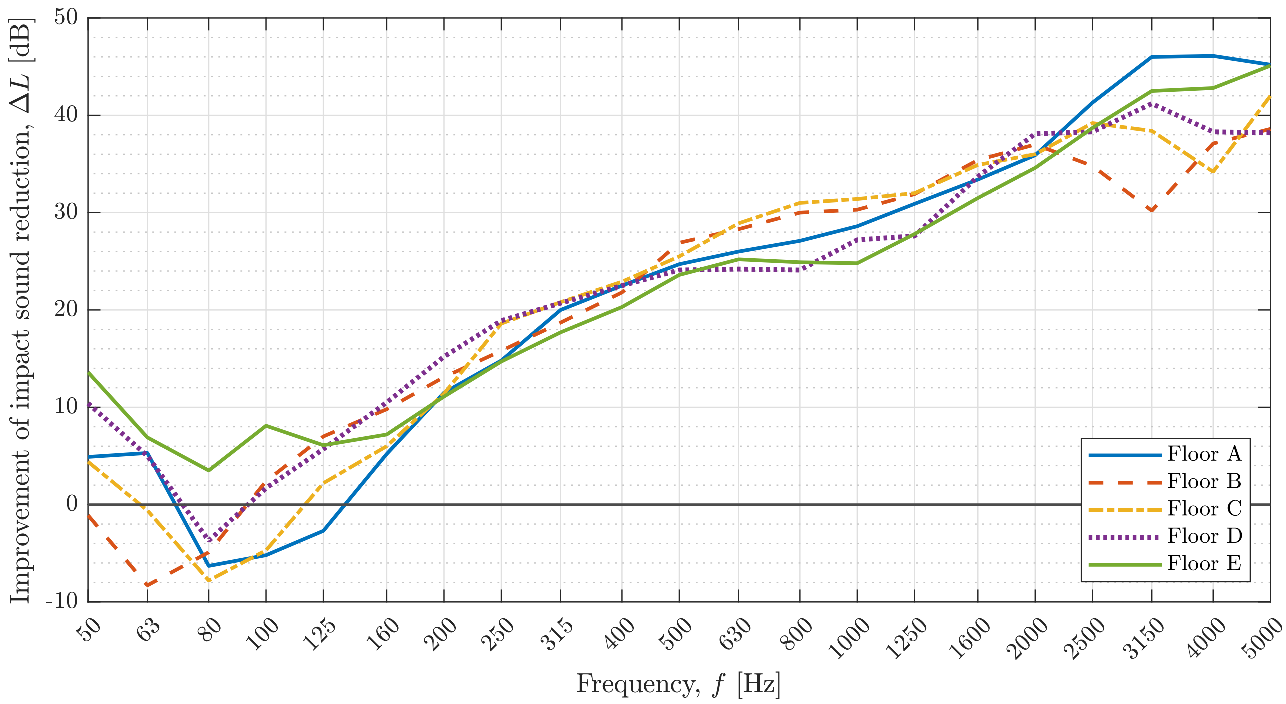

Figure 2. ΔL as a function of frequency for the five floors used in this study.

The first path considers $C_{\mathrm{I},50-80}$ as a direct alternative to $C_{\mathrm{I},50-2500}$. The other path considers calculating $C_{\mathrm{I,r},50-80}$ as a low frequency spectrum adaption term that is tied to ΔL_w, without affecting the use of $C_{\mathrm{I},50-2500}$. In essence, for the second path, ΔL_w describes 100–3150 Hz while $C_{\mathrm{I,r},50-80}$ works as a tool for an extended frequency range, describing only 50–80 Hz.

The goal is for the measured $L_\mathrm{n,w} + C_{50-80/2500}$ for the entire floor to align with the measured $L_\mathrm{n,0,w}$ for the bare reference floor minus ΔL_w for the floating floor plus the suggested low frequency spectrum adaption term, ideally on the conservative side. Additionally, ΔL_w and $C_{\mathrm{I},50-2500}$ are generally favouring floating floors with a low resonance frequency, which is good for the lowest frequencies in the traditional 100–3150 Hz range, but significantly less so for the extended part of the frequency range. A low frequency spectrum adaption term to accompany ΔL_w should therefore ideally also reflect how well the floor in question handles the lowest frequencies.

It the follwing, it is important to be aware that $C_{\mathrm{I},50-80}$ or $C_{\mathrm{I},50-2500}$ refers to the spectrum adaption term calculated from the measured $L_\mathrm{n,w}$ of a complete floor, while $C_{\mathrm{I},\mathbf{r},50-80}$ or $C_{\mathrm{I},\mathbf{r},50-2500}$ refers to the spectrum adaption term calculated to go alongside ΔL_w. The calculation procedures are described in ISO 717-2, and are also briefly explained in chapter 3 below.

3. CALCULATION PROCEDURE

When measuring the weighted improvement of impact sound reduction, ΔL_w, according to ISO 10140-1 [5] and ISO 10140-3 [6], a reference measurement is performed on a bare reference floor, and then the measurement is repeated on the test floor. The first set of measurement values are denoted as $L_\mathrm{n,0}$ and the latter as L_n. The frequency dependent reduction of impact sound pressure level, ΔL, may then be calculated as follows:

$$\Delta L = L_\mathrm{n,0} - L_\mathrm{n}. \tag{1}$$

Following from this, one can calculate ΔL_w with the help of the reference spectra that are defined between 100 and 3150 Hz in ISO 717-2. For the heavyweight reference floor the spectrum is denoted as $L_\mathrm{n,r,0}$. This calculation is performed in two steps, with the first being

$$L_\mathrm{n,r} = L_\mathrm{n,r,0} - \Delta L. \tag{2}$$

At this point, $L_\mathrm{n,r,w}$ is calculated from $L_\mathrm{n,r}$ using the regular procedure for calculating the normalized weighted impact sound level given in ISO 717-2. Then, the second step is

$$\Delta L_\mathrm{w} = L_\mathrm{n,r,0,w} - L_\mathrm{n,r,w}, \tag{3}$$

where $L_\mathrm{n,r,0,w}$ equals 78 dB for heavyweight floors.

As for spectrum adaption terms, they are calculated with the following formula, normally for the frequency range 100–2500 Hz or 50–2500 Hz:

$$C_\mathrm{I} = L_\mathrm{n,sum} - 15 - L_\mathrm{n,w}, \tag{4}$$

where

$$L_\mathrm{n,sum} = 10\lg \sum_{i=1}^{k} 10^{L_i/10}. \tag{5}$$

The same calculation can be carried out for $L_\mathrm{n,r}$ and $L_\mathrm{n,r,w}$, then denoted as $C_\mathrm{I,r}$. It is not explicitly stated in the standard that Eqn. (4) may be used for other frequency ranges, but any calculations of $C_{\mathrm{I},50-80}$ and $C_{\mathrm{I,r},50-80}$ in this paper have been performed using this equation.

4. RESULTS AND DISCUSSION

4.1 Measurement and calculation data

Measurement data for the five floors are given in Tab. 1 and Tab. 2. Calculated $C_{\mathrm{I,r},50-80}$ for the five floating floors and four extensions of the reference spectra are shown in Tab. 3.

Table 1. $L_\mathrm{n,w}$ and ΔL_w for the five floors.

Floor	A	B	C	D	E
$L_\mathrm{n,w}$	53 dB	51 dB	53 dB	49 dB	50 dB
ΔL_w	22 dB	26 dB	23 dB	28 dB	28 dB

Table 2. $C_{\mathrm{I},50-5000}$ and $C_{\mathrm{I},50-80}$ for the five floors.

Floor	A	B	C	D	E
$C_{\mathrm{I},50-2500}$	4 dB	4 dB	4 dB	3 dB	1 dB
$C_{\mathrm{I},50-80}$	-2 dB	3 dB	0 dB	0 dB	-8 dB

Table 3. Calculated $C_{\mathrm{I,r},50-80}$ for the five floors and four extended spectra.

Floor	A	B	C	D	E
$C_{\mathrm{I,r},50-80,\alpha}$	2 dB	10 dB	5 dB	6 dB	-1 dB
$C_{\mathrm{I,r},50-80,\beta}$	1 dB	7 dB	3 dB	4 dB	-3 dB
$C_{\mathrm{I,r},50-80,\gamma}$	0 dB	5 dB	2 dB	3 dB	-5 dB
$C_{\mathrm{I,r},50-80,\delta}$	-2 dB	4 dB	1 dB	2 dB	-6 dB

4.2 Path one

As Tab. 2 shows, $C_{\mathrm{I},50-80}$ is 0 or lower for four of the floors. which suggests that it's poorly suited as a low frequency spectrum adaption term. Even for Floor B, which is by far the worst performing floors at these frequencies, $C_{\mathrm{I},50-80}$ is lower than the presently used $C_{\mathrm{I},50-2500}$.

However, Tab. 2 also highlights a major weakness in $C_{\mathrm{I},50-2500}$, which is the same for floors A, B and C despite Floor B being very different to the other two. In fact, ΔL for Floor B is negative in all three third octave bands below 100 Hz due to the floor's low resonance frequency, which has a strong positive impact on ΔL_{w}, and a less strong, but nonetheless positive, impact on $C_{\mathrm{I},50-2500}$.

One could, however, consider using a different constant than 15 in Eqn. (4) for the calculation of $C_{\mathrm{I},50-80}$, see Fig. 3.

As the figure shows, it is difficult to obtain values for $C_{\mathrm{I},50-80}$ that show particular likeness with $C_{\mathrm{I},50-2500}$ using this calculation method. Other frequency ranges, like 50–100 Hz or 50–125 Hz could also be considered, but as Fig. 4 shows, $C_{\mathrm{I},50-x}$ moves quickly towards $C_{\mathrm{I},50-2500}$ as x goes above 80 Hz. It is difficult to find good arguments for why any of these alternative spectrum adaption terms are any better than $C_{\mathrm{I},50-2500}$, and therefore it seems sensible to avoid this path.

4.3 Path two

$C_{\mathrm{I},50-80}$ may be a poor choice for a spectrum adaption term to go along with $L_{\mathrm{n,w}}$, but when calculated as a spectrum adaption term to go alongside ΔL_{w}, the numbers in Tab. 3 are showing more promise. An issue with using $C_{\mathrm{I,r},50-2500}$ are the relatively high reference values at 100–160 Hz, which normally lead to very conservative values for $C_{\mathrm{I,r},50-2500}$ no matter how steeply the curve for the reference floor is dropping below 100 Hz [7].

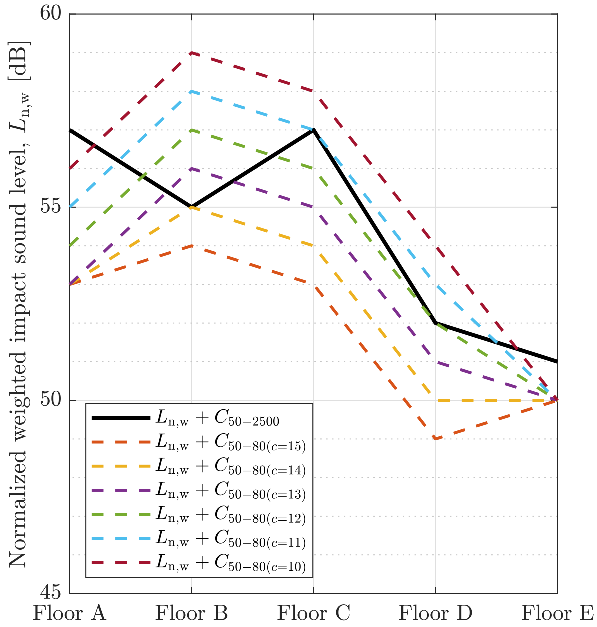

Figure 3. Alternatives for calculating $C_{\mathrm{I},50-80}$.

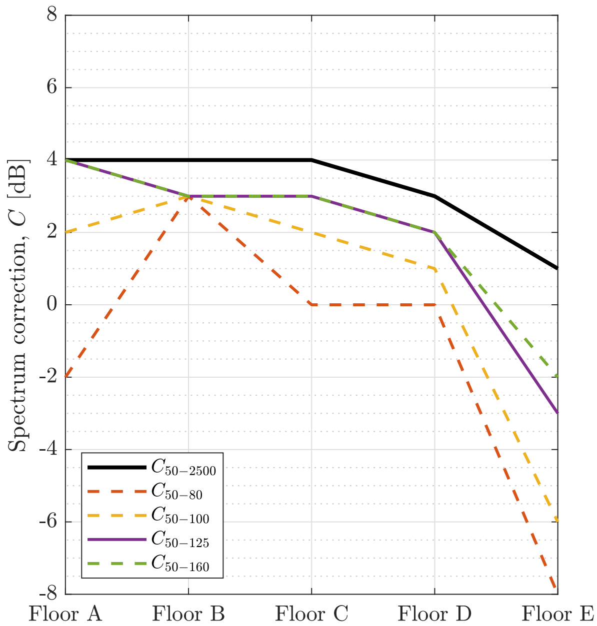

Figure 4. A graphical representation of how different evaluation ranges affect the calculated spectrum adaption terms.

By adding up $L_{n,0,w}$ for the 140 mm concrete floor, which is 79 dB, ΔL_w from Tab. 1 and $C_{I,r,50-80}$ from Tab. 3 and comparing the numbers with the measured $L_{n,w} + C_{I,50-2500}$, relatively similar results are achieved for the more aggressive approaches to the extension of the reference spectrum. This is assuming negative values are not to be counted, which at least is the case in Norway [1]. This is visualised graphically in Fig. 5.

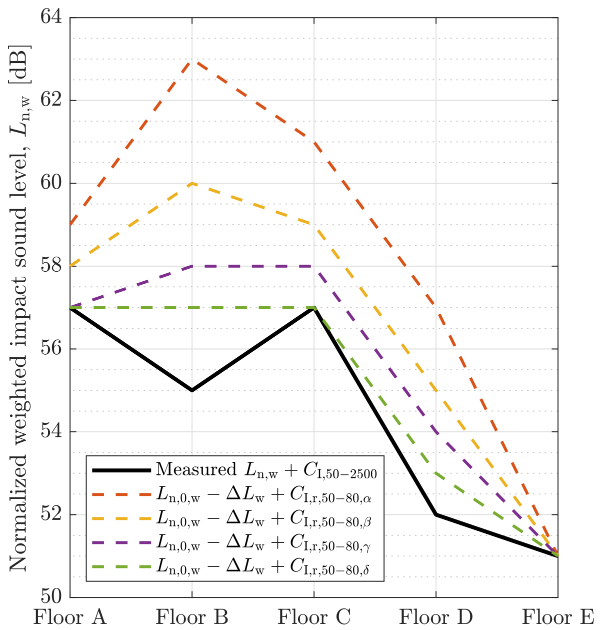

Figure 5. A graphical representation of how the calculated spectrum adaption terms in Tab. 3 align with measured results.

As the figure shows, the results for the δ-spectrum are very close to the measured results, with the exception of Floor B. However, given Floor B's poor low frequency characteristics it can be argued that this is a good thing. In this format, $C_{I,r,50-80}$ acts as a number that can be added to ΔL_w to obtain a relatively good approximation of $L_{n,w} + C_{I,50-2500}$, but it can also be used as a comparison tool for the five floating floors. Floor B has the worst low frequency characteristics of the five, and therefore also the highest $C_{I,r,50-80}$. Floor E, on the other hand, has excellent low frequency characteristics, and $C_{I,r,50-80}$ for that floor is correspondingly low.

Thus, the values in Tab. 3 can be used as a simple way to rank the low frequency characteristics of a number of floors. The relative low frequency strength of the five floors seems to be generally well represented in Tab. 3, perhaps with the exception of Floor D. However, any low frequency spectrum adaption term is calculated in context of the $L_{n,w}$ of the floor, meaning that although Floor D's low frequency characteristics in isolation are the second best of the five, they are relatively poor in context of the floor's measured $L_{n,w}$.

The negative values for Floors A and E can perhaps be used as an argument against this method, but when using the data to calculate the expected $L_{n,w} + C_{I,50-2500}$, any negative values will be set to 0. As a tool to compare the different floors, large variations can be positive. It should also be noted that the spectrum adaption terms for floors A and E effectively are 0 for both the δ and γ spectra. This is a cause for concern, but Floor E has $C_{I,50-2500}$ of 1, so the difference here is small. The difference is significantly larger for Floor A, but Floor A is also somewhat of an outlier, with the largest difference between $L_{n,w}$ and $L_{n,0,w} - \Delta L_w$, see Fig. 6.

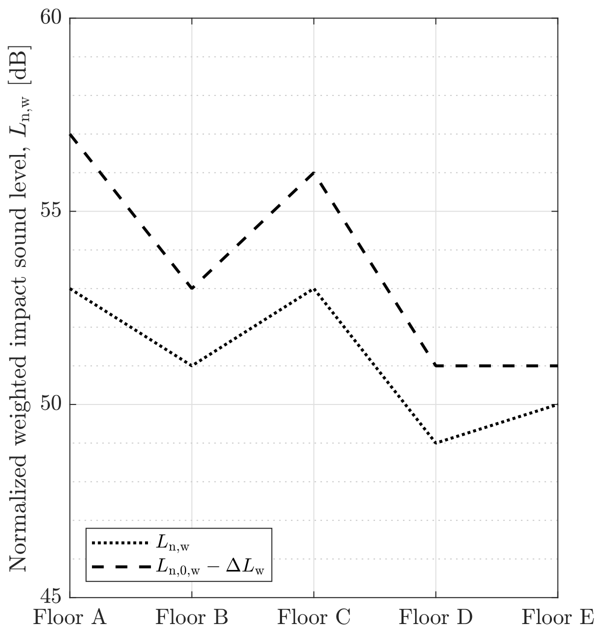

Figure 6. The difference between $L_{n,w}$ and $L_{n,0,w} - \Delta L_w$.

4.4 Summary

It has been difficult to find a way to calculate a low frequency spectrum adaption term for ΔL_w that is directly comparable to $C_{I,50-2500}$. Using $C_{I,r,50-2500}$ is not a good option because it leads to very conservative results. $C_{\mathrm{I,r,50-80}}$ does however give sensible results for some of the suggested extensions of the reference spectra in ISO 717-2, but it isn't directly comparable to $C_{\mathrm{I,50-2500}}$, and replacing $C_{\mathrm{I,50-2500}}$ with $C_{\mathrm{I,50-80}}$ or similar variations does not seem to be a good idea.

As a possible solution, it is suggested to use $C_{\mathrm{I,r,50-80}}$ as a term that is strictly connected to ΔL_{w}. For the γ and δ spectrum extensions suggested in this paper, $C_{\mathrm{I,r,50-80}}$ provides good differentiation between the different floors. This makes $C_{\mathrm{I,r,50-80}}$ suitable as a tool to rank the low frequency performance of different floors as well as to calculate the expected $L_{\mathrm{n,w}} + C_{\mathrm{I,50-2500}}$ for a floor construction based on $L_{\mathrm{n,w}}$ for the bare floor, and ΔL_{w} and $C_{\mathrm{I,r,50-80}}$ for the floating floor.

5. FURTHER WORK

The findings above suggest that $C_{\mathrm{I,r,50-80}}$ may be an option for how frequencies lower than 100 Hz can be tied to ΔL_{w} via a low frequency spectrum adaption term. However, the findings are based on a small sample size from one lab, and to obtain a better basis for decision, deeper studies with more data from several labs are needed.

6. CONCLUSION

When $C_{\mathrm{I,50-2500}}$ gets introduced in building legislation, there is a need to update ISO 717-2 to facilitate calculations of a low frequency spectrum adaption term for the weighted improvement of impact sound reduction, ΔL_{w}. To be able to perform such a calculation, an extension of the reference spectra in ISO 717-2 down to 50 Hz is necessary.

In this paper, some alternative extensions for the heavyweight reference floor are suggested, and the low frequency spectrum adaption term $C_{\mathrm{I,r,50-80}}$ is assessed as a possibility. The findings show that $C_{\mathrm{I,r,50-80}}$ in combination with one or more of the suggested spectra may well be a viable solution. However, since this paper is based on a small sample size from one lab, further and more comprehensive studies are needed.

7. ACKNOWLEDGMENTS

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