AN EXAMINATION OF THE GUIDANCE FOR FIELD MEASUREMENTS OF SOUND INSULATION IN THE ISO 140 SERIES OF STANDARDS; INITIAL RESULTS

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1 INTRODUCTION

Approved Document E (2003 Edition) (ADE) requires airborne and impact sound insulation in dwellings to be measured as part of a process of pre-completion testing unless Robust Details are used on sites registered with Robust Details Limited. ADE requires the measurements to be conducted in accordance with ISO 140-4 (airborne sound insulation) and ISO 140-7 (impact sound insulation). These standards have been criticised by acoustics professionals for taking insufficient account of conditions for testing on site. It is felt by some that the guidance is more suited for controlled laboratory conditions and it is widely accepted that some of the guidance in the standards is ambiguous.

This paper presents some preliminary results from research into the effect of different interpretations of the guidance in ISO 140-4. Results from measurements to assess the effect on measured airborne sound insulation due to differences of more than 6 dB in adjacent 1/3 octave bands and different sound source positions are presented.

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2 BACKGROUND

Despite criticism of ISO 140-4 and ISO 140-7, the importance of optimizing reproducibility of field measurement results is recognized by acoustics professionals. The current version of Approved Document E gives minimum values of airborne sound insulation and maximum values of impact sound insulation between dwellings that must be achieved for compliance with Building Regulations. This, along with credits awarded for sound insulation performance in the Code for sustainable homes (CSH), means that it can be argued that the importance of reliable field sound insulation measurements is greater now than when the 1992 version of ADE was in force and average values of measured sound insulation were used to decide whether performance standards for sound insulation had been achieved. Particularly since failure to meet the performance standards in the 1992 Edition of ADE did not itself mean a failure to comply with the Building Regulations 1991.

The laboratory standards in the ISO 140 series are currently being reviewed and, when this review is complete, the field standards for sound insulation measurements will be considered. Therefore, a review of the guidance in ISO 140-4 and ISO 140-7 is timely.

Efforts to improve the reproducibility of sound insulation measurements in buildings are not new. In the 1970s a working group comprising seven leading UK test organizations devised a test procedure to minimize differences in measurement results from different testers[1]. The new measurement protocol was used by all participants, along with their normal procedures, to measure airborne and impact sound insulation in a building located at the BRE Garston site.

The new measurement protocol specified the locations of sound sources and six fixed microphones in the rooms. It resulted in slight reductions in the variability of measurements compared with individual testers' normal methods. However, it was noted that all participants had considerable experience of testing in buildings so dramatic improvements could not reasonably have been expected.

More recent work at BRE investigated field measurements of low frequency airborne sound insulation between rooms[2]. Particular attention was paid to airborne sound insulation in the 50 Hz, 63 Hz and 80 Hz 1/3 octave bands and the $C_{50\text{-}3150}$ and $C_{tr50\text{-}3150}$ single number quantities. The methodology developed used sound pressure levels obtained using fixed microphone positions in the corners of the rooms and sound pressure levels measured in accordance with ISO 140-4. These sound pressure levels were weighted relative to each other to produce the average sound pressure levels in the three 1/3 octave bands below 100 Hz which were then used to calculate sound insulation.

The research currently being undertaken considers the guidance in the standards for field measurement of sound insulation that are referred to in Approved Document E (2003 Edition). It will investigate whether different interpretations of the guidance in ISO 140-4 and ISO 140-7 can affect the results of field sound insulation measurements.

The research will be completed by late 2008 and it is intended that the results of this study will help to inform discussions on future revisions of the ISO 140-4 and ISO 140-7. As part of this research, a round robin series of measurements is planned and organized in conjunction with NHBC Acoustic services. The measurements will be conducted in a building at the BRE Garston site and consultants interested in taking part are invited to contact the authors.

3 6 dB LEVEL DIFFERENCE IN ADJACENT 1/3 OCTAVE BANDS IN SOURCE ROOM

ISO 140-4 requires differences between sound pressure levels in adjacent 1/3 octave frequency bands in source rooms to be ≤ 6 dB and there has been discussion concerning the relevance of this requirement amongst acoustics consultants. Some consider this requirement to be 'left over' from the time when only analogue filters were available for use in equipment used for measuring sound pressure levels. Filters in sound level meters have limited roll-off which means that measured sound pressure levels in a 1/3 octave frequency band can be affected by levels in the adjacent bands if those levels are significantly higher. However, filters in modern equipment have greater roll-off than was available in the past and has been argued that, when using modern equipment, the guidance is not relevant.

To date, the authors have not identified the basis of the 6 dB criterion. It may be due to limited roll-off of analogue filters. It could be that differences in adjacent 1/3 octave bands in source rooms greater than 6 dB indicate that a particular room mode or group of modes is being driven harder than others and that this may, in turn, drive resonances that affect measured airborne sound insulation. If this is the case the requirements for the source spectrum in ISO 140-4 can be justified and still have relevance.

To investigate the effects of not satisfying the 6 dB criterion, measurements of airborne sound insulation were carried out on a timber floor with an independent ceiling installed in the BRE vertical transmission suite. The spectrum in the source room was adjusted to ensure that there were differences between adjacent 1/3 octave bands > 6 dB. The measurement results are shown in Table 1.

For these measurements, sound insulation was calculated in accordance with the method in Annex B of ADE (2003 Edition). However, because the sound insulation of the floor had initially been measured in accordance with ISO 140-3, *R'* values are shown in addition to $D_{nT,w}$ values. Although significant flanking sound transmission is unlikely in the laboratory (flanking limit 70 dB R_w), *R'* is used because the measurements were not conducted using the three preferred source positions identified from the laboratory commissioning process. Instead two corner loudspeaker positions were used as might be the case in the field. *R'* was calculated in accordance with Annex B of ADE (2003 Edition). The single number quantities from the ISO 140-3 measurement are shown in Table 2. The variation of the *R* values with frequency are shown in Figure 1.

Figure 1 also shows the average source room sound pressure levels with a B&K 4224 cabinet loudspeaker operating with sound generated only in the 160 Hz 1/3 octave band. The reason for doing this is that, as shown in Figure 1, there is some evidence that there might be a resonance in the 160 Hz 1/3 octave band. This was an attempt to drive the source room as hard as possible in this band.

The source room sound pressure levels were sufficiently high to be able to derive *R'* values for the 125 Hz, 160 Hz and 200 Hz 1/3 octave bands. These values are shown in Table 3. All the ISO 140-4 measurements were made using rotating booms and B&K 4224 cabinet loudspeakers located in opposite corners of the lower room and raised 0.63 m and 1.25 m above the and floor.

Table 1: single figure values with and without level differences > 6 dB in adjacent 1/3 octave bands

Single number quantity	ISO 140-4 measurement	1/3 octave band with level > 6dB greater than in adjacent bands					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	3150 Hz
	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)
R'_w	57	57	57	57	57	57	57
C	-3	-3	-3	-3	-3	-3	-3
C_{tr}	-8	-8	-8	-8	-8	-8	-8
$R'_w + C_{tr}$	49	49	49	49	49	49	49
SumUDiff	29	31	31.6	30.7	29.5	31	30.9
$D_{nT,w}$	57	57	57	57	57	57	57
C	-2	-3	-3	-3	-3	-3	-3
C_{tr}	-7	-8	-7	-8	-7	-8	-8
$D_{nT,w} + C_{tr}$	50	49	50	49	50	49	49
SumUDiff	27	29.3	29.6	28.7	27.7	29.4	29.3

Table 1 shows that deliberately introducing level differences greater than 6 dB had no effect on the measured values of *R'* or the single number quantities derived using the values of *R'*. There were some changes in the single number quantities derived using $D_{nT,w}$. There was no evidence that introducing differences > 6 dB between adjacent third octave 1/3 octave frequency bands affected the measured sound insulation values in these bands or the single number quantities.

The 160 Hz 1/3 octave band source room level shown in Figure 1 was 8.1 dB and 11.4 dB greater than those in the 125 Hz and 200 Hz 1/3 octave bands. Table 3 shows that this resulted in *R'* values that were different to the mean values (the arithmetic mean from the measurements that produced the data in the last four columns of Table 1) by at least 1.75 standard deviations. In the 125 Hz and 160 Hz 1/3 octave bands, the *R'* values in column 2 of Table 3 are significantly higher than those in column 3.

Using the column 2 values for the 125 Hz - 200 Hz bands instead of the average *R'* average values changed the single number quantities to $R'(C;C_{tr})$ = 58(-3;-7) dB with *R'* and C_{tr} having the same numerical values as those derived from the ISO 140-3 measurement. However, drawing conclusions about the 6 dB source room criterion from just one experiment is not justified.

Table 2: single number quantities from ISO 140-3 measurement and ISO 140-4 measurements in individual 1/3 octave bands

Single number quantity	ISO 140-3 measurement (dB)
R_w	58
C	-2
C_{tr}	-7
$R_w + C_{tr}$	51
SumUDiff	26.2

Table 3: comparison of 125, 160 and 200 Hz *R'* values with sound generated only in the 160 Hz band and arithmetic mean and standard deviation values from 4 measurements with level differences < 6 dB in these bands

1/3 octave frequency band (Hz)	*R'* (dB): (160 Hz noise only generated)	Results from 4 measurements	
		Mean *R'* (dB)	Standard deviation in *R'* (dB)
125	41.1	35.2	0.4
160	40.7	37.4	0.6
200	40.6	41.3	0.4

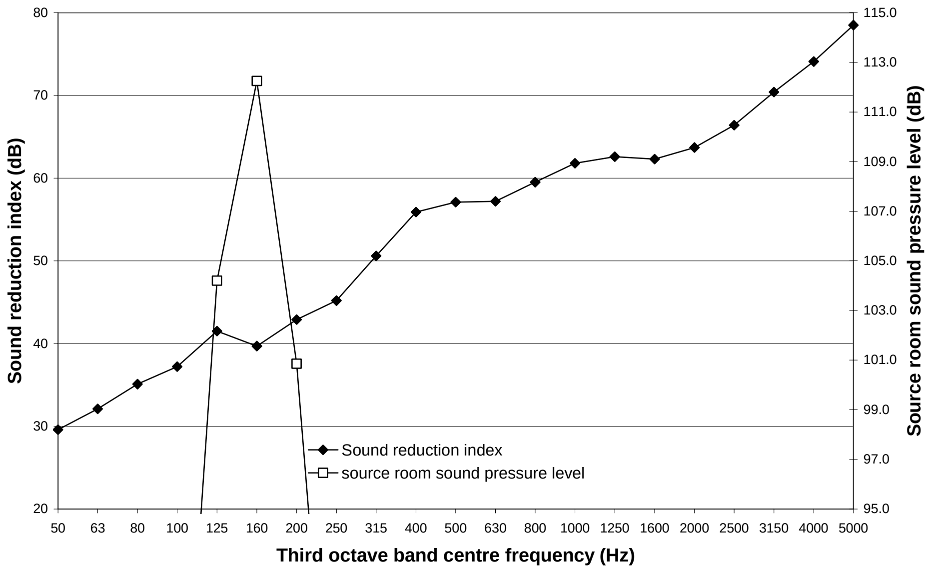


Figure 1: sound reduction index of floor with independent ceiling and source room sound pressure levels with sound generated in 160 Hz 1/3 octave band

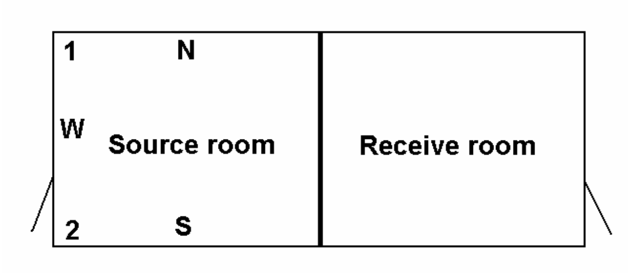
4 LOUDSPEAKER POSITIONS

Annex A of EN ISO 140-4 states that:

1. the distance between different loudspeaker positions shall not be less than 0.7 m;
2. at least two loudspeakers shall be not less than 1.4 m apart;
3. the distance between the sound source and the room boundaries shall be not less than 0.5 m;
4. different loudspeaker positions shall not be located within the same planes parallel to the room boundaries;
5. “it is often of advantage” to use loudspeaker positions in the corners of the source room.

Point 5 above means that where necessary, points 3 and 4 above need not be adhered to. In addition, placing loudspeakers on the floor in corners means that the two positions are in the same plane relative to the floor and ceiling in most rooms. Therefore it was considered worthwhile to investigate whether or not using different loudspeaker positions that complied with the guidance in ISO 140-4 affected measured sound insulation. At the time of writing only a cabinet loudspeaker has been used but omnidirectional sound sources will also be used in this research.

Figure 2 shows the layout of the rooms used for the measurements. The corners used for the loudspeaker in the source room are identified as 1 and 2. The separating wall is opposite the wall labelled W. The measurements were conducted using a B&K 4224 cabinet loudspeaker and the locations used for the measurements are identified in Table 4.



Source room volume = 30 m^3
3.95 m x 3.01 m x 2.49 m

Receive room volume = 27 m^3
3.90 m x 2.74 m x 2.49 m

Plastered solid brick separating wall ≈ 230 mm thick.

Figure 2: layout of rooms used for measurements

The results from the measurements are given in Table 5, Table 6 and Table 7. Results are given for loudspeakers in corners, loudspeaker positions that comply with ISO 140-4 but are not in corners and other positions where loudspeaker positions might, for example, be in the same plane relative to the room surfaces. The loudspeaker locations for each measurement are given along with the single number quantities derived. The mean and standard deviations values of the single number quantities are also given.

Examination of the tables suggests that there is no significant difference between the mean values of the single number quantities derived from each set of measurements.

Table 4: cabinet loudspeaker locations in source room

Loudspeaker position identifier	Loudspeaker location
1a	On floor facing corner 1, cabinet touching walls
1b	On floor facing corner 2, cabinet touching walls
2a	On floor facing corner 1, cabinet 0.5 m from walls N and W
2b	On floor facing corner 2, cabinet 0.5 m from walls S and W
3a	0.5 m high facing corner 1, cabinet 0.5 m from walls N and W
3b	0.5 m high facing corner 2, cabinet 0.5 m from walls S and W
4a	0.7 m high facing corner 1, cabinet 0.7 m from walls N and W
4b	0.7 m high facing corner 2, cabinet 0.7 m from walls S and W
5a	0.9 m high facing corner 1, cabinet 0.7 m from walls N and W
5b	0.9 m high facing corner 2, cabinet 0.7 m from walls S and W
6a	0.7 m high facing N, 0.5 m from N, 0.5 m from W
6b	0.7 m high facing S, 0.5 m from S, 0.5 m from W
7a	0.7 m high facing N, 0.5 m from N, 0.9 m from W
7b	0.7 m high facing S, 0.5 m from S, 0.9 m from W
8a	0.7 m high facing W, 0.9 m from N, 0.5 m from W
8b	0.7 m high facing W, 0.9 m from S, 0.5 m from W

Table 5: measurement results with loudspeaker in corners

Loudspeaker positions	$D_{nT,w}$ (dB)	C (dB)	C_{tr} (dB)	$D_{nT,w}+C_{tr}$ (dB)	SumUDiff (dB)
1a+1b	57	-2	-5	52	29.6
1a+2b	57	-2	-5	52	28.3
1a+3b	57	-2	-6	51	29.8
1a+4b	57	-2	-6	51	29.4
1a+5b	56	-1	-5	51	22.1
1b+2a	56	-1	-4	52	24.3
1b+3a	56	-1	-4	52	24.5
1b+4a	56	-1	-4	52	23.6
1b+5a	56	-1	-5	51	26
2a+2b	57	-2	-5	52	32
2a+3b	56	-1	-5	51	24.4
2a+4b	56	-1	-5	51	24.2
2b+3a	56	-1	-4	52	24.4
2b+4a	57	-2	-5	52	31.6
2b+5a	56	-1	-5	51	26.1
3a+3b	56	-1	-5	51	25.1
3a+4b	56	-1	-5	51	24.7
3a+5b	56	-1	-5	51	25.9
3b+4a	56	-1	-5	51	24.2
3b+5a	56	-2	-5	51	26.8
4a+4b	56	-1	-5	51	23.8
4a+5b	56	-1	-5	51	24.9
4b+5a	56	-1	-5	51	24.9
5a+5b	56	-2	-5	51	27.5
Mean	**56.3**	**-1.3**	**-4.9**	**51.3**	**26.2**
Std Deviation	**0.4**	**0.5**	**0.5**	**0.5**	**2.6**

Table 6: measurement results with ISO 140-4 compliant loudspeaker positions

Loudspeaker positions	$D_{nT,w}$ (dB)	C (dB)	C_{tr} (dB)	$D_{nT,w}+C_{tr}$ (dB)	SumUDiff (dB)
3a+6b	56	-1	-5	51	24.7
3a+7b	57	-2	-5	52	30.4
3a+8b	56	-1	-5	51	26.5
3b+6a	56	-1	-5	51	24.1
3b+7a	57	-2	-5	52	29.4
3b+8a	56	-1	-4	52	23.5
5a+6b	56	-1	-5	51	26.3
5a+7b	57	-2	-6	51	31.8
5a+8b	56	-2	-5	51	28
5b+6a	56	-1	-5	51	24.9
5b+7a	57	-2	-5	52	30.4
5b+8a	56	-1	-4	52	24.5
Mean	**56.3**	**-1.4**	**-4.9**	**51.4**	**27.0**
Std Deviation	**0.5**	**0.5**	**0.5**	**0.5**	**2.9**

Table 7 measurement results with non-ISO 140-4 compliant loudspeaker positions

Loudspeaker positions	$D_{nT,w}$ (dB)	C (dB)	C_{tr} (dB)	$D_{nT,w}+C_{tr}$ (dB)	SumUDiff (dB)
4a+6b	56	-1	-5	51	23.8
4a+7b	57	-2	-5	52	29.3
4a+8b	56	-1	-5	51	25.5
4b+6a	56	-1	-5	51	23.8
4b+7a	57	-2	-5	52	29.1
4b+8a	56	-1	-4	52	23.1
1a+7b	57	-1	-5	52	26.6
Mean	**56.4**	**-1.3**	**-4.9**	**51.6**	**25.9**
Std Deviation	**0.5**	**0.5**	**0.4**	**0.5**	**2.6**

5 SUMMARY

No evidence was found that level differences greater than 6 dB in adjacent 1/3 octave frequency bands in the source room affects the single number quantities used in ADE. However, the timber floor used for the investigation had an independent ceiling and relatively high sound insulation. It may be that driving resonances hard at specific frequencies due to 6 dB issues only affects the single number quantities for sound insulation of structures with lower airborne sound insulation such as ADE internal walls. Should this prove to be the case, it may be that failing to comply with the 6 dB criterion in the field is unlikely to affect the measured airborne sound insulation of separating walls and floors in the field more significantly than other issues encountered in buildings. However, more investigation is needed before any proposals can be made about the 6 dB source room criterion.

The different pairs of sound source positions used for the measurements do not appear to have had any significant effect on the measured sound insulation between the two small rooms separated by the solid masonry wall. BRE tends to favour corner positions for loudspeakers when measuring sound insulation in the field because point sources in corners excite more room modes than in other locations in rooms like the ones used, see Hopkins[3] for example. The cabinet speaker used cannot really be considered to be a point source and, hence, omni-directional. The use of omni-directional sound sources for field measurement of airborne sound insulation will be investigated as part of this research.

6 REFERENCES

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