Development and Commissioning of an IEC Standard Listening Room and Two Research Applications

Gian Schmid (1), Arron Chan (2)

(1) Acoustics Testing Service, University of Auckland, Private Bag 92019, Auckland

Email: g.schmid@auckland.ac.nz

(2) School of Architecture and Planning, University of Auckland

Abstract - A project aimed at improving the impact insulation of flooring systems prompted the need for verification of associated subjective improvements. To provide for this we designed and furnished a room to meet the acoustical requirements of IEC Standard 268-13 for standardised listening rooms and equipped it with hidden loudspeakers to play recordings of impact sounds. Because floor impacts often generate spectra extending down to the infrasonic range the specification for the reproduction system in the listening room was for a system capable of a flat response down to 12 Hz.

This presentation describes the development of the listening room, the installation of the loudspeaker systems and shows some results from (a) the floor project and (b) a brief study of the acceptability of sounds in multi-family dwellings comparing floor noise from neighbours living above with floor noise from neighbours living to the side.

Introduction

As part of a project to design and develop Light Timber Frame (LTF) floor-ceiling systems with good impact sound insulation we constructed an IEC Listening Room [1] for carrying out subjective assessments of potential solution floors. This space was equipped with a 10.2 loudspeaker reproduction system and used to present recordings of impact sounds from a range of specifically constructed floor-ceiling systems.

Figure 1: View of the Listening Room conforming to IEC268-13

Our approach was novel in a number of ways including that –

- the listening room – in addition to meeting the specifications of the IEC standard – was furnished to look and feel like a domestic environment (see fig 1)
- the loudspeakers of the reproduction system – except for the 2 sub-woofers – were concealed within the ceiling

and one of the walls to provide directional realism.

- the system was designed and equalised to provide a flat frequency response down to 16 Hz (see fig 6)

Listening Room Design

To fulfil the criteria outlined in IEC 268-13 the reverberation times (see fig 2) were controlled by the addition of carpet with underlay, soft seating (see fig 1), insulating material installed behind curtaining (see fig 3) and a suspended plasterboard ceiling-tile ceiling lined with insulating material.

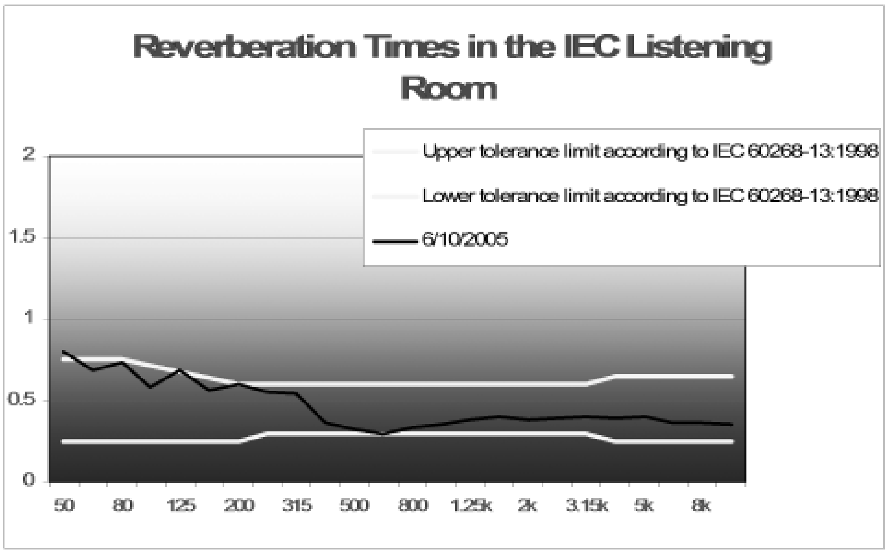

Figure 2: Final Reverberation Times

Reproduction System Installation

One requirement for placement of the loudspeakers was to have them hidden from the subjects so the space would read as a more realistic domestic environment. Self powered studio monitors were used due to their inherent low noise and high sound quality; four of these loudspeakers were mounted inside the suspended ceiling cavity in fabric covered medium density fibreboard ceiling panels, six were installed on foam isolation pads in the LTF plasterboard wall with fabric covered panels hung on the wall to hide them (see fig 4 & 5)

Obtaining The Recording

Experimental floor-ceiling systems were constructed in the ceiling opening (7 x 3.2m) of a purpose-built concrete block reverberation chamber. In total 26 systems were built and tested according to ISO 140-6. In addition the constructions were tested using the Japanese heavy impact source (tire drop) [2] and the Japanese light impact ball. In conjunction with the standard testing we made near-field recordings underneath the ceilings (70 mm from the ceiling). 4 microphone positions spaced across a diagonal of the chamber for a sequence of impact excitations of each floor-ceiling construction. These excitations comprised –

- the standard tapping machine at a central floor position

Figure 3: Curtains with Insulating Material

- heavy tyre drops at 4 positions along a diagonal (above the mic positions)
- a 72 Kg male walking along the diagonal
- the same male running along the same diagonal
- light impact ball drops at the 4 diagonal positions
- cutlery (spoon) drops from bench-top height (1.2m) at the 4 positions.

In each case simultaneous recordings were made from the 4 near-field mics. The RT of the chamber was reduced for these recordings by laying out a complete floor covering of thick polyester sound absorber. The aim was to reduce reverberant sound picked up by the near-field mics.

Replaying The Recording

When the first subjective listening experiment was carried out the individual loudspeakers in the ceiling of the listening room were each fed with 1 channel of the recordings. The 2 woofer loudspeakers were fed an average mix of the low frequency signals from the 4 microphones. The levels at the subject's listening position were adjusted to account for differences in RT between the reverberation chamber and the listening room based on the ISO 140 impact measurement spectra. During the second listening experiment three of the loudspeakers in the ceiling and the lower three of the wall loudspeakers were each fed with 1 channel of the recordings and as for the first test the woofer loudspeakers were fed with an average mix of the low frequency signals.

Application 1

Information collected from the subjects.

31 subjects were invited to participate in the initial experiment. This group was chosen to give a wide age range (with a mean age of 31 and maximum of 61), adequate mix of males and females and free from any hearing impairment (to the best of the subjects knowledge). Each participant was asked to complete a profiling questionnaire to provide information on their

- listening habits
- noise sensitivity and
- privacy rating

The impact insulation performance of a steel reinforced 150mm concrete slab floor with a suspended plasterboard ceiling lined with insulating material was taken as a reference and the LTF floor recordings were paired with the equivalent recording from the concrete slab and presented in an A/B comparison for assessment of (a) preference and (b) 'difference".

Of the 24 floor ceiling systems tested 8 were selected that were considered most relevant to the overall project. 4 impact types were used (walking on bare floor, walking on carpeted floor, tapping machine and ball drop), to give 32 paired assessments for each subject.

The preference question took the form of a 2-Alternative-Forced-Choice experiment with no ties allowed [3] and for this the subjects were asked to imagine they were going to live in an apartment where they had to choose a floor-ceiling construction to separate them from the apartment above. The presented sounds in each pair being the typical sounds they might hear from 2 alternative floor-ceiling constructions. In each case one of the pair was the sound from the concrete reference floor although this was not communicated to the subjects.

The "difference" question took the form of asking the subjects to mark on a continuous 'semantic differential' scale how different the pair of sounds seemed. The extremes of the scale were marked "Not significantly different" and "Markedly different" and the mid point was marked "Noticeably different".

Results

The intention was to use the 'difference' judgements to provide a ranking of the different floor constructions relative to one another. It became evident, however, that subjects approached their judgement in two differing ways. This difficulty has prompted a repeat stage of experimentation (which will be reported at the conference) but the results from the 2AFC question do in general support the rankings found by the difference method.

Figure 4: Wall mounted loudspeakers rear view

Figure 5: Fabric covered panel

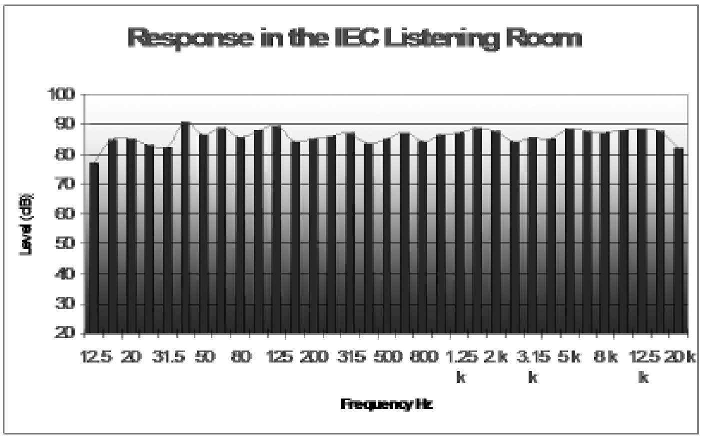

Figure 6: Final response of the reproduction system

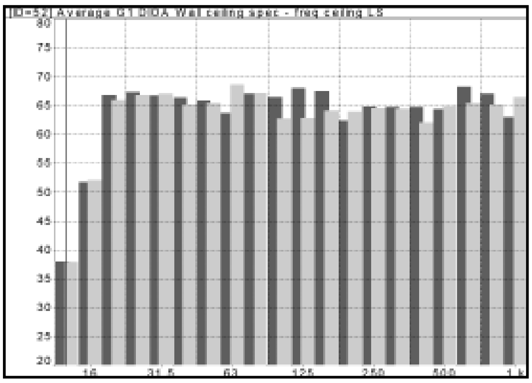

Figure 7: Overlaid frequency response of the two replay directions

The cohort of subjects was too small to allow any clear indications of differences between subjects of significantly different Noise Sensitivity or Privacy Rating. When the subjects were divided into Low, Average and High groups for Noise Sensitivity and Privacy Rating the results showed no consistent trend, - but with such small numbers of subjects in the extreme groups (e.g. the High Noise Sensitivity and Low Privacy Rating groups each comprised only 3 subjects) this cannot be relied on as indicating no dependency.

When divided by sex a small but consistent difference between men and women was evident (e.g. an average of 0.32 for the tapping machine and 0.53 for the Ball drop - these values being distances on the continuous scale of length 10) with women judging differences overall to be slightly smaller.

When the subjects were divided into two age groups first those aged <30 (n=14) and those aged >40 (n=10) the judgements were not different for the tapping machine sounds but for the Ball drops the younger subjects consistently judged the differences larger by an average of 1.2.

Apart from providing a direct indication of the relative satisfaction to occupants of LTF and standard concrete floor constructions we hoped that the subjective experiment results would help clarify if existing objective measures are adequate for ranking occupant preference. The issue here is that the standard building insulation measures [4] – even with the ISO low frequency extensions [5] – don't cover the full bandwidth used in this experiment.

However, Loudness (in Sones) and A-weighted SPL are both standardised measures and can be extended to include all the low frequencies (see [6] for the Loudness calculation) and the correlations between these and the subjective preference scores are shown in figures 2 to 4.

The results show surprisingly good correlations for both the A-weighted

SPL (Leq 10s) and Loudness with the subjective judgements. The plots and the R2 values are obtained from the mean values of the subjects in each case.

The rankings consistently show floor 9 (the floor used in the subjective experiment which is closest to the final evolved floor i.e. floor 25) as either close to, or better than, the concrete reference construction whatever the impact source or floor covering. But can we conclude that overall it is as satisfactory a construction as the concrete slab? The critical condition is when the floor is subjected to heavy impact where the Loudness and A-weighted SPL results and the subjective preferences do distinguish the floors as different (we can note that Ln'w and IIC values are not helpful here because the tapping machine has such a different excitation spectrum!). However, are these differences likely to be significant and to make the floors differ in the acoustic comfort they provide?

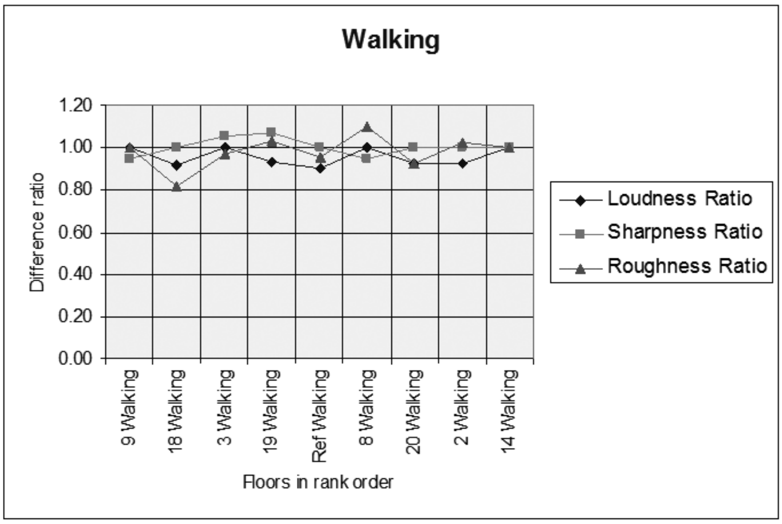

Figure 8: Ratio of psychoacoustic parameters for walking, a value >1 shows that the wall measurement is higher than the ceiling measurement

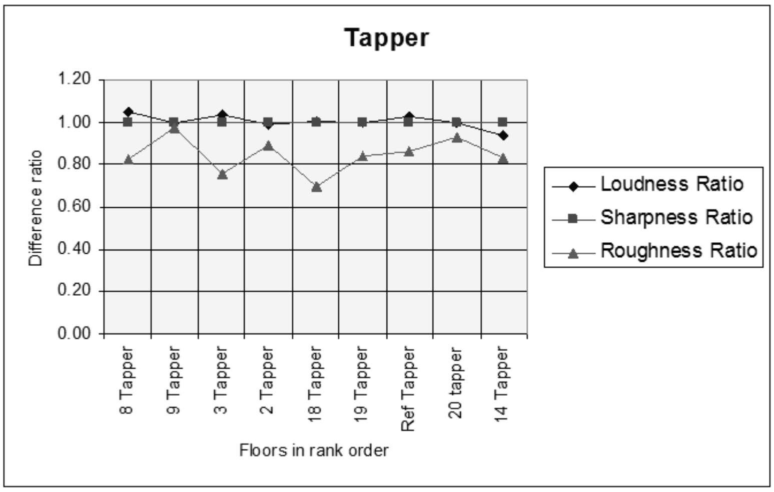

Figure 9: Ratio of psychoacoustic parameters for tapping machine, a value >1 shows that the wall measurement is higher than the ceiling measurement

Application 2

Introduction

In this application we set out to investigate whether the the annoyance of impact noise heard in typical dwellings is the same for equivalent sounds received from neighbours above and from neighbours to the side (i.e. on the same level).

The addition of loudspeakers concealed within the wall made it possible to simulate horizontal neighbour noise, so, in conjunction with the ceiling mounted loudspeakers the full range of sounds associated with apartment/multi-family dwellings can be re-created. After installation was complete (see figs 4&5), the two reproduction systems were adjusted to deliver equivalient sound pressure levels at the listeners' position over the frequency range concerned (see fig 7). Furthermore, the psycho acoustical parameters were measured at the listeners' position to show any differences between the two directions (see figs 8&9).

Nine floor/ceiling systems were chosen for this experiment, these were

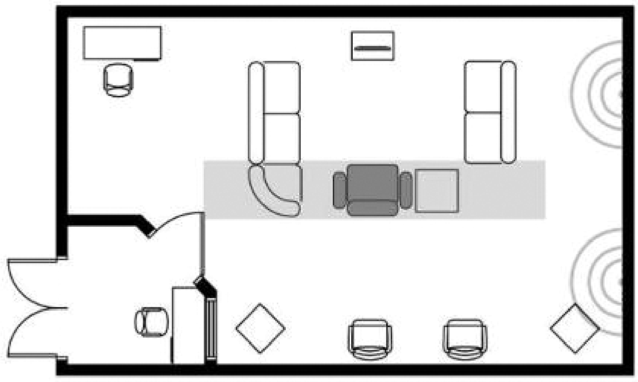

Figure 10: Listeners position (dark grey chair) and loudspeaker positions in wall (light grey semi circles) and in the ceiling (light grey rectangle)

chosen for their performance shown in subjective test application 1.

The subjects

53 test subjects with ages ranging from early 20's to mid 60's participated voluntarily in the experiment.

In the initial experiment, 31 test subjects were invited individually to be seated in the listeners' position (see fig 11).

The test subject was given an answer sheet comprising 26 sliding A/B forced choice Likert scales (see fig 11) and to imagine they were in an apartment/ multi-family dwelling that was on a short list of dwellings they were intending to purchase.

On a computer screen in front of them was an "A" and "B" button, when selected each of these would replay the associated sound file through either one of the two directions.

The subject would then place an "X" on the scale corresponding to their choice.

The subjects also had space for any relevant comments they may have had regarding the two sounds hey were assessing.

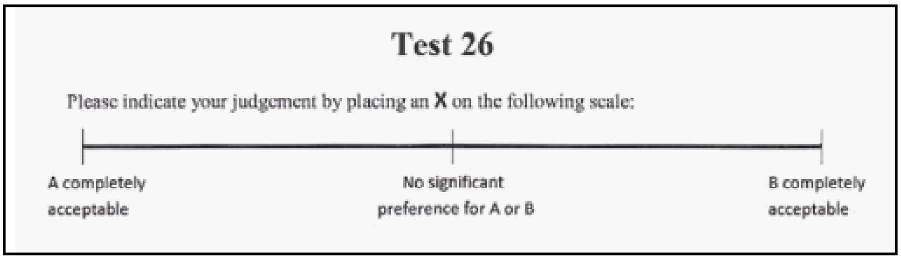

Figure 11: Sample answer showing forced choice Likert Scale

Results

Once the initial 31 test subjects (Group A) had completed the experiment, the resulting data was analysed.

Because the participants were given two sounds to compare, 'A' and "B", the order of which the ceiling and wall source with respect to sound 'A' and 'B' varied for every test, therefore to compare the results we 'normalised' the data such that all ceiling sources become 'A'. 50 was the mid-point marking the no preference option.

For the cases when the ceiling sound sample was sound 'B', the preference value recorded was subtracted from 100 in order to invert the scale and normalise the figures for comparison.

These results show that the subjective preferences fall below the '50' preference value (<50 shows the ceiling as more preferable) and that the preferences had a greater standard deviation with respect to the walking sounds than those of the tapping machine.

We can also see a correlation (though small) between the single figure rating Ln,W values and the overall trend in the preferences.

One observation with respect to the findings is that the ability to localise a sound from directly above is more difficult than that from the side because the sound from above is received by both ears simultaneously, whereas sound from the side is reduced to the furthermost ear due to head shadow.

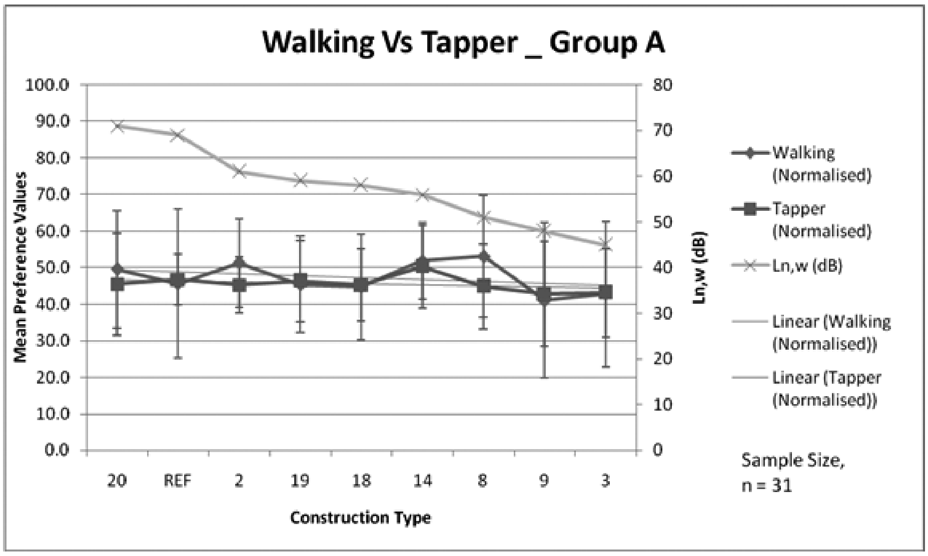

Figure 12 Results Showing the mean preference value of each significant test against its floor construction ranked in terms of their insulation performance

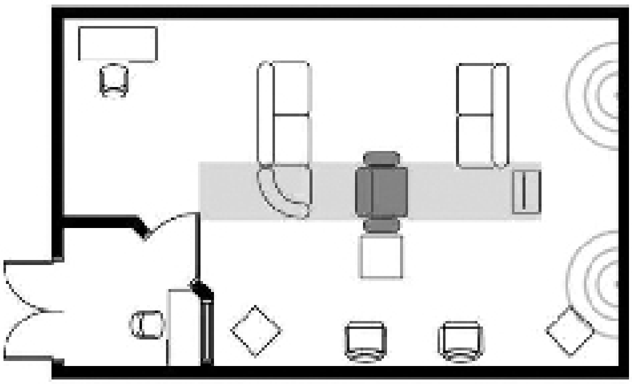

Figure 13: Listeners position 2 (dark grey chair) and loudspeaker position in wall (light grey semi circles) and in the ceiling (light grey rectangles)

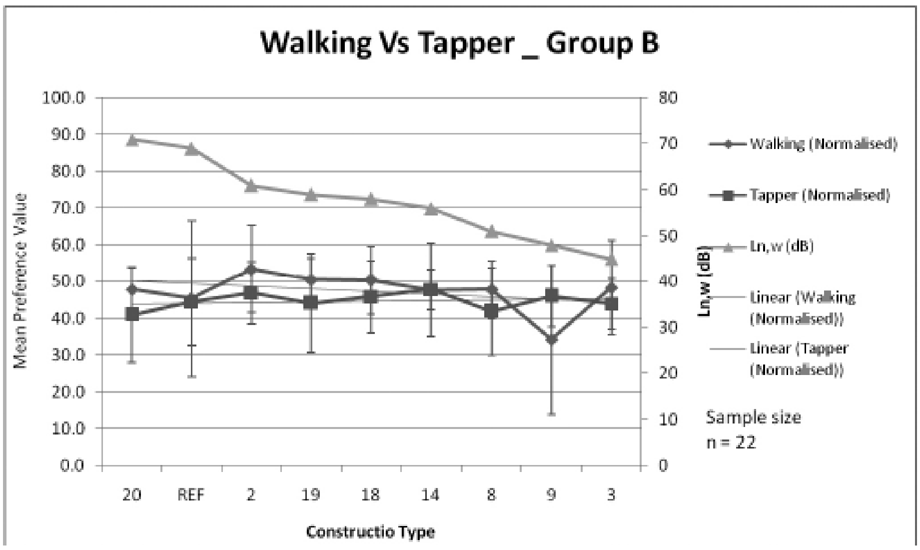

Figure 14: Results showing the mean preference value of each significant test against its floor construction ranked in terms of their insulation value

However, we might have expected that this would have created a less acceptable situation for the sounds from the ceiling and therefore ceiling transmitted sound to be more annoying!

This finding prompted stage 2 of the experiment where we repeated the preference experiment with more subjects with the listener's chair rotated so that the subject was facing directly at the wall mounted loudspeakers (see fig 13).

In this orientation we remove the head shadow effect.

Stage 2

The testing procedure for stage 2 was the same as for the initial listening test and comprised the same answer sheets and sound files.

22 subjects (Group B) were invited to participate in this test.

Results

On completion of the second stage of listening tests in position 2 the resulting data was analysed (see fig 14)

As for the first round of testing (Group A), the results from Group B show a trend toward a preference for transmission from above rather than that from the wall (in this situation from the front) and similarly more so for the tapper than the walking sounds.

Conclusion

The conclusions, some discussion and further details on the results were delivered in the presentation at the conference

References

[1] IEC Standard 268-13 "Recommendation for Listening Room"

[2] JIS A 1418 "Measurement of Floor Impact Sound Insulation of Buildings – Heavy Impact Source" Japanese Industrial Standard

[3] ASTM Standard E 2263-04 "Standard Test Method for Paired Preference Test"

[4] ASTM Standard E989 "Standard Classification for Determination of IIC"