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FLOOR IMPACT NOISE AND FOOT SIMULATORS

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INTRODUCTION

In response to adverse criticism of the standard tapping machine test [1,2], a modified machine and test procedure were described in an ASTM proposal in 1979. The work described here aims to examine this proposal and to develop a procedure for rating floors more accurately than the standard tests. For the lightweight floors common in Canada, a major problem is that the standard tests do not measure low-frequency sound levels, which cause most complaints. Steady-state low-frequency sound measurements in small rooms are complicated and of doubtful value. It was hoped that the modified test could avoid some of the complications by measuring peak octave-band levels. These should be largely independent of room properties but will be influenced by the size of the floor. For each floor installed in the laboratory, impact tests were made using the ISO machine, 2 walkers and 2 experimental tapping machines. Force pulses from walkers and hammers as well as foot impact velocities were also measured.

Experimental Tapping Machines

One of the experimental tapping machines complies with the ASTM proposal and has a cylindrical hammer with a mass of 200 g faced with a rubber tip (compliance $=7 \times 10^{-7}$ m/N). It impacts at 0.55 m/s and generates a force pulse with a peak of 350 N and a half width of 0.75 ms. The experimental NRC hammer is meant to generate a force pulse similar to that produced by a shoe and the lower leg. The tip mass (170 g) is faced with the same rubber as the ASTM hammer, but it has a heavier mass (4.8 kg) and a more compliant rubber layer ($=4 \times 10^{-6}$ m/N) attached above it. The impact velocity is 0.35 m/s.

Foot Velocity and Force Pulse Measurements

A force pulse generated by the NRC hammer is shown in Fig. 1. The two initial short pulses, separated by about 2 ms, are similar to those often generated by walkers. The pulses cause a bump in the force spectrum at 500 Hz which is also evident in the acoustical spectra measured in the room below (Fig. 6). Because the hammer rebounds, its force pulse is much shorter than those generated by walkers, but the force spectrum in the frequency range of these measurements is similar. Force pulses for hammers and human feet were obtained from a floor-mounted transducer. The average peak precursor force generated by 13 female subjects was 45 N with a half width of 1.2 ms. The mean peak value of the main force was 70 N and the mean half width was 20 ms.

Measurements of foot velocity were made using an optical tracking device that produces voltages proportional to the horizontal and vertical position of a bright target in the field of view. A light attached to one foot produced signals that were digitized at 100 Hz to produce data like Fig. 2. The mean value of impact velocity of 26 male and female subjects walking normally was 0.25 m/s. The impact velocity for the NRC hammer lies between this value and the ASTM recommendation of 0.55 m/s. When the experimental hammer strikes the floor at 0.55 m/s, it produces blows much more violent than footsteps.

Acoustical Analysis Procedures

A microphone 1 m from the underside of the floor fed signals to a computer system through a set of filters (A-weighted and 32 to 4000 Hz), each with its own logarithmic amplifier and integrator (τ = 35 ms). Sound decay rates in the receiving room were increased so that the decaying sound signal from one hammer blow did not interfere with the next; however, a walker produces widely varying peak sound levels and the signal from one footstep may not rise above the decaying

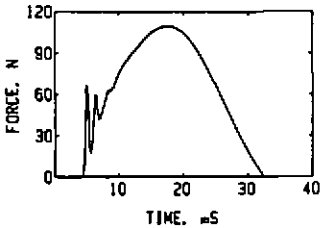

Fig. 1.
Force pulse from NRC hammer

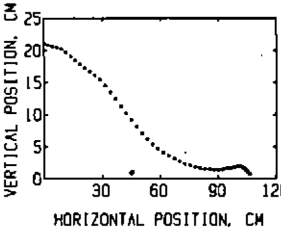

Fig. 2.
Position vs time for a walker; 100 samples/s

signal from the preceding one. (Footstep signals are even more difficult to measure with peak-sound-level meters because of the slow decay rate in the meter circuits.)

Comparisons Between Acoustical Test Results

Figure 3 shows the correlation between the A-weighted long-term rms level generated by the ISO machine and peak impact levels generated by the male and female walkers. Figure 4 shows slightly improved correlation for the ASTM hammer and the walkers, and Fig. 5, a further improvement for the NRC hammer. Table 1 gives the values of the coefficients of determination (R^2) for each of the octave bands and shows that the NRC hammer generally agrees best with the walkers. The correlation is poorer in the 1 to 4 kHz bands because signals are often lost in noise in these bands. In the lowest 3 bands, the poorer correlation may be partly explained by the difference in impact areas for walkers and hammers. Following the ASTM proposal, the hammers struck in the middle of the floors, but walkers walked in a circle close to the floor edges because of the small floor size (2.44 × 2.44 m). A single experiment to investigate this showed

Table 1. Coefficients of determination ($R^2 \times 100$) % for male (M) and female (F) walkers and three hammer machines.

Frequency Hz	M vs F	M & F vs NRC	M & F vs ASTM	M & F vs ISO
32	39	27	33	--
63	55	55	41	--
125	90	76	71	66
250	95	88	81	63
500	95	92	81	76
1 k	92	77	74	75
2 k	82	32	49	36
4 k	78	19	36	15
A-wt	88	85	70	62

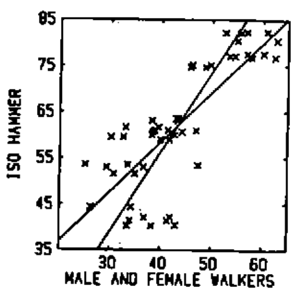

Fig. 3.
Relation between A-weighted rms level (dB) for ISO machine and peak A-weighted level (dB) for walkers.

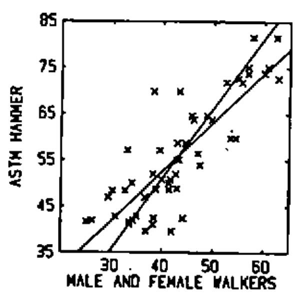

Fig. 4.
Relation between peak A-weighted levels (dB) for ASTM hammer and walkers.

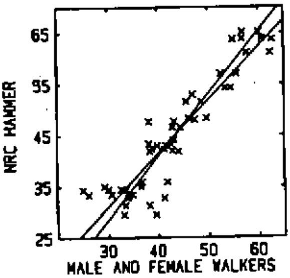

Fig. 5.
Relation between peak A-weighted levels (dB) for NRC hammer and walkers.

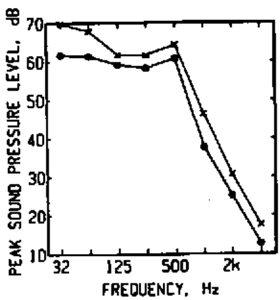

Fig. 6.
Effect of using different impact areas with NRC hammer; x - 5 positions in middle of floor, ● - 18 positions on 2 m diameter circle.

substantial variations in peak sound levels when the hammer was moved to strike the floor along the path followed by the walkers (Fig. 6). Whether this effect will introduce a systematic or a random difference for different floors is not known. The other possible explanation for the poorer agreement at low frequencies is the lack of walker consistency. Table 1 shows that the peak sound levels for the male walker do not agree well with those for the female in these bands.

CONCLUSIONS

This work suggests that test procedures can be improved to give results in good agreement with live walkers.

REFERENCES

[1] ISO 140/6-1978, "Laboratory measurements of impact sound insulation of floors".
[2] ASTM E492-77, "Laboratory measurement of impact sound transmission through floor-ceiling assemblies". ASTM Headquarters, 1916 Race Street, Philadelphia, U.S.A.