THE DEVELOPMENT OF A SIMPLE TEST FOR THE DETERMINATION OF IMPACT SOUND INSULATION

Bernadette McKell

Robin MacKenzie Partnership, 16 Royal Crescent, Glasgow G3 7SL.

1. INTRODUCTION

The use of the present standard methods for testing and evaluation of impact insulation namely; ISO 140 "Methods of measurement of sound insulation in buildings and of building elements, Part 7: Field measurement of impact sound insulation of floors" and ISO 717 "Rating the sound insulation in buildings and of building elements, Part 2 Method for rating the impact sound insulation", require specialised acoustical knowledge and are time consuming in their execution. The impracticalities of the above methods have to some extent encouraged bad workmanship or lack of adequate attention to detail within the construction industry with particular regard to floor/ceiling systems. These claims can be backed with evidence contained in reports published during the 1970's when it was reported that in a survey of 565 floors tested, 66% failed to meet the requirements of the Building Regulations of the time,(1).

In October 1981, the Acoustic commission W.51 of the International Council of Building gave special emphasis during its meeting to the discussion of the subject and requested the member countries undertake research into such methods. In 1982 the International Standards Organisation Technical Committee 43 established a working group to 'formulate short test methods for field measurement of sound insulation for quality control purposes'. More recently in 1990 the Commission of the European Communities Standing Committee for Construction issued a draft for consideration in the Standing Committee 89/106 which contained a Mandate for Standardisation, including the standardisation of a "Single number rating of impact noise transmission of Floors".

2. REQUIREMENTS OF SCREENING TEST

2.1 The complex nature of the full test method and the errors involved in the measurement results,(2), dictate that the short test method can never be considered to be more than a screening test for the purposes of weeding out the poorer floor constructions.

DEVELOPMENT OF SCREENING TEST FOR IMPACT SOUND

2.1.1 The basic requirement of a short test for the estimation of impact sound insulation is that it should be consistent with the respective short test method for airborne sound insulation. In January 1988 I.S.O. Technical Committee 43/SC.2, accepted a Draft Proposal for an airborne short test,(3). The practical requirements are that it should use the same equipment, with the exception of the sound source, as the short airborne test method and that for the impact test it should be capable of yielding results in the field by means of a nomogram. The tapping machine should be as light and portable as possible but the possibility of using the ISO 140 standarised tapping machine in a screening test should also be considered. As with the airborne test the normalisation of receiving room levels should not be by measurement but by a standardised correction factor for the room conditions, namely; furnished, unfurnished and unfurnished plus carpet.

3. REFERENCE CURVES

An examination of the quantitative relationship between objective and subjective ratings has shown that while the ISO reference curve yields a reasonable correlation with the subjective evaluations of annoyance and loudness the correlation can be improved by a change in the shape of the reference curve,(4). The alternative reference curves were as follows; $L_{nTw'}$ - this curve begins at 100Hz and increases 1dB per one third octave up to 3150Hz. $L_{nTw''}$ - this curve starts at 50Hz and increases 1dB per one third octave up to 3150Hz.

The improvement in correlation by the alternative reference curve can be attributed to the increased emphasis given to the low frequencies while at the same time not over emphasising the contributions of the high frequencies. The development of the screening test ultimately looked at both the standard reference curve and the alternative reference curve which would yield an $L_{nTw'}$ rating.

4. BASIS FOR SIMPLE TEST

4.1 The basis for development of simple testing was acknowledged in the 1960's, (5), when it was commented that the ISO rating procedure comprised two essential elements; (i) frequency weighting embodied in the shape of a reference curve and (ii) level determination, corresponding to the curve fitting procedure.

The validity of using the reference curve as a weighting network has been established in recent research,(6). Following on from this the calculated overall weighted levels for a large number of floors were correlated with the single figure ratings $L_{nT,w}$ and $L_{nTw'}$. This involved an examination of the following relationships; $L_{nT,w}$ and L_g, and $L_{nT,w'}$ and L_{lin}, L_A and L_g, $L_{nT,w'}$ and L_c and $L_{nT,w'}$ and L_x where; L_g is the overall weighted impact sound pressure level, the weighting g being implied in the use of the ISO 717-2 reference curve. L_x is the overall weighted impact sound pressure level, the weighting x being implied in the use of the alternative reference curve described above. L is the overall linear impact sound pressure level. L_A is the overall A-weighted impact pressure level. The weightings referred to are given in Table 1.

Table 1. Weighting Networks

Frequency(Hz)	'A'	'C'	Linear	'g'	'x'
100	-19.1	-0.3	0	-5	10
125	-16	0.2	0	-5	9
160	-13.3	-0.1	0	-5	8
200	-10.8	0	0	-5	7
250	-8.6	0	0	-5	6
315	-6.6	0	0	-5	5
400	-4.8	0	0	-4	4
500	-3.2	0	0	-3	3
630	-1.9	0	0	-2	2
800	-0.8	0	0	-1	1
1K	0	0	0	0	0
1.25K	+0.6	0	0	3	-1
1.6K	+1.0	-0.1	0	6	-2
2K	+1.2	-0.2	0	9	-3
2.5K	+1.3	-0.3	0	12	-4
3.15K	+1.2	-0.5	0	15	-5

4.1.1 ISO Reference Curve. The resulting correlation coefficients (r) between overall weighted levels and single figure ratings and the coefficients of determination are given in Table 2.

The results given in Table 2 indicate that there is very good agreement between L_{nTw} and the overall normalised g-weighted levels. The normalisation of the overall weighted level will have an effect on the accuracy of any prediction as can be seen from Table 3.

Table 2. Correlation coefficients (r) and coefficients of determination (r^2) :$L_{nT,w}$ values and overall denormalised weighted values (n=552).

	'g'	
	r	r^2
$L_{nT,w}$	.93	.87

Table 3. Correlation coefficients (r) and coefficients of determination (r^2) :$L_{nT,w}$ values and overall normalised weighted values (n=552).

	'g'	
	r	r^2
$L_{nT,w}$	.99	.98

4.1.2 Alternative Reference Curve $L_{nTw'}$. The results given in Table 4 indicate that $L_{nT,w'}$ there is good agreement between $L_{nTw'}$ and the overall denormalised x-weighted level. The comparison with overall normalised levels can be seen by reference to Table 5.

Table 4. Correlation coefficients (r) and coefficients of determination (r^2) : $L_{nT,w'}$ values and overall denormalised weighted values (n=552)

	'x'	
	r	r^2
$L_{nT,w'}$	.96	.92

Table 5 Correlation coefficients (r) and coefficients of determination (r^2) : $L_{nT,w'}$ values and overall normalised weighted values (n=552).

	'x'	
	r	r^2
$L_{nT,w'}$	.99	.98

4.1.3 Alternative weightings. For the practical application of this relationship to a screening test the relationships between and amongst the alternative weightings and ratings defined earlier were examined.

A practical approach requires that the predictive nature of the relationship between the overall g-weighted and overall A-weighted levels be examined. The results in Table 6 indicate that there is a very good correlation (r=.9334) between overall denormalised g and A-weighted levels and between the linear levels and the overall denormalised x-weighted levels.

Table 6 Correlation coefficients (r) : overall denormalised A-weighted and g-weighted levels and overall denormalised linear and x-weighted levels (n=552)

	'A'	Linear
'g'	.944	.795
'x'	.627	.946

4.1.4 Regression Analysis. On the basis of these results it is reasonable to assume that an A-weighted level is capable of predicting an $L_{nT,w}$ value with an accuracy which can be determined from a linear regression analysis on the two variables of concern. When the independent variable is taken to be the overall denormalised A-weighted level the equation of the straight line is;

$$L_{nT,w} = 0.81\ L_A\text{denorm} + 4.1 \qquad \text{eqn (1)}$$

The standard error of estimation, which measures the amount of variability in the dependent variable not explained by the estimated model is 2.43dB and therefore at the 95% confidence level the value of $L_{nT,w}$ as given in Equation 1 has an accuracy of ±4.76dB.

When the independent variable is taken to be the overall normalised A-weighted level the equation of the straight line is;

$$L_{nT,w} = 0.92 L_A\text{norm} - 0.46 \qquad \text{eqn (2)}$$

The standard error of estimation is 0.95dB and therefore at the 95% confidence level the value of L_{nTw} as given in Equation 2 has an accuracy of ± 1.86dB

Following on from this it is therefore reasonable to assume that an overall linear level is capable of predicting a $L_{nT,w}$. value with an accuracy which can be determined by a linear regression analysis in the two variables of concern. When the independent variable is taken as the overall denormalised linear level the equation of the straight line is as follows;

$$L_{nT,w'} = 0.96\ L_{11s}\text{denorm} - 10.4 \qquad \text{eqn (3)}$$

The standard error of estimation is 2.41dB and therefore at the 95% confidence level the value of $L_{nT,w'}$ as given in Equation 3 has an accuracy of ±4.72dB When the independent variable is taken to be the overall linear normalised level the equation of the straight line is;

$$L_{nT,w'} = 1.08\ L_{11s}\text{norm} - 16.61 \qquad \text{eqn (4)}$$

The standard error of estimation is 1.84dB and therefore at the 95% confidence level the value of $L_{nT,w'}$ as given in Equation 4 has an accuracy of ±3.61.

5. Normalisation

Normalisation of the receiving room levels was investigated and a method involving the use of a standardised correlation factor for different receiving room correlation has been proposed,(4), this involves applying the correction factors as given in Tables 7 and 8.

Table 7. Correction for Measurement Condition of Receiving Room when Measuring A-weighted Impact Sound Pressure Level.

Receiving Room Condition	Correction to be added to measured A-weighted Impact Sound Pressure Level
dB	dB
Unfurnished Unfurnished + Carpet Furnished	+1 +3 +6

Table 8. Correction for Measurement Condition of Receiving Room when Measuring Linear Impact Sound Pressure Level.

Receiving Room Condition	Correction to be added to measured linear Impact Sound Pressure Level
dB	dB
Unfurnished Unfurnished + Carpet Furnished	0 +1 +4

6. Simplification of Tapping Machine

The development of impact testing has from the outset been faced with the problem of the use of a suitable impacting device. The choice was, and still is limited. The three realistic options considered during the early stages of development all assumed that footstep noise was the correct impact noise to determine acceptability of impact sound insulation. These were as follows; the use of live walkers, a device to simulate live walkers or a device which would generate a quasi continuous noise. It has been shown that despite the tapping machine producing a spectrum that is quite different in shape and level from that of a footstep spectrum, reasonable correlation can be achieved between the objective and subjective results,(4), although the correlation can be improved if the shape of the reference curve is altered.

On this basis the spectrum generated by the impacting device on a given floor was maintained. The quantities which characterise an impacting device are the internal impedance of the impacting device and the point impedance of the floor. A three hammer version of the existing tapping machine was found to provide the most suitable design of impact device in terms of correlation with the results of the full ISO test,(4). The type of tapping machine used in any test must be noted and if the simplified tapping machine is used 2dB must be added to the measured level.

7. Instrument Type

The type of sound level meter used, i.e.integrating or non-integrating, was found to influence the results and the correction factors to be applied are given in Table 9.

Table 9. Correction for Type of Meter Used in Measurement of Impact Sound Pressure Level.

Type of sound meter level	Correction to be subtracted from measured impact sound pressure level
dB	dB
Integrating: I.E.C 804 Type	0
Non-Integrating:IEC 651 Type	1

DEVELOPMENT OF A SCREENING TEST FOR IMPACT SOUND

SUMMARY

A Screening Test for determining the impact sound insulation of floors has been developed. The proposed test method uses the same equipment with the exception of the source as the short test method for airborne sound. A truncated impacting device has beeen proposed with the required correction for the type of device given. The correction factors for the type of measuring instrument and room normalisation are also given. A screening test for the determination of the impact sound insulation of floors has been developed. The final result can be predicted using nomograms based on regression equations.

REFERENCES

(1) SEWELL, E.C.and SCHOLES, W.E. (1978) "Sound Insulation Performance Between Dwellings Build in the Early 1970's. Building Research Establishment CP20/78.

(2) KASTELEIJN, M.L. (1965) "The Statistical Spread of Measured Airborne and Impact Sound Insulation in the Field". J. Sound and Vibration 3 (1), 36-45.

(3) MACKENZIE, R.K. (1988) "The Development of an I.S.O. Short Test Method for the Measurement of Airborne Sound Insulation in Buildings". Proceedings of the Institute of Acoustics Vol 10: part 8, 103-110.

(4) MCKELL, BERNADETTE. (1991) "The Development of a Screening Test to Determine the Impact Sound Insulation". Ph.D, Thesis, Herriot Watt University.

(5) GOSELE, K. (1965) "Sur bewertung der schalldammung von bauteilen nach sollkurven" (The Evaluation of Sound Isolation of Building Components using Rating Curves). Acoustics 15 264-270.

(6) PARMANEN, J. (1989) "Principles of Construction a Short Test Method For Impact Sound Insulation Measurements". J. Sound and Vibration 128(2), 181-194.