CLASSIFICATION SCHEMES WITH HIGH-FREQUENCY IMPACT NOISE RATING (HIR)

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The authors have introduced a new impact noise isolation metric for high-frequency sources named High-frequency Impact Rating (HIR), which encompasses the frequency range of 400-3150 Hz. The advantages of this rating include better correlation with subjective reaction and improved rank-ordering of finish flooring and sound mats. This is demonstrated with comparison of HIR and $L'_{n,w}$ for example assemblies. Based on a large number of field and laboratory tests, a classification scheme for high frequency impact isolation is developed. The results are compared to the COST Action TU0901 classification scheme and the International Code Council Guideline for Acoustics.

Keywords: high-frequency, impact isolation, footfall, HIR

1. Introduction

In most jurisdictions in the United States of America (USA), there are only minimal requirements for impact noise isolation between dwelling units. Recently, the International Code Council in ICC-G2 Guidelines for Acoustics [1] were published, which defined two additional (non-mandatory) classes of performance, Acceptable and Preferred, which are in addition to Minimum Building Code requirements. These guidelines are based on Normalized Impact Sound Rating (NISR) [2] which is similar to the ISO rating $L'_{nT,w}$ [3] except that the rating scale is reversed so that higher ratings correspond to lower noise levels ($L'_{nT,w} \approx 110 - NISR$). In Europe, the COST Action TU0901 [4] has proposed a classification scheme with six classes. These are summarized in Table 1. The 110–NISR is also calculated for ease of comparison with the COST Action classes.

Table 1: Impact Isolation Classification

COST Action TU0901		ICC-G2		
Class	$L'_{nT,50}$, $L'_{nT,w}$	**Class**	NISR	110–NISR
Class A	≤ 44			
Class B	≤ 48			
Class C	≤ 52	**Preferred**	≥ 57	≤ 53
Class D	≤ 56	**Acceptable**	≥ 52	≤ 58
Class E	≤ 60			
Class F	≤ 64	**Minimum**	≥ 45	≤ 65

The authors have recently published a new dual-rating system for evaluating impact noise isolation, in which the noise level in the low frequency and high frequency bands are evaluated independently. [5] In this paper we develop preliminary classifications for the new metrics within the framework of the Minimum/Acceptable/Preferred classes.

2. Low-frequency impact ratings

The shortcomings of the existing single number ratings (IIC/$L_{n,w}$) with regards to low-frequency "thudding", particularly in lightweight structures, have received considerable study. Such thudding typically occurs below the 100 Hz lower limit of the IIC/$L_{n,w}$ ratings. Several methods to quantify this low-frequency noise have been developed, including the use of the heavy/soft impact source [6]. Ratings which use the standard tapping machine include the spectrum adaptation terms in ISO 717-2. [3] The COST Action limits are defined in terms of $L'_{nT,50} = L'_{nT,w} + C_{I,50\text{-}2500}$, which is the un-weighted sum of the impact sound level from 50–2500 Hz:

$$C_{I,50-2500} = L_{sum} - 15 = 10\log\sum_{i=50}^{2500} 10^{L_i/10} - 15 \quad (1)$$

This is claimed to be "more representative of the A-weighted impact levels as caused by walking for all types of floor." [3] The COST Action notes that this metric is used as it "has emphasis on low frequencies as this is more relevant for subjective assessment."

The authors have proposed to evaluate the impact noise isolation in the low and high-frequency domains independently. [5] The low frequency rating is call Low-frequency Impact Rating (LIR) and is calculated from the impact sound pressure level produced by the tapping machine in the 50, 63, and 80 Hz bands. It is defined as

$$LIR = 190 - 2L_{50-80} = 190 - 20\log\sum_{i=50}^{80} 10^{L_i/10}. \quad (2)$$

Therefore, both ratings are based on the energetic sum of the ISPL, with the only significant difference being the range of summation. Eq. (1) is a sum over 18 bands while Eq. (2) is a sum over just 3 bands. However, for many types of floor, particularly lightweight joist-framed structures in which low-frequency impact is a concern, the ISPL spectrum is highest at the low frequencies and drops off quickly at higher frequencies. For these spectra, the term L_{sum} in Eq. (1) and the term $L_{50\text{-}80}$ in Eq. (2) are similar, and the ratings are therefore highly correlated.

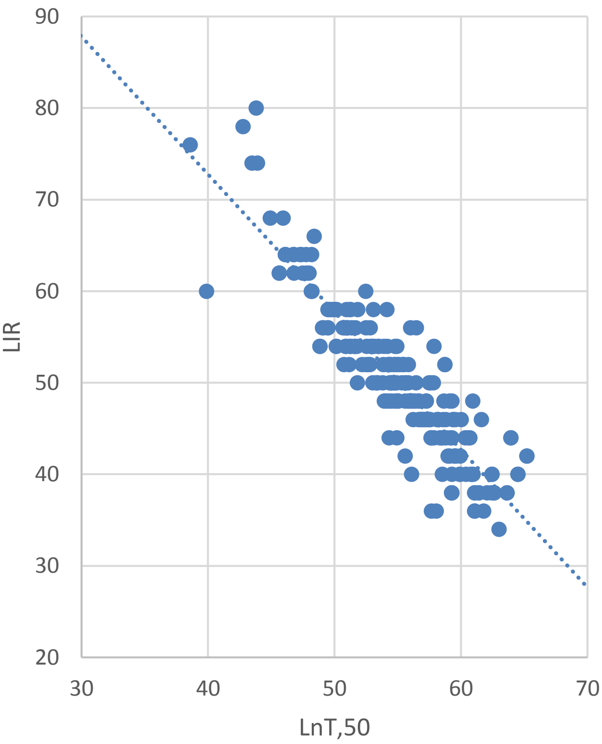

Figure 1. Comparison of LIR and $L'_{nT,50}$ ratings for lightweight floors.

Figure 1 shows the relationship between the two ratings for a set of field test data previously presented [7]. This data set includes a wide variety of finish floors, but the same base assembly, which is a lightweight joist-framed structure with a 25 mm gypsum concrete topping and a resiliently mounted gypsum board ceiling. The coefficient of correlation between the ratings is $R = -0.91$. For this type of assembly, therefore, these two ratings behave similarly.

As described in Ref. 5, the choice of numerical constants in Eq. (2) was set so that LIR of 50, 60, and 70 corresponded to Minimum, Acceptable, and Preferred classes of performance, based on our experience with occupant reactions. Estimating from Fig. 1, LIR of 50, 60, and 70 correspond roughly to $L'_{nT,50}$ of 55, 50, and 45, respectively. This correspondence is shown in Table 2.

Table 2: Low-frequency Impact Isolation Classification

COST Action TU0901	
Class	$L'_{nT,50}$
Class A	≤ 44
Class B	≤ 48
Class C	≤ 52
Class D	≤ 56
Class E	≤ 60
Class F	≤ 64

Proposed	
Class	LIR
Preferred	70
Acceptable	60
Minimum	50

Comparison of Tables 1 and 2 shows that in terms of existing single ratings (NISR), the American classes are significantly less stringent than the COST Action classes. The Preferred class corresponds only to Class C, for example. In terms of the low-frequency performance using the authors' proposed LIR, however, the Preferred class corresponds to Class A, and the Minimum corresponds to Class D. Table 2 shows that for low-frequency impact isolation there has been a convergence of classifications using different metrics.

3. High-frequency impact ratings

3.1 Proposed Ratings

A separate rating for mid- and high-frequency impact noise does not seem to be necessary as this frequency range is covered by existing NISR or $L'_{nT,w}$ ratings. However, for high-frequency impact noise such as dropping objects, heel clicks, and dragging furniture, the existing ratings do not perform well in evaluating the performance, even in the absence of thudding. Often changes to the finish flooring or sound mats below floating floors causes a large change in the sound level due to these sources, but only a small change to the rating. The authors have demonstrated [5] that changes in ISPL due to changes in finish flooring or sound mats occurs primarily within the frequency range of 400 Hz and above. For a wide range of assemblies, the overall IIC/$L_{n,w}$ ratings are controlled by the ISPL below 400 Hz. Because the ISPL at these frequencies does not typically change with changes in floor topping, the existing ratings are therefore *not* representative of the effectiveness of the assembly with respect to mid-and high-frequency impact noise.

The authors therefore proposed a new rating called High-frequency Impact Rating (HIR) to evaluate the performance at these frequencies. The reference spectrum is the same as the existing reference spectrum except that the lowest frequency band is 400 Hz. The curve fitting procedure is the same as IIC, with a maximum of 20 deficiencies (2 per band). Like the ISO standard, the 8 dB rule is not implemented. Since this is a classification method that can be calculated using any ISPL spectrum, this is actually a family of ratings for both laboratory and field testing using various normalization methods, which are summarized in Table 3. For additional information, see Ref. 8. Note that this rating can be easily calculated from existing test data, and can therefore be evaluated for previously tested assemblies.

Table 3: Proposed family of high-frequency impact noise single-number ratings and their correspondence with existing ratings.

	Rating	**Name**	**Normalization**	**Existing Ratings**	
				ASTM	ISO
Field	HIR	High-frequency Impact Rating	None	ISR	L'_w
	NHIR	Normalized HIR	T_0 = 0.5 s	NISR	$L'_{nT,w}$
	AHIR	Absorption-normalized HIR	A_0 = 10 m^2	AIIC	$L'_{n,w}$
Lab	HIIC	High-frequency Impact Insulation Class	A_0 = 10 m^2	IIC	$L_{n,w}$
	ΔHIIC	Improvement in HIIC	A_0 = 10 m^2	ΔIIC	ΔL_w

As mentioned, LIR was defined with a classification scheme in mind. Since the rating curve for HIR was already defined, no such scaling has taken place. Defining suitable numerical classes requires evaluation of occupant satisfaction of a large number of assemblies. The proper way to determine these classes is a scientific survey of ratings and occupant satisfaction. In this paper we present a preliminary suggestion for HIR classification based on our experience using this metric (approximately 10 years).

3.2 Case Studies

A detailed review of a large set of residential projects for a single developer has been presented in Ref. 9. These projects involved a continuous and iterative optimization of the assembly in terms of acoustical performance, cost, and ease of construction. The low-frequency rating for this assembly remained mediocre, with an average of approximately LIR 50. The high-frequency rating steadily improved throughout the process, from a starting average of NHIR 56 to an eventual average of 69. High-frequency isolation appears to be more important to this client and their tenants than low-frequency performance. The high-frequency isolation is considered very good by most tenants. These units have hard surfaced flooring at all locations except bedrooms, which are carpeted.

We recently performed a number of tests at two new buildings. Both were luxury condominium buildings located in cities with very high property values. Both had large units with open plans and hard surfaced flooring at all locations except bedrooms. At one building, there were numerous complaints of high-frequency impact noise, specifically footfalls from women wearing heels. The median ratings were LIR 52 and NHIR 57. The second project had a small number (<4%) of occupants complain of footfall noise. The median ratings at the second project were LIR 66 and HIR 71.

3.3 High-frequency impact rating classification

Based on these measurements and additional experience, it appears that HIR ratings exceeding 65 are acceptable even for high-end properties, and only the most sensitive tenants will complain. HIR ratings in the mid-50's are significantly better than code minimum, acceptable for mid-level apartment buildings, but will result in complaints within properties that have more discerning occupants

It is useful to examine the relationship between NISR (existing) and NHIR (high-frequency). This is shown in Figure 2 for the tests discussed in Ref. 9. For lower-rated assemblies, the ratings are very similar, which is expected since such floors typically have high-frequency deficiencies. As the floors improve and become more influenced by the level below 400 Hz, the NISR stops increasing while the NHIR continues to increase. For higher performing floors, therefore, the NISR under-represents the high frequency isolation. In other words, NISR has a upper limit with hard surfaced flooring

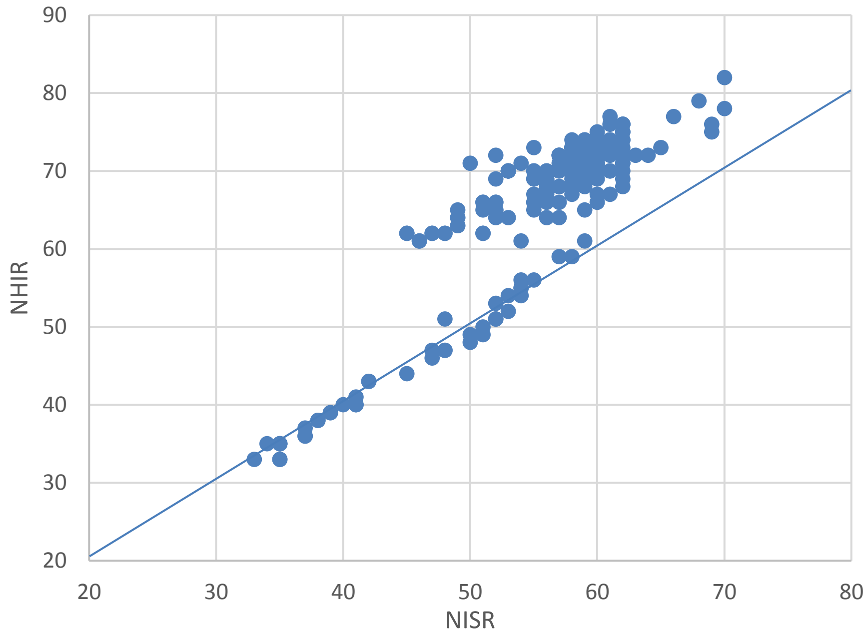

Figure 2. Comparison of NISR and NHIR.

For floors with ratings in the 45–52 range, the NISR and NHIR will be similar. However, assemblies with high NHIR ratings over 55 typically have NISR ratings that are 10 or more points lower. Therefore, we expect that the classification will have higher numerical values with NHIR compared to NISR for the better-performing classes.

4. Summary

Within the framework of the 3 classification levels that is recommended in the USA, the authors suggest the values in Table 4 as a preliminary classification scheme for ratings in the two domains of low and high-frequency impact noise isolation.

Table 4: Impact Isolation Classification

Class	LIR	NHIR
Preferred	70	65
Acceptable	60	52
Minimum	50	45

While it is not necessary or possible to completely harmonize these classifications with others such as the COST Action, for a subset of assemblies (see Table 2), Preferred corresponds to Class A, Acceptable to Class B or C, and Minimum to Class D. This broad correspondence is encouraging as it shows congruence between classes developed using different metrics. Although not possible to compare different ratings directly, similar correspondence should hold for the high frequency rating.

The classification scheme in Table 4 using the two rating method (LIR and NHIR) of evaluating impact noise isolation provides a basis for research to refine the relationship of human experience to these ratings.

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