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# Rating of floors with the proposed impact sound reduction index

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The ISO 717 standards defining the calculation methods of the single-number quantities for evaluation of sound insulation are currently under revision. It has been suggested that impact sound insulation should be evaluated with impact sound reduction indices instead of the impact sound pressure levels. Weighted normalized impact sound pressure levels $L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$ and impact sound reduction indices $R_{impact}$ of 50 Finnish intermediate floors have been calculated. In the National Building Code of Finland, the requirements for impact sound insulation are given as weighted normalized impact sound pressure levels $L'_{n,w}$. Use of the proposed impact sound reduction index changes the rating compared with $L'_{n,w}$ because of the enlarged frequency range. However, compared with the structures that usually do not cause complaints, impact sound reduction index still gives equal or even better rating for the structures that are subjectively evaluated as problematic or unacceptable. The proposed calculation method of impact sound reduction indices includes an assumed spectrum of the sound source. As the proposed method does not necessarily have much effect on the rating order of the problematic floors, changing the source spectrum should be put under consideration.

## 1 Introduction

The measurement method for impact sound insulation has been criticized since the tapping machine was standardized internationally in the beginning of the 1960's. The criticism has especially dealt with the lower limit 100 Hz of the measured frequency range. Since the 1960's, the research has shown that in some cases the frequencies below 100 Hz have a remarkable effect on the subjective evaluation of the intermediate floors. [1–9]

The ISO standards defining the measurement and rating methods have since the 1990's made possible to enlarge the frequency range down to 50 Hz [10]. However, most countries have not included this possibility into their national building regulation [11]. In Finland, the reason for this has been the expected increase in measurement uncertainty caused by the properties of the soundfield. The research has, however, already shown that in measurement of impact sound insulation, the change in frequency range does not necessarily raise the measurement uncertainty significantly. The measurement uncertainty depends more on the structural type of the floor and sound spectra than the frequency range. The difference in measurement uncertainty occurs also at the frequency range over 100 Hz. Thus, the frequency range enlarged down to 50 Hz cannot be put under question on the basis of increasing measurement uncertainty. [12–13]

The ISO 717 standards defining the calculation methods of the single-number quantities for evaluation of sound insulation are currently under revision. For the revision, a new quantity, impact sound reduction index $R_{impact}$, is presented by Scholl et al [14–15]. The use of the proposed impact sound reduction index in rating of impact sound insulation will mean that the measured frequency range will change from 100…3150 Hz to 50…2500 Hz.

The change in the single-number quantities for rating impact sound insulation in buildings means that the acceptance limits for national building regulation have to be set again. The purpose of this paper is to study how the suggested single-number quantities change the rating order of Finnish intermediate floors. Weighted normalized impact sound pressure levels $L'_{n,w}$ and $L'_{n,w} + C_{I,50\text{-}2500}$ and impact sound reduction indices $R_{impact}$ of 50 Finnish intermediate floors have been calculated to compare the rating of the different floor types.

# 2 Measured structures

Normalized impact sound pressure levels $L'_n$ and weighted normalized impact sound pressure levels $L'_{n,w}$ have been measured in 50 Finnish multi-storey apartment buildings. The load-bearing walls have been constructed of precast concrete elements, and the bearing structures of the intermediate floors has been either hollow core slabs or cast concrete slabs. On the basis of acoustic characteristics of floor covering, the floors can be dealt into five groups (Fig 1):

- group A: cushion vinyl as floor covering, n = 11
- group B: multi-layer parquet with soft underlayment as floor covering, n = 21
- group C: like group B, but suspended ceiling under the floor slab, n = 3
- group D: raised floor system, n = 5
- group E: floating floor, n = 10

The measurements of normalized impact sound pressure levels $L'_n$ have been carried out according to the standard ISO 140-7 [16]. In the Finnish building regulation, the requirement for impact sound insulation between dwellings is set as weighted normalized impact sound pressure levels $L'_{n,w}$. The value of $L'_{n,w}$ should not exceed 53 dB. From the normalized impact sound pressure levels, the weighted normalized impact sound pressure levels $L'_{n,w}$ have been calculated according to standard ISO 717-2 [10]. All the measurement results fulfill the requirements given in the Finnish building regulation: in all cases the weighted normalized impact sound pressure level $L'_{n,w}$ is not more than the allowed 53 dB.

In addition to $L'_{n,w}$, the proposed single-number quantities for impact sound insulation, impact sound reduction indices $R_{impact}$ have also been calculated according to the method presented by Scholl. Calculation of impact sound reduction index is based on measured normalized impact sound pressure level $L'_n$. [14] As the calculation of the present and suggested single-number quantities is given in references [10] and [14], the calculation procedures are not repeated here. Figure 2 shows an example of calculated normalized impact sound pressure levels $L'_n$ as well as impact sound reduction indices $R_i$ of one floor structure.

The standard ISO 717-2 requires that the weighting with reference curve method is done by moving the reference curve in steps of 1 dB. [10] In order to achieve more precise understanding of the uncertainty of the quantities, the simulation was done by moving the reference curve in steps of 0,1 dB. [17] Impact sound reduction indices were also rounded to 0,1 dB.

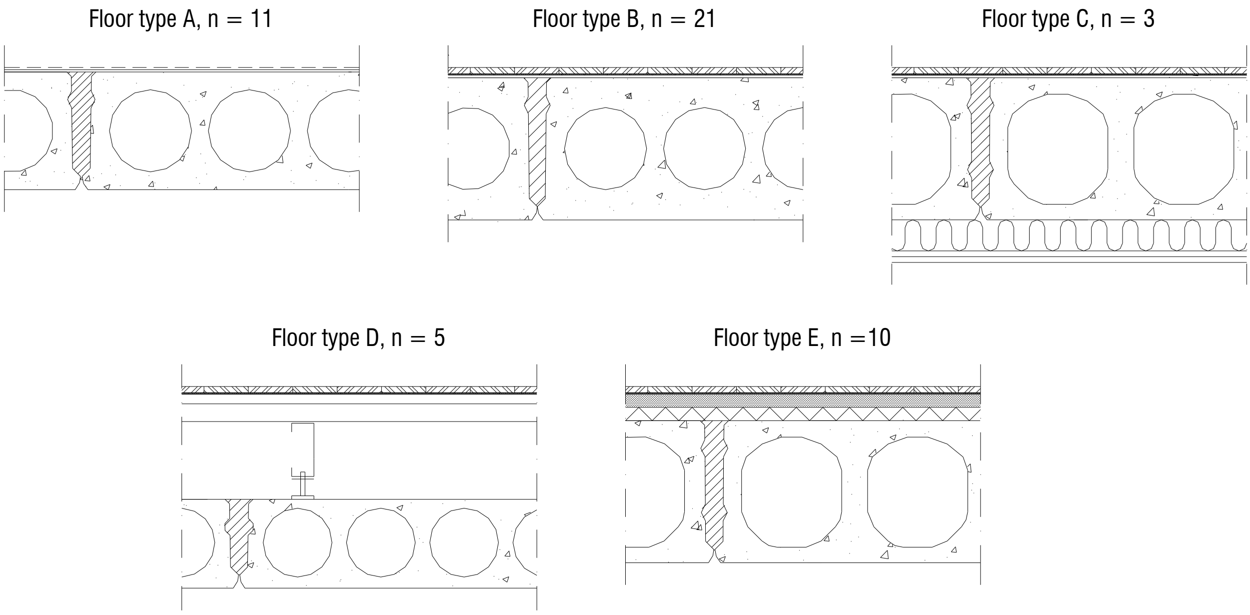


Figure 1: Structural types of the studied intermediate floors. Here, the bearing structure is shown as hollow core slab, but cast concrete slabs are included in the reference material, too.

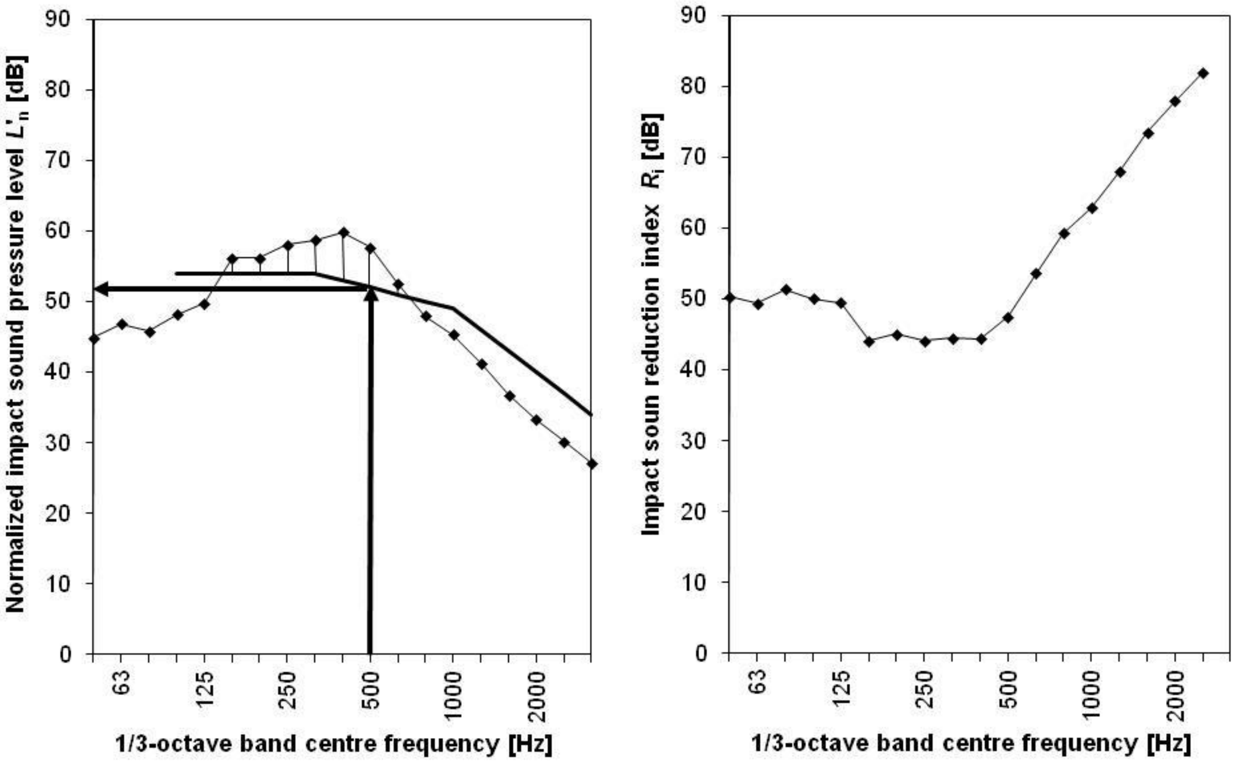


Figure 2: An example of calculated normalized impact sound pressure levels $L'_n$ and impact sound reduction indices $R_i$ of one floor structure. Single-number quantities $L'_{n,w}$ and $R_{impact}$ are 52 dB and 53 dB, respectively.

# 3 Results

In figure 3, the calculated single-number quantities $L'_{n,w} + C_{I,50\text{-}2500}$ and $R_{impact}$ of all five floor types are shown as a function of weighted normalized impact sound pressure level $L'_{n,w}$. Figures 4, 5 and 6 show the same correlation, but now separately for the floor types A, B and C. Straight lines in the figures show the linear regression lines fitted in the results. In table 1, the correlation between impact sound reduction index and the two other single-number quantities are shown. Floor types C and D are not included in this analysis while the amount of measured floors is small.

Figures 3–6 show that the proposed single-number quantity $R_{impact}$ is actually the same measure as sum of weighted normalized impact sound pressure level and spectrum adaptation term $L'_{n,w} + C_{I,50\text{-}2500}$. Figures 4 and 5 as well as correlations given in table 1 show that rating of floor types A and B remain similar independent on the chosen evaluation method. In the case of floor type E, the spectrum adaptation term $C_{I,50\text{-}2500}$ varies from 2,5 dB to 11,6 dB. If sum $L'_{n,w} + C_{I,50\text{-}2500}$ or $R_{impact}$ are used in rating of these floors, the order of the floor will change compared with rating based on weighted normalized impact sound pressure level $L'_{n,w}$.

Table 1: Correlation between impact sound reduction index $R_{impact}$, weighted normalized impact sound pressure level $L'_{n,w}$ and sum $L'_{n,w}$ and $C_{I,50\text{-}2500}$.

| Floor type | Correlation between $R_{impact}$ and $L'_{n,w}$ | Correlation between $R_{impact}$ and $L'_{n,w} + C_{I,50\text{-}2500}$ |
|---|---|---|
| All floor types | -0,80 | -0,65 |
| Type A: cushion vinyl | -0,92 | -0,99 |
| Type B: parquet with underlayment | -0,98 | -0,99 |
| Type E. floating floors | -0,62 | -1,00 |

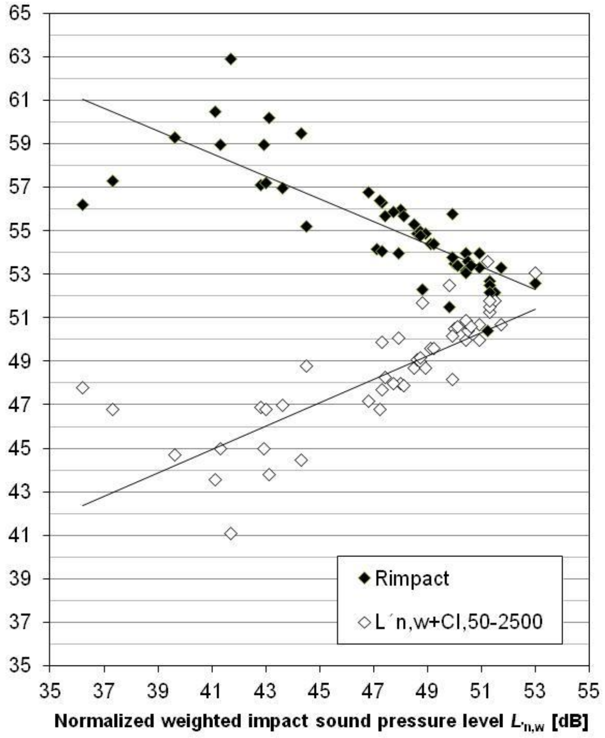


Figure 3: Single-number quantities $L'_{n,w} + C_{I,50\text{-}2500}$ and $R_{impact}$ of all floor types A-E as function of weighted normalized impact sound pressure level.

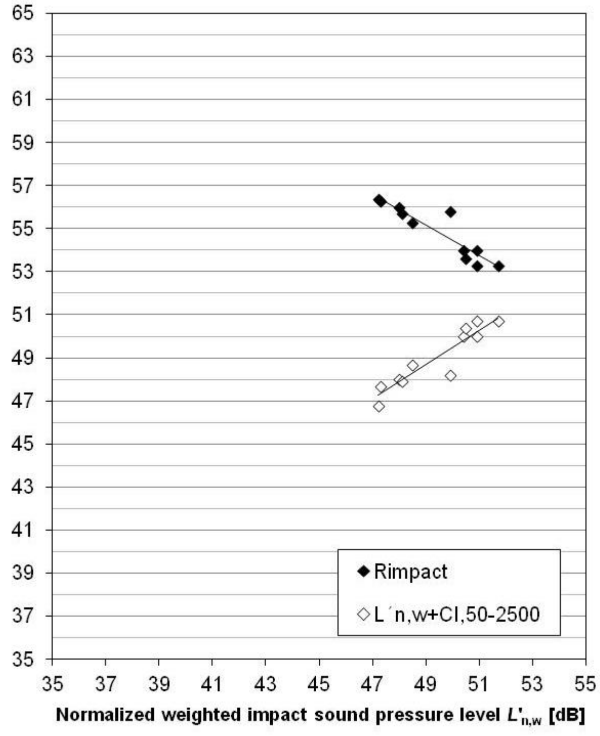


Figure 4: Single-number quantities $L'_{n,w} + C_{I,50\text{-}2500}$ and $R_{impact}$ of floor type A as function of weighted normalized impact sound pressure level.

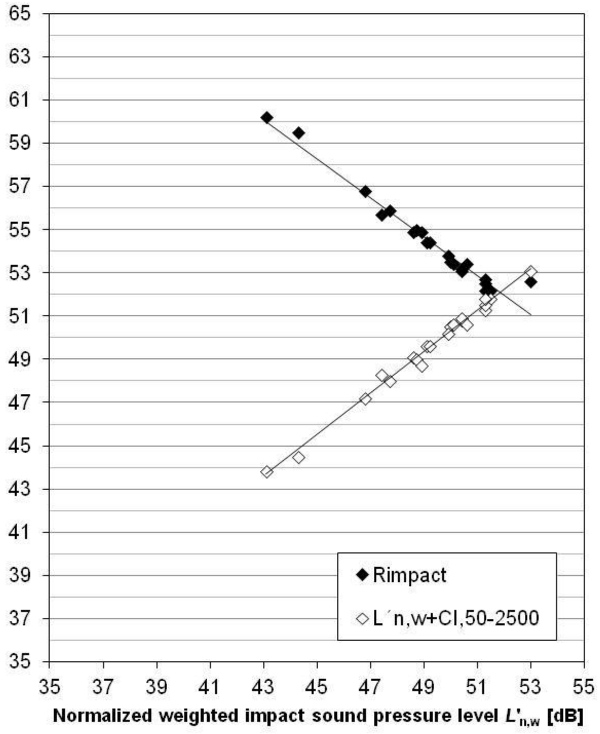


Figure 5: Single-number quantities $L'_{n,w} + C_{I,50\text{-}2500}$ and $R_{impact}$ of floor type B as function of weighted normalized impact sound pressure level.

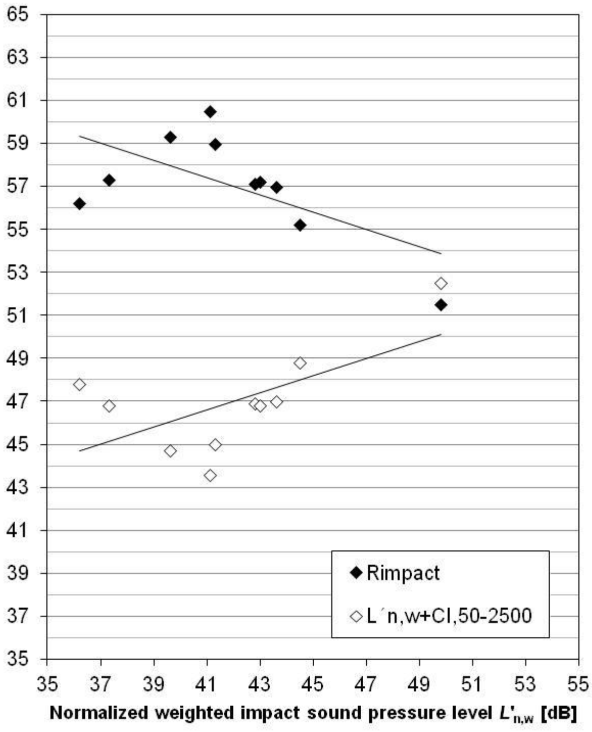


Figure 6: Single-number quantities $L'_{n,w} + C_{I,50\text{-}2500}$ and $R_{impact}$ of floor type E as function of weighted normalized impact sound pressure level.

# 4 Discussion

If the suggested impact sound reduction index $R_{impact}$ was taken into use, there would be a need to set the limit for acceptable measurement result between dwellings. Obviously, this limit would be set so that the limit would correspond to the present limit set as value of weighted normalized impact sound pressure level $L'_{n,w}$. On the basis of the figure 3, the limit set in this way might be 52 dB or 53 dB. The limit of 52 dB would mean that 96 % the measurement results presented in this paper would be acceptable. It the limit was 53 dB, the proportion of acceptable results would be 86 %.

In an earlier paper [18], impact sound level spectra from eight floor structures producing complaints were given. All thse structures were clearly acceptable when evaluated with weighted normalized impact sound pressure level $L'_{n,w}$ as is required according to the Finnish building regulation. The spectra of the structures are shown in figure 7. The single-number quantities $L'_{n,w} + C_{I,50\text{-}2500}$ and $R_{impact}$ are also calculated and shown in figure 8.

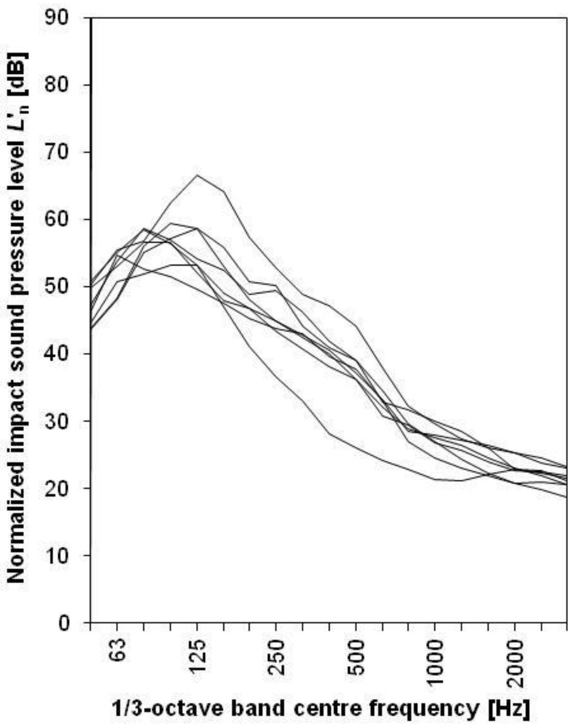


Figure 7: Impact sound level spectra from eight floor structures measured because of complaints.

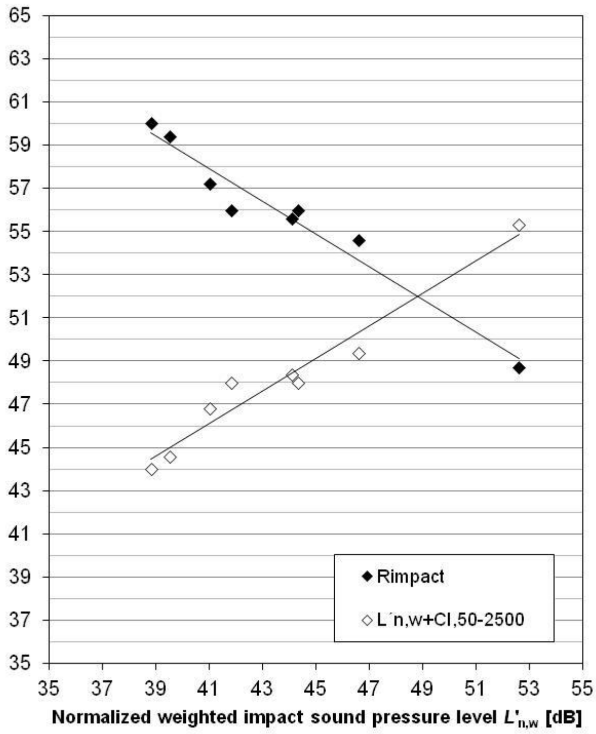


Figure 8: Single-number quantities $L'_{n,w} + C_{I,50\text{-}2500}$ and $R_{impact}$ calculated from spectra in figure 7 as function of weighted normalized impact sound pressure level.

If the acceptance limit for the suggested impact sound reduction index $R_{impact}$ was set to 52 dB or 53 dB, seven of the eight measurement results shown in figures 7 and 8 would be acceptable. Some of the results would also be very good compared with the acceptance limit as the best values are near 60 dB. On the basis of these few results, it seems to be so that the suggested impact sound reduction index does not necessarily rank the floor well enough: the correlation between the single-number quantity and subjective ranking might be low.

In the literature, there is some evidence which shows that the sum $L'_{n,w} + C_{I,50\text{-}2500}$ does not always produce a good correlation with people's subjective evaluation of impact sound insulation of floors. [9] As the suggested impact sound reduction index is basically the same quantity as $L'_{n,w} + C_{I,50\text{-}2500}$, the results found by Hagberg [9] are valid when impact sound reduction index $R_{impact}$ is used in rating of impact sound insulation.

The proposed calculation method of impact sound reduction indices $R_{impact}$ includes an assumed spectrum of the sound source. It is well known that the sound spectra of walking do not correspond with the spectra produced with the standardized sound source, the tapping machine. The sound spectra of both walking and tapping machine depend on structure type of the floor and the difference between them is not constant between different structures. [1–9] As the proposed method does not necessarily have much effect on the rating order of the problematic floors, changing the source spectrum included in the evaluation method should be put under consideration.

# 5 Conclusions

Use of the proposed impact sound reduction index $R_{impact}$ changes the rating of floors compared with rating done with the weighted normalized impact sound pressure level $L'_{n,w}$ because of the enlarged frequency range. However, compared with the structures that usually do not cause complaints, impact sound reduction index still gives equal or even better rating for the structures that are subjectively evaluated as problematic or unacceptable. The proposed calculation method of impact sound reduction indices includes an assumed spectrum of the sound source. As the proposed method does not necessarily have much effect on the rating order of the problematic floors, changing the source spectrum should be put under consideration.


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